



Cenozoic Mollusca of New Zealand

A.G. BEU AND P.A. MAXWELL

DRAWINGS BY R.C. BRAZIER

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A.G. Beu and P.A. Maxwell, drawings by R.C. Brazier

New Zealand Geological Survey

DSIR, Lower Hutt



Ian Speden
Director

Lower Hutt, New Zealand 1990

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SUMMARY

The book provides a new overview of the Cenozoic molluscan fauna of New Zealand, including a large number of previously unrecorded taxa, in a much fuller synthesis than anything attempted previously. Four introductory chapters review the history of the description of the fauna, introduce molluscan paleoecology, tabulate the time ranges of the most biostratigraphically useful taxa (both genera and species), and provide an illustrated glossary.

Most of the book is taken up with an extensive new description of the fauna, arranged in 12 chapters, subdivided by age—from Early Paleocene to mid-late Pleistocene. In these 12 chapters, 550 species are described in detail, with discussions of related taxa and of their utility in biostratigraphy and paleoecology; all are illustrated in 49 plates of 720 new drawings by Ron Brazier. Chapter 17 introduces the huge topic of “micromolluscs”, describing 43 genera as examples of New Zealand’s extensive fauna of molluscs with shells less than 10 mm across, and illustrates all 43 genera in eight plates of new scanning electron micrographs. The faunal description is followed by (1) an extensively updated checklist of all Cenozoic Mollusca recorded from New Zealand (about 3200 species), and (2) a comprehensive bibliography of about 1000 publications on New Zealand Cenozoic Mollusca.

Three species are renamed because of homonymy. Six genus-group names and 85 species-group names are synonymised with earlier names, and 216 species are listed in new combinations (*not* including those resulting from changes in the rank of genus-group names).

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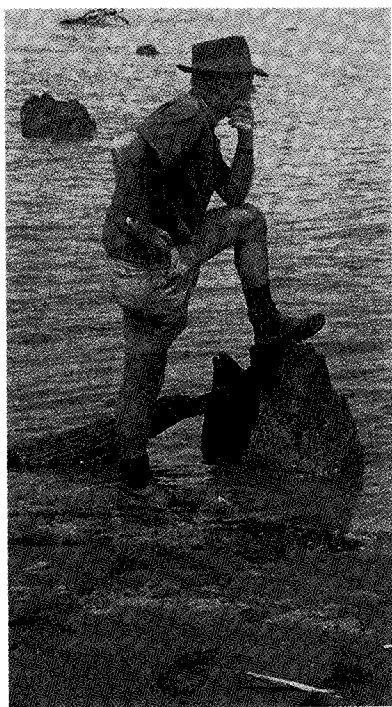
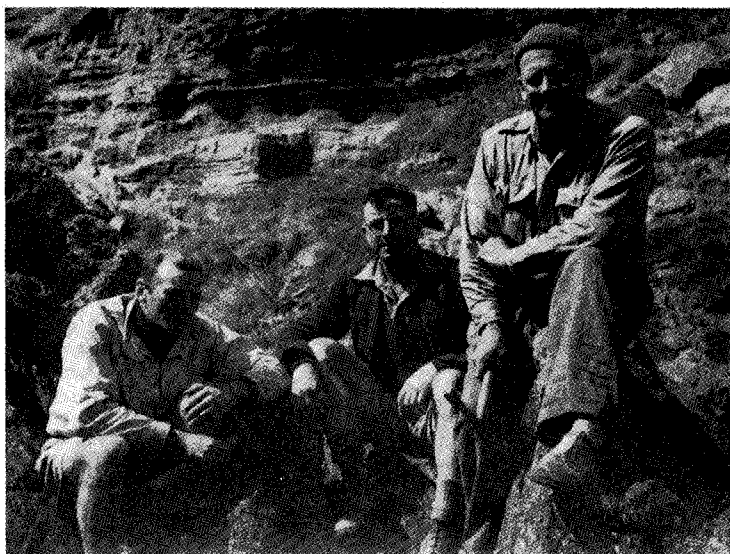
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DEDICATION

SIR CHARLES ALEXANDER FLEMING, KBE, FRS



Charles Fleming—some field snapshots.

Top Left: Charles (left) at Castlecliff, Wanganui, with Jack Marwick (centre) and Baden Powell, March 1945, during field work for Wanganui bulletin (photo: A.C. Beck).

Top right: With a newly collected Castlecliffian fossil *Pecten novaezelandiae* at the mouth of Ohinekoao Stream, Matata, Bay of Plenty, March 1984 (photo: B.W. Hayward).

Bottom left: At the "fossil forest" c. 800 m upstream from the mouth of Waitotara River, west of Wanganui, February 1957 (see Fleming 1957, N.Z. Journal Sci. Technol. B38, p. 726; the stumps are dated at 1000

years old by C14) (photo: N. de B. Hornibrook).

Bottom centre: A camp breakfast on Urupukapuka Island, Bay of Islands, on an Offshore Islands Research Group trip, January 1980 (photo: B.W. Hayward).

Bottom right: At the Earthquakes, Duntroon, Waitaki Valley, 1947; bored disconformity between Whaingaroan Earthquakes Marl and Duntroonian Kokoamu Greensand (the "Marshall paraconformity") at knee height. (photo: J. Marwick).

The relatively advanced state of knowledge of the New Zealand Cenozoic molluscan fauna is due to devoted study by many scientists over almost 125 years. Chief

among these were six people whose life work advanced the subject very greatly. The first was Frederick Wollaston Hutton (1836-1905), the early describer of many of the

more common species. The next was Henry Suter (1841-1918), who described further species and pointed out the relationships and status of many of Hutton's species. It was not until foraminiferal biostratigraphy enabled the unravelling of Cenozoic stratigraphy and until the distinctiveness of many New Zealand Mollusca was demonstrated by John Marwick (1891-1978), Harold John Finlay (1901-1951) and Arthur William Baden Powell (1901-1987) that the diversity and complex relationships of the fauna were realised; the approach to a modern taxonomy had begun.

To Charles Fleming, the sixth of these major students of the fauna, fell the role of modern synthesiser who began the job of reinterpreting the fauna in terms of modern evolutionary biology, as well as filling an important role in making others aware of the way the molluscan fauna fits in with changes in geography and in the rest of the biota. Charles was our mentor in Cenozoic Mollusca for more than 20 years. His great interest in the early history of the science, his intense interest in the evolution, ecology and biogeography of New Zealand Mollusca (as well as of so many other groups), and his ever-bubbling enthusiasm for new ideas were always a great inspiration. Other important contributions to the present book, rather more in the

background, were his most generous acquisition of many rare early books on Mollusca for the Geological Survey library (making accurate taxonomic studies much easier, as well as greatly helping the compilation of our bibliography), his preparation of the inspirational predecessor to this book (Fleming 1966b) and, above all, his very influential, long-continued patronage of broad, liberal, taxonomy-based paleontology in the New Zealand Geological Survey.

This book was well advanced when Charles died suddenly on 11 September 1987, two days after his 71st birthday, and after the publication of his Geological Survey Paleontological Bulletin on New Zealand Mesozoic Trigoniacea. He had been as pleased as we were to see (earlier in the year) the completed plates of Ron Brazier's beautiful drawings and to know we intended to dedicate this book to him. It is a most fitting tribute to the leading synthesiser of the history of the New Zealand biota that we dedicate this book to Charles Fleming. For more information on Charles' life and work, see the historical introduction (below), and the obituary by Hornibrook et al. (1988).

Alan Beu
Phillip Maxwell

CHAPTER 1. INTRODUCTION

Fossil shells that lived during the Cenozoic Era (roughly the last 66 million years) are widespread and abundant in most lowland areas of New Zealand, their enclosing sedimentary rocks having been eroded off most mountainous areas during the relatively recent uplift of the mountains. The larger fossils can be collected easily at most localities with a geological hammer, an ordinary hammer and screwdriver or chisel or even, in many Pleistocene rocks (deposited during the last 1.6 million years), picked out with a pocket knife or fingers. Smaller shells can be collected by sieving shelly matrix, preferably under running water, although most require a microscope for adequate identification (see the section on "micromolluscs", below). If they are extracted carefully from the rock, most specimens should be complete enough to be compared with the shells found now on New Zealand beaches, living on intertidal rocks, or dredged on the continental shelf. Such a comparison illustrates several interesting aspects of fossil shells:

- (1) the vast majority of fossil species are not the same as living species, and not all living species are known fossil. A long history (nearly 125 years) of study of fossil molluscs in New Zealand has demonstrated that, as everywhere else overseas, fossils become more and more different from the living fauna and flora as we go back in geological time. This is one of the many lines of evidence for evolution. It also leads to the use of fossils in biostratigraphy—dating of rocks by the different suites of fossils they contain (see section on "molluscan biostratigraphy," below).
- (2) Most geological units (one bed of rock, or a single small lens within a bed) contain fossils that, by comparison with modern shells, we can tell lived in some particular environment, for example a few metres of water off a sandy ocean beach, or in 80-100 m of water on the continental shelf well away from land. A few formations (mostly beach deposits) contain shells from a mixture of environments. The determination of the environments in which fossils lived, one aspect of the study of paleoecology (paleoenvironmental analysis), is very useful for understanding the situations in which rocks were deposited, an important aspect of geological history (see section on "molluscan paleoecology", below).
- (3) Perhaps the most valuable in the long term is the light all these studies cast on the different influences (evolution, dispersal, and extinction) that have produced the modern New Zealand molluscan fauna.

Fossils are particularly common in the main Cenozoic basins of New Zealand: Taranaki—Wanganui, the North Island east coast from East Cape to Palliser Bay, the South Island east coast and southern lowlands from Marlborough to Te Waewae Bay, the South Island west coast, and the Chatham Islands. Smaller areas of fossiliferous Cenozoic rocks occur in many other areas, too, particularly in Northland and Auckland.

This book attempts to provide an introduction to and overview of the New Zealand Cenozoic molluscan fauna for all who are interested, from amateur natural

historians to field geologists and advanced students of paleontology. The only previous similar book, "Marwick's illustrations of New Zealand shells" (Fleming 1966b), is out of print, and was illustrated with the drawings that Dr John Marwick used in his many scientific papers between 1923 and 1965. As Marwick described many uncommon species from remote areas, and only in some monographic revisions (of *Glycymeris*, *Struthiolariidae*, *Naticidae*, *Volutidae*, *Veneridae*, *Pectinidae*, *Notocallista*, *Cardiidae* and *Turritellidae*) illustrated species that had been named by earlier authors, the illustrations in Fleming (1966b) do *not* include most of the common Cenozoic Mollusca that collectors will recognise at most of the classical fossil localities. This book sets out, then, to convey more of the general nature of the New Zealand molluscan fauna than the earlier book could.

The great strength of this book is the 49 plates of more than 730 beautiful, scientifically accurate drawings by Ron Brazier, paleontological artist in New Zealand Geological Survey. Ron commenced the drawings in July 1975, and continued work on them between other projects (occupying about two thirds of Ron's time) for nearly 12 years, until March 1987. They were drawn on "stipple board" (card with a reticulate or dimpled surface), using a wall projector ("epidiascope") for larger specimens and a camera lucida for smaller ones. Details were then drawn in carefully with a pale pencil, using a microscope for accurate examination of sculpture of at least half the specimens, before finishing with a heavy black EE pencil. To make the drawings more useful, we have included a description of each illustrated species, with comparisons with many of the other listed but unillustrated species. We have also included a rather full illustrated glossary, so that the descriptions can be understood by readers not familiar with the special terms used for Mollusca. The 550 species selected for illustration (nearly half with more than one view) are noteworthy for their abundance, biostratigraphic utility, biogeographic or evolutionary significance, or previously unrecognised occurrence in the fauna. Some were included because they are spectacular, attractive members of the fauna, even though in some cases they are relatively uncommon fossils. In most cases, the descriptions are followed by notes on the biostratigraphic and/or paleoecological usefulness of each species, as we are sure this will increase the value of the text to many readers. We have illustrated the holotype or a paratype of the species wherever it was available, unless a more complete specimen characterised the species more fully. To compile the descriptive text we have had, in many cases, to revise previously accepted taxonomic ideas quite substantially. This part of the book represents a digestion of our accumulated knowledge of the New Zealand fauna, and we hope it will prove to be an important aspect of the book.

We have also included a checklist of all the Mollusca recorded as Cenozoic fossils in New Zealand, updated as fully as possible from that included by Fleming (1966b). The list takes account of all the changes in molluscan classification proposed between 1965 and mid-1988, as well as our own conclusions on the relationships and generic or specific synonymies of many

AGE, M.Y.	INTERNATIONAL DIVISIONS					NEW ZEALAND SERIES AND STAGES			SYMBOL	AGE, M.Y.
5 10 15 20 25 30 35 40 45 50 55 60 65	CENOZOIC	NEOGENE	PLEISTOCENE			SEE FIG. 2				
			PLIOCENE							
			MIOCENE	LATE	MESSINIAN	TARANAKI	KAPITEAN	Tk		
					TORTONIAN		TONGAPORUTUAN	Tt		
				MIDDLE	SERRAVALLIAN	SOUTHLAND	WAIAUAN	Sw		
					LANGHIAN		LILLBURNIAN	Sl		
				EARLY	BURDIGALIAN	PAREORA	CLIFDENIAN	Sc		
					AQUITANIAN		ALTONIAN	Pi		
			OLIGOCENE	LATE	CHATTIAN	LONDON	OTAIAN	Po		
					RUPELIAN		WAITAKIAN	Lw		
		EARLY		DUNTROONIAN	Ld					
							WHAINGAROAN	LATE	Lwh	
		EARLY		RUPELIAN	ARNOLD					Runangan
				PRIABONIAN			KAIATAN	Ak		
		LATE		BARTONIAN	DANNEVIRKE		BORTONIAN	Ab		
				LUTETIAN			PORANGAN	Dp		
		EOCENE		MIDDLE	YPRESIAN		DANNEVIRKE	HERETAUNGAN	Dh	
								MANGAORAPAN	Dm	
			EARLY	WAIPAWAN	Dw					
				PALEOCENE	LATE	SELANDIAN		TEURIAN	Dt	
		DANIAN	"WANGALOAN"			Mw				

Figure 1 Stage and series subdivisions of Cenozoic time used in New Zealand, with their symbols (right column) used to indicate ages in the checklist of Cenozoic Mollusca, and a correlation with the European standard time scale (left column). Based on Edwards et al. (1988). Upper right portion expanded in Figure 2.

abundant fossils that formed the basis of early studies of New Zealand Cenozoic geology, the determination of the relative ages of many (particularly Eocene to Miocene) faunas was not possible before the advent of H. J. Finlay's fundamental papers on New Zealand foraminiferal biostratigraphy. Readers are particularly recommended the two classical benchmark papers combining Finlay's foraminiferal biostratigraphy and Marwick's molluscan biostratigraphy (Finlay and Marwick 1940, 1947) in which the sequence of New Zealand stages and their faunas was clarified to such an extent that it has served as a standard (with only relatively minor changes) ever since.

In the introductions, below, to each age period, we have included maps showing the general location of the main localities of that age. We have carefully *not* included detailed information on most localities, although some (such as the internationally important Castlecliff section, west of Wanganui) are so richly diverse and so well known that suppressing their whereabouts would be pointless, and in any case inexhaustible material lies there for all to collect. The conservation of some of the older localities and some as yet undescribed is important, and collectors are urged to collect specimens carefully, and to leave much for those who will follow. Amateur collectors who find fossils they cannot identify, or particularly spectacular examples of some of the shells in this book, are urged to show them to staff in university geology departments or DSIR (particularly Geological Survey branches in Auckland, Rotorua, Nelson, Christchurch and Dunedin, or the authors of this book, in Lower Hutt). Freedom with information and generosity with scientifically valuable specimens will ensure a good relationship with scientists in this field, leading to a corresponding freedom with information to collectors on good localities and faunas, and in general to the kind of promotion of our science that is beneficial to all who are genuinely interested.

General subjects such as the composition of the Phylum Mollusca and full descriptions of New Zealand living shells (and all those common Pliocene and Pleistocene fossils that also occur in the living fauna) are covered by other books, notably Powell's (1979) "New Zealand Mollusca". We have concentrated here on an overview of the New Zealand Cenozoic molluscan fauna, the provision of a checklist and bibliography for access to all the taxa (more than 80% of the fauna) we don't have room to illustrate, and an illustrated glossary.

A SUMMARY OF THE ORIGINS OF NEW ZEALAND'S CENOZOIC MOLLUSCAN FAUNA

The highly diverse and unusual present-day molluscan fauna of New Zealand has developed gradually throughout Late Cretaceous and Cenozoic time (the last 100 m.y.), partly from an original Gondwanan fauna, but largely through the immigration of genera from elsewhere, and their subsequent evolution in New Zealand. The Cenozoic fossil record demonstrates that many other molluscan genera reached New Zealand, but became extinct in the region and so do not appear in the modern fauna. The long-continued, and still continuing, processes of immigration, evolution and extinction have

produced a long series of distinct faunas throughout Cenozoic time. Most distinct faunas correspond, at least in part, to recognised stages or groups of stages. Figs. 1 and 2 are tables of the stage and series divisions of Cenozoic time recognised in New Zealand, with their equivalent European divisions (recognised as the international standard sequence of divisions), their approximate absolute ages in years, and their abbreviated symbols. The symbols down the right-hand columns of Figs. 1 and 2 are used in the checklist and range charts (Figs. 5-8), to indicate the time ranges of each species.

We must emphasise that the plates were arranged and the text compiled using as a time-scale Stevens' (1981) Geological Society of NZ wall chart, with amendments from A.R. Edwards (NZGS; pers. comm.) and Beu et al. (1987). Figs 1 and 2 follow the latest NZGS time scale compiled for the Cretaceous-Cenozoic Project (Edwards et al. 1988).

Fleming (1963) has discussed the biogeographic elements in our fauna, and has provided (Fleming 1962c, 1975, 1979) very readable accounts of the origins of much of the present fauna and flora. Some Cenozoic Mollusca are thought to be survivors from Cretaceous or earlier faunas of Gondwana (the paleoaustral element; includes *Neilo*, perhaps *Cucullaea*, *Pinna*, *Isognomon*, *Acesta*, *Limatula*, *Zenatia*, *Panopea*, and *Crepidula*, probably most or all archaeogastropods (as very few of these have planktonic larvae), the Struthiolariidae, but probably relatively few other molluscs), and in our opinion it is likely that a considerable proportion of the Cenozoic and Recent molluscan fauna of New Zealand arrived here as planktonic larvae in ocean currents. There are clearly problems with assuming this origin for taxa that have a demonstrated *brief* larval life, insufficiently long for the genus or species to have crossed oceans, and the lack of preservation of shallow-water rocks that were deposited during early Cenozoic time (Paleocene to early Middle Eocene) has certainly masked a more diverse early fauna or very early arrivals for which there is no evidence. Nevertheless, many Cenozoic Mollusca appear to have arrived as larvae from nearby areas of the Pacific and from eastern Australia, still a source of larvae in the case of such modern trans-Tasman Sea species as *Semicassis pyrum*, *Cabestana spengleri*, *Agnewia tritoniformis*, *Sassia parkinsonia*, *Argobuccinum pustulosum tumidum*, *Tonna cerevisina*, and many others. Apparent influxes of warm-water taxa were particularly prominent during the Otaian and Altonian stages, leading up to and during the late Early Miocene-early Middle Miocene thermal maximum. From latest Miocene time onwards, the inception of West Antarctic glaciation and consequent enhancement of the circulation of cold water around Antarctica in the circum-polar current have brought to our shores a significant cool-water, circum-subantarctic faunal element, called by Fleming (1963) the neoaustral element, which includes many molluscs that are very familiar in the modern fauna, such as *Mytilus edulis*, *Aulacomya ater*, *Tiostrea chilensis*, *Chlamys patagonica*, *Argobuccinum pustulosum*, *Semicassis pyrum*, and many others.

We see then, a mixture of origins for the New Zealand molluscan fauna. There were three main periods when long-ranging, mid-Cenozoic to late Cenozoic or Recent genera seem to have arrived here (remembering again the proviso about the rarity of preservation of shallow-water facies):

- (1) Bortonian (late Middle Eocene);
- (2) Duntroonian (Oligocene); and
- (3) Kapitean (latest Miocene) to the present day, a smaller Neoaustral element.

A further period during the Early Miocene (Otaian and Altonian stages) saw the apparent influx of a large number of genera from warmer areas, but the subsequent progressive extinction of this warm-water element has been one of the most obvious features of our Late Miocene to Pleistocene faunal history. The Neogene history of the New Zealand molluscan fauna has therefore, involved the interplay of three factors:

- (1) The gradual step-wise extinction of warm-water taxa (Beu 1987b);
- (2) the evolution of many long lineages, culminating in characteristic Pliocene or Pleistocene to living species of the New Zealand region, such as *Struthiolaria papulosa*, *Zeacolpus vittatus* and *Austrofusus glans* (many of these taxa expanded and contracted their ranges as temperatures rose and fell during the Cenozoic); and
- (3) the dispersal of many taxa to New Zealand as planktonic larvae in ocean currents.

The relatively complete Neogene fossil record makes it certain that frequent arrival as widely dispersed planktonic larvae has been a significant factor in New Zealand marine molluscan biogeography. That it continues to be at present is shown by the recent sudden appearance and dramatic blooming in New Zealand of *Crassostrea gigas* (Thunberg) (although this edible oyster was possibly introduced accidentally by man) and *Limaria orientalis*. These two bivalve species were not recorded in the New Zealand modern fauna before about 1968-1970, although *L. orientalis* appears to have expanded and contracted its larval range, and so appeared on and disappeared from the local scene, many times throughout Duntroonian and Neogene time (Beu 1977c). Many marine invertebrates have long-lived planktonic larvae, which they have evolved as a dispersive phase in their life cycles (to be distinguished from the adult reproductive phase), and it seems hardly surprising that arrival as larvae should be a marked biogeographic factor in an oceanic archipelago such as New Zealand.

DESCRIPTION OF THE NEW ZEALAND CENOZOIC MOLLUSCAN FAUNA: A BRIEF HISTORY

The history of the description of the New Zealand Cenozoic molluscan fauna has been described in some detail, with copies of many early illustrations of fossils, by Fleming (1965). This short account is based on Fleming's longer one.

The description of the Cenozoic molluscan fauna is inextricably bound up with that of the Recent fauna, as so many scientists have worked in both fields, and as so many species still living around New Zealand occur fossil in Pliocene and Pleistocene rocks. Quite a number of extant species are known fossil in Miocene rocks, and a very few even in late Paleogene or earliest Miocene rocks (Duntroonian-Waitakian: *Chlamys* cf. *gemmulata*, *Anomia trigonopsis*, *Limaria orientalis*, *Dosinia lambata*, *Cleidothaerus albidus*, and possibly *Mesopeplum burnetti*

(= *convexum*?) and *Acesta levitesta*; interestingly, all are bivalves; perhaps all are examples of the lack of criteria making taxonomic discrimination difficult). Fleming (1965) included quite a detailed history of the early description of the living molluscan fauna of New Zealand, but we will concentrate here largely on the history of the Cenozoic fossils. It is sufficient to mention that a few living species that occur fossil were named in the first work recognised in nomenclature as a valid zoological publication (Linné 1758) and a few other species (most probably originating from Cook's voyages) found their way into other well-known early zoological works (eg, Martyn 1784; Lightfoot 1786; Gmelin 1791; Röding 1798; Lamarck 1816, 1819, 1822). More frequent exploration and the colonisation of New Zealand gradually led to more and more modern molluscs from New Zealand being named in Europe. From the 1840s on, colonisation and the exploration of the interior of New Zealand began to bring to light the fossil shells we now realise are so widespread. The earliest record of which we are aware of fossils from New Zealand (other than moas) is by the German explorer-geographer Ernst Dieffenbach (1841) who, in an account of a visit to the Chatham Islands, recorded the presence of fossils. He described in some detail a stratigraphic sequence on the north coast of Chatham Island, clearly that along the beach to the east of Tioriori. Part of his description reads:

"the lowermost of the horizontal strata is, for about a mile [1.6 km], a dark green friable sand [Tuturi Greensand; Teurian-Waipawan, Paleocene]. Over this, about 3 feet [one metre] above the level of the sea, there is a horizontal bed, from ½ a foot to a foot [15-30 cm] thick, of broken decomposed shells of the nautilus and oyster tribe".

He goes on to describe a complex alternation of Tioriori Greensand with Tumaio Limestone (Campbell et al. 1988), apparently not exposed during this century, and the overlying thick deposit of peat. The "oyster" is clearly *Pycnodonte* (*Notostrea*) *tarda* which is abundant at Tioriori, but nautiloids have not been recollected here. Other fossils collected in New Zealand by Dieffenbach, and by Dr Andrew Sinclair, a medical doctor interested in botany and shells, were reported on by J. E. Gray (Keeper of Zoology, British Museum (Natural History)) in his survey of the Mollusca known from New Zealand (Gray 1843, p. 258; p. 296). These included an interesting record of turritellids in a conglomerate, collected by Sinclair at Parengarenga Harbour in the far north of the North Island, a remote locality that has only come to the attention of paleontologists again during the last 30 years. Other material included a variety of species from the Kapitean exposures near East Cape; oysters, a brachiopod, a spatangoid echinoid, and (presumably) *Lentipekten hochstetteri* from Kawhia and Whaingaroa, south-west Auckland; and "*Gryphaea*" (presumably the *Pycnodonte tarda* collected by Dieffenbach) from the Chatham Islands.

The next early report was by Gideon Mantell (1850) (well-known English author of "Fossils of the South Downs", etc.) who reported identifications by Gray and by the neontologist Lovell Reeve of fossil shells sent by his son Walter Mantell, a New Zealand Company colonist and later member of the New Zealand parliament.

Mantell's paper (1850) included the first illustrations of New Zealand fossils (Fleming 1965, fig. 6): *Zeacolpus vittatus* and *Stiracolpus delli* from Wanganui, and *Dentalium centenniale* from Hampden Beach, Otago.

The detailed bibliography of New Zealand paleontology by Thomson (1913, p. 51-75; covering 1841-1912) lists several minor papers mentioning New Zealand fossils between 1845 and 1863. The highlight of New Zealand Cenozoic molluscan paleontology before New Zealand residents began systematic study, though, was the monograph by Zittel (1864) of the collections made by Ferdinand von Hochstetter during the visit of the "Novara", published lavishly in the "Novara" Expedition reports, with seven large quarto lithographic plates of Cenozoic Mollusca and echinoids. Common, well known species named by Zittel (1864) include *Athlopecten athleta*, *Lentipekten hochstetteri*, *Phialopecten triphooki*, *Crenostrea wuellerstorfi*, *Eucrassatella ampla*, *Pellicaria canaliculata*, and *Cirsotrema lyratum*. The collections were made mainly at Whaingaroa Harbour, south-west Auckland (Dunroonian-Waitakian), Awatere Valley, Marlborough (Kapitean-Waipipian), and The Cliffs, Nelson (Whaingaroan). This excellent work marks the beginning of the scientific study of New Zealand Cenozoic molluscs, nearly 125 years ago. Fleming (1959c) published extracts from Sir David Monro's diary about Hochstetter's visit to Nelson, with useful accounts of people who were the source of Hochstetter's fossils, and consequently of Zittel's species names (e.g., Robinson; Fleming 1959c, p. 958, footnote).

Hochstetter's regional geological surveys, carried out during and after the "Novara" Expedition visit, for the provincial governments of Auckland and Nelson, that brought to light the fossils reported on by Zittel (1864), showed the value of geological exploration of New Zealand for the discovery of coal and other economic minerals needed by the young country. With the discovery of gold in Otago, geological interest became intense, culminating in the national government establishing the Colonial Museum and Geological Survey Department in 1865, with its first director Dr (later Sir James) Hector. (This first scientific establishment in New Zealand later gave rise to many of the existing government scientific organisations: Geological Survey, Chemistry Division and Geophysics Division in DSIR, and the National Museum). Hector early realised the importance of determining the ages of New Zealand rocks by the development of a *local* biostratigraphy based on New Zealand fossils, and soon employed Alexander McKay (a Scottish former stonemason) as a fossil collector, and later as the most valuable and insightful of New Zealand's early geologists. Hector also employed a draughtsman, John Buchanan, who began illustrating the burgeoning fossil collections (some examples were published by Fleming 1965, fig. 8), but Hector's plans to publish on fossils were soon swamped in other work. Only the four drawings in the "Outline of New Zealand geology" (Hector 1886) ever saw the light of day (Fleming 1965, fig. 9). These species are now known as *Chama huttoni*, *Hedecardium brunneri*, *Struthiolaria spinosa*, and *Echinophoria pollens* (Finlay) (Hector's name *Cassis muricata* being preoccupied). Buchanan's two large foolscap folios of drawings are still held in the Geological Survey library.

Hector's next project on natural history was much more fruitful. In 1870 he employed Frederick Wollaston Hutton, a retired British Army Captain with training in geology, initially as a geologist but later to study New Zealand fossil and living Mollusca. Hutton published his two most important works in 1873, the "Catalogue of marine Mollusca" (Hutton 1873a) and the "Catalogue of Tertiary Mollusca and Echinodermata" (Hutton 1873b). These fundamental works, though brief, not illustrated (except for one plate in the "Catalogue of marine Mollusca") and plagued by homonyms and incorrect usages of overseas names that saw many of Hutton's names changed subsequently, form the foundation of the local study of Cenozoic and living Mollusca.

Boreham (1965) provided a valuable modern interpretation and reillustration of Hutton's (1873b) Cenozoic bivalve types, but a similar study is still needed for many of his gastropods. In 1873 Hutton left the Geological Survey (presumably because of difficulties with the autocratic Hector) to work as provincial geologist in Otago and curator of the Otago Museum, and later Canterbury Museum, where he devoted a long career (until his death in 1905) to the study of New Zealand zoology and paleontology. He described many of the more common Cenozoic Mollusca in his main works (Hutton 1873b, 1877b, 1885a, 1886a, 1893) and in several shorter papers, and will always be remembered as the founder of New Zealand Cenozoic molluscan paleontology.

The early collections dating from Dieffenbach's day and later presentations by New Zealand residents, as well as the purchase of collections, brought a useful collection of New Zealand Cenozoic Mollusca together in the British Museum (Natural History). Harris (1897) described the collections of Australasian Cenozoic Mollusca in a valuable, detailed monograph, with accurate illustrations, far ahead of anything being produced in New Zealand at the time. This was, though, the last significant overseas contribution to New Zealand Cenozoic molluscan studies.

The reorganisation of the Geological Survey under J. M. Bell in 1905 led to renewed realisation of the importance of a local biostratigraphy. The brilliant J. Allan Thomson, newly returned from Britain where he was New Zealand's first Rhodes Scholar, was appointed as the first official paleontologist in 1911. He proceeded to prepare, in *NZGS Paleontological Bulletin 1*, a very useful overview of the state of New Zealand paleontology at that time, with a list of fossil localities and a bibliography (Thomson 1913). He soon realised the importance of Mollusca being studied by a taxonomist with more specialised knowledge than his own. Thomson moved on to become director of the Colonial (later Dominion, now National) Museum, where he published a series of very important works on brachiopods. Apart from these, he realised relatively little of his potential because of years of struggle against tuberculosis, and an early death.

Henry Suter was a Swiss amateur malacologist who emigrated to the goldfields of Preservation Inlet and later took up land in the infamous "40-mile bush" in northern Wairarapa. He maintained his interest in Mollusca in his adopted land, publishing a series of small papers on land and marine Mollusca. After about 20 years here, he was commissioned by the government to write a "Manual of

the New Zealand Mollusca" (Suter 1913), the single most important work ever published on our Mollusca. This enormous task (considering the scarcity of library resources then, so far from northern hemisphere centres of learning) was accomplished magnificently, and this *magnum opus* is a lasting monument to Suter's knowledge and perseverance. It had an enormous, unforeseen influence on New Zealand and Australian molluscan taxonomy for the next 40 years, as it built on the most recent works of the northern hemisphere "giants" of the subject such as W. H. Dall, H. A. Pilsbry and E. A. Smith, and therefore suddenly projected New Zealand taxonomy to the highest levels then reached. Landmark papers (Iredale 1915; Finlay 1926c) that, in turn, built upon Suter's "Manual" to update the nomenclature and name many distinctive new genera and species, brought the subject up to date and formed an excellent basis for the work carried out during the middle part of this century.

These three works on Recent Mollusca had, of course, an equally profound affect on Cenozoic Mollusca. Following completion of his "Manual", Suter was employed by the Geological Survey to study Cenozoic Mollusca, and produced four of the early NZGS Paleontological Bulletins (Suter 1914, 1915, 1917, 1921), along with several smaller papers on Cenozoic Mollusca. However, the work on fossils did not produce the revolution that his "Manual" did—his eye-sight began to fail in his later years, his identifications became suspect, and the value of his later work tapered off.

Meanwhile, the two leading New Zealand molluscan paleontologists of the early half of the 20th century were at Otago University College, and in 1923 both began to publish, building strongly on Suter's and earlier paleontologists' foundations. Harold John Finlay was a crippled (probably by polio) but brilliant, incisive-minded molluscan enthusiast. His early training in geology under Patrick Marshall, who insisted (following 19th century views of a stable globe) on the long isolation of New Zealand from other land-masses, convinced Finlay that most apparent similarities of New Zealand molluscs to overseas ones resulted from convergence. He proceeded to propose local generic names for most of our Cenozoic Mollusca. Perhaps the worst aspect of this insistence on long isolation (reflected in such Finlayan generic names as *Insolentia* and *Inclaster*) was his influence on the Australian malacologist Tom Iredale. Correspondence preserved in NZGS Micropaleontology Section shows that Iredale and Finlay corresponded frequently during Iredale's early years at the Australian Museum, Sydney.

Initially they planned to coauthor the "further commentary" on Suter's "Manual" (Finlay 1926c) but after delays by Iredale, Finlay completed it and published it himself (this explains the somewhat enigmatic title, "A further commentary on New Zealand molluscan systematics"; it was "further" to Iredale's (1915) earlier paper). They undoubtedly influenced each other a good deal, and it is hard now to say who was more to blame for their increasingly idiosyncratic, isolationist taxonomy, but certainly their tendency to "name everything" as an apparently endemic genus in Australia and New Zealand has taken much of the subsequent years to eradicate, and has led to outright (and often unjustified) dismissal of Finlay and Iredale generic names by some northern

hemisphere taxonomists. Nevertheless, Finlay's influence on New Zealand Cenozoic molluscan taxonomy was profound, and over-all for the good; in particular, his naming of large numbers of species from the classical South Island localities (particularly in Oamaru district and at Clifden) greatly advanced knowledge of the fauna.

Finlay's greatest interest towards the end of his molluscan career was the enormous family Turridae, but this work was to see fruition only with the sale of his collection and notes to Auckland Museum, and its completion by A. W. B. Powell (1942). The "great depression" of the 1930s saw Finlay jobless, so at Jack Marwick's suggestion he gave up Mollusca for Foraminifera, and was initially employed by oil companies but later (from 1937) by the Geological Survey. There he turned his vast energy, speed of working, and enthusiasm to become the leading "foram" worker for 15 years, single-handedly revolutionising the biostratigraphy of the huge, complex sequences of Cenozoic mudstone that make up so much of New Zealand, some of which are potentially valuable sources of oil. Few people can have had such brilliant careers in two different fields, yet died so young (in 1951, aged 50). A very interesting account of Finlay's early work and his relationship with Marwick was published by Hornibrook (1971).

The other leading molluscan paleontologist coeval with Finlay was John (Jack) Marwick, a quieter but perhaps a steadier type, a Maheno (near Oamaru) boy who became interested in fossils at secondary school. The dedication of *Maoricolpus horni* is instructive (Marwick 1971, p. 44):

"dedicated to Aubrey Horn who, as a schoolboy at Waitaki Boys' High School, as early as 1904 was the first, to the writer's knowledge, to collect Mollusca from the Target Gully shellbed as fossils and not merely as fowl grit for which the pit was formerly exploited. From him the writer learned the rudiments of molluscan classification and first heard the word *Turritella*."

He was fortunate, also, in the headmaster of Waitaki Boys' High School, Dr J. R. Don, commemorated also in *Maoricolpus doni* (Marwick 1971, p. 44), who taught him geology, an unusual secondary school topic in those days. Marwick went on to become the major student of New Zealand Cenozoic Mollusca. He was employed as a paleontologist in the Geological Survey (after war service) from 1920 to 1952, and is still talked of very fondly as a person of calm, patient, wise intellect, a steadying influence on all. His clear comprehension of realistic taxonomic discriminating characters in many groups that were formerly little-understood (eg., hinges of Veneridae) allowed him to make great advances with monographs of groups (*Glycymeris*, Struthiolariidae, Naticidae, Volutidae, Veneridae, *Notocallista*, Cardiidae, Turritellidae), interspersed with faunal descriptions (Hawke's Bay Nukumaruan, Lorne, North Taranaki, Chatham Islands, Chatton, Gisborne district, Otahuhu well, Wairoa district). All these led to his naming of most of the more common species at most fossil localities (other than at Oamaru and Clifden, named by Finlay), apart from those relatively few named earlier by Hutton. A valuable contribution in Marwick's work, apart from

making the fauna known, is his interest in the evolutionary relationships of taxa—an evolutionary perspective that led to far more appreciation of faunal history than could be obtained from Finlay's somewhat bald descriptions. One of Marwick's major accomplishments, for the future of New Zealand paleontology, was to have Finlay employed by the Geological Survey. The great highlights of Cenozoic paleontology during this century have resulted from the joint work of Finlay and Marwick: the Wangaloa monograph (1937), and the biostratigraphic subdivision of Cenozoic rocks into a local stage scheme, using Finlay's forams and Marwick's molluscs (1940, 1947). As a monument to a leading scientist, Fleming (1966b) gathered Marwick's many scientific drawings of Cenozoic Mollusca in taxonomic order, in a very useful faunal catalogue that was the fore-runner to the present work.

Other, less frequently publishing scientists were working before and during the Finlay and Marwick period. Patrick Marshall made major contributions in an amazing variety of fields of geology, and from 1915 to 1923 published a number of papers on Cenozoic Mollusca, bridging the period between Suter and Finlay and Marwick. It is probably no coincidence that he ceased publishing on Cenozoic Mollusca when Finlay and Marwick started to publish. He brought to light the diverse faunules at Hampden Beach, Otago, at Wangaloa, and at Pakaurangi Point, Kaipara, and later combined with Wanganui amateur malacologist Robert Murdoch to describe a number of new species from near Wanganui, bringing to light the distinctive fauna of the Waipipi shellbeds.

Arthur William Baden Powell, at first an amateur but later for many years conchologist at the Auckland Institute and Museum, was the major student of the living molluscan fauna during this century, and his large overview book (Powell 1979) stands as a monument to a lifelong career. He published several important faunal monographs on Cenozoic fossil Mollusca, notably those on Kaawa Creek (Bartrum and Powell 1928), the Waiheke Island faunules (Powell and Bartrum 1929; Powell 1938a) and the Haweran Te Piki bed (Powell 1934). His major contribution, however, was to the study of New Zealand and world Turridae. He brought this huge, complex, previously chaotic group (he stated there are 10,000 named species) from a taxonomic nightmare to being reasonably well understood. For a fuller appreciation of Powell's contributions to New Zealand natural history, see the obituary by Dell (1988).

Teachers' Training College and Auckland University paleontologist Charles Reed Laws made his mark (as noted in the section below on "micromolluscs") by being the first paleontologist systematically to process bulk rock samples for small Cenozoic Mollusca. His earlier papers were on the more usual "large" Mollusca, but he soon began to study the full size range in faunules such as those at Pakaurangi Point, Kaawa Creek, and Hokianga. His lasting monument is the series of papers (Laws 1937a-d, 1938, 1939b, 1940c, 1941a) monographing the taxonomically "difficult" family Pyramidellidae.

The last paleontologist important in the history of description of New Zealand Cenozoic Mollusca was Charles Alexander Fleming (later Sir Charles; see also the dedication). After coast-watching at the Auckland Islands

(the "Cape Expedition", a war-time code name) for a year in 1942, Fleming mapped Wanganui ironsand deposits as a war-time economic project. He subsequently worked in Dannevirke Subdivision, then being mapped by Arnold Lillie, resulting in the most major scientific idea of his career—the realisation of the taxonomic identity and consequent paleoclimatic significance of *Chlamys patagonica delicatula* (published as "Molluscan evidence of Pliocene climatic change in New Zealand;" Fleming 1944). His interest in the Wanganui coastal sequence was high, following a visit there as a boy with Baden Powell in 1930, because of his interest in mapping the *Chlamys patagonica delicatula* zone more widely, because of his general interest in Plio-Pleistocene climatic and ecological changes, and because of his previous ironsand work, so he spent the later 1940s carrying out a geological study of Wanganui basin (Fleming 1953). This detailed stratigraphic subdivision, mapping, and paleoecological analysis is by far the most important work to date on new Zealand Plio-Pleistocene stratigraphy and fossils, clarifying for the first time the stratigraphy of the classical Wanganui sequence that had been the source of so very many molluscs since the days of Hutton. These two seminal works have together led on to all the subsequent recognition of the stratigraphic complexity, faunal and climatic changes, and glacio-eustatic sea-level changes that characterise New Zealand marine Plio-Pleistocene rocks; their implications are still being realised. In Cenozoic molluscan taxonomy, Fleming's major monograph was that of *Pecten* at Wanganui (Fleming 1957) (he made significant contributions also to Devonian and Mesozoic molluscan paleontology). Other significant papers on Cenozoic Mollusca were those on Dannevirke district (1943), Cenozoic cephalopods (1945), Pahi, Northland (1950a), Te Waewae Bay (1955a), Mytilidae (1959a), *Bassina* (1962a), *Galeodea* (*Galeocorys*) (1966a), "Marwick's illustrations" (1966b), the Clifden section (with Hornibrook and Wood, 1969), and *Limatula* (1978). However, he will be remembered most as an "ideas man", a synthesiser; he was the leading New Zealander to adopt the ideas of G.G. Simpson and Ernst Mayr on allopatric speciation and population taxonomy, providing a strongly evolutionary and paleobiological context for Cenozoic Mollusca (as well as birds and other groups). Probably his most important contribution to paleontology was to make all in the field aware of taking into account the biogeographic origins and history of the New Zealand biota, as he interpreted them in his biogeographic surveys (Fleming 1962c, 1975, 1979). These were conceived unashamedly from a historical perspective, "a paleontologist's approach", and one that proved extremely fruitful and serves as a model for other accounts of the biotic history of a region. Fleming's contributions to paleontology were many and broad; they will be a lasting basis for future work.

Fleming was also a deeply committed conservationist, and his interest in birds, molluscs, fossils of many groups, cicadas and conservation lasted all his life; he was perhaps the last of New Zealand's "complete naturalists".

Work continues by the present generation (among others B. A. Marshall, W. F. Ponder, and the authors of this book) to make knowledge of our fauna ever more complete. Fleming (1965) called the early third of this century (when large numbers of species were named by

Finlay, Laws, Marshall, Marwick, Murdoch, and Powell) the "golden age" of New Zealand Cenozoic Mollusca, and if sheer numbers are important it was so. But the present generation strives, not to name large numbers of species, but to improve classification through precision in taxonomy, and so to arrive at a more complete and detailed knowledge of the fauna that will improve its applications to studies of evolution, biogeography, faunal history, paleoecology and biostratigraphy.

Authorship: The dedication, chapters 1, 3, 4 and 12-16, the bibliography, and drafting are wholly or primarily by A. G. Beu, chapters 2, 5-11, 17 and 18 by P. A. Maxwell.

CONVENTIONS ADOPTED

Authorship of taxonomic names

As the authorship and date of all names for fossil species can be found from the checklist, these have been omitted everywhere in the text. The exceptions are extra-New Zealand species and those Recent species with no known fossil record, for which the author's name has been included.

Ages of some formations

In order to record time ranges for the species in our Cenozoic molluscan checklist, we have had to make somewhat arbitrary decisions about the ages of a few formations that are not well dated, or whose age has been debated. Some other formations have been redated in recent years. Significant ages adopted are:

- (1) Red Bluff Tuff, Chatham Islands: at base of sequence, near Pukekio, south of Pt. Weeding, Chatham Island, is early Teurian (Early Paleocene); elsewhere, mid-late Teurian or Waipawan at different localities, including on Pitt Island (Middle Paleocene to Early Eocene) (see Campbell et al. 1988 for revised ages of all Chatham Islands Cenozoic formations).
- (2) Upper reaches, South Branch, Waihao River sequence, basal part of section near "Pentland Hills" station: Mangaorapan.
- (3) Otaio Gorge fauna (Marwick 1960): Porangan.
- (4) Waiareka Tuff, Lorne: the block of green tuffaceous conglomerate near the former Lorne railway station, inland from Oamaru, source of molluscs from "Lorne", appears to have fallen from the top of the high bluff behind and is probably from high in the Waiareka Volcanic Formation. Its age is possibly Runangan rather than the usually accepted Kaiatan; we have adopted a late Kaiatan age.
- (5) Coastal sequence east of Te Araroa, East Cape: there has been considerable (unpublished) debate in recent years about the age of this sequence, which has a diverse, warm-water molluscan faunule; for some time, *Globorotalia* biostratigraphy seemed to point to a latest Tongaporutuan rather than Kapitean age. The question has been concluded to not be resolved by foraminifera (G. H. Scott, NZGS, pers.comm.) and we adopt a Kapitean age because of the occurrence of the classical Kapitean index molluscs *Sectipecten wollastoni* and *Austrofusus coerulescens*.

(6) Whenuataru Tuff, Pitt Island: previously regarded as Opoitian; now known to be Waipipian at most localities, ranging up to Mangapanian at a few localities.

(7) Castlecliffian—Haweran boundary: following Beu et al. (1987), this stage boundary is now adopted at the top of Putiki Shellbed, at Putiki, Wanganui (top of the range of *Pecten benedictus marwicki*); consequently, Landguard Formation at Wanganui and the Mingaroa shellbed in the Rangitikei River sequence are now dated as Haweran.

(8) Te Piki, Cape Runaway: this young deposit with an extremely diverse fauna (Powell 1934; Grant-Mackie and Chapman-Smith 1971) has previously been regarded as late Castlecliffian, and correlated with the Landguard Formation (which, however, is now regarded as early Haweran) at Wanganui. New evidence from tephrostratigraphy, calcareous nannoplankton, and terrace stratigraphy has shown that its age is mid-Haweran, about 200,000 years (oxygen isotope stage 7) (A. R. Edwards, NZGS, pers.comm.).

Collection and locality numbers

The only two abbreviations that need explanation are collection and locality numbers for the described specimens:

GS numbers: New Zealand Geological Survey macrofossil collection numbers.

W23/f286 (etc.): locality numbers in the National Fossil Record (Geological Society of New Zealand); the first half is the sheet number in N.Z. Map Series 260 (1:50 000), the second half is the individual locality number within that sheet.

Dates of publication

Finlay's (1926c) major publication on New Zealand molluscan taxonomy, "A further commentary on New Zealand molluscan systematics", has consistently been dated as 1927 by recent New Zealand authors, no doubt partly because of the acceptance of 1927 as its date of publication by the ICZN in Opinion 479 (International Commission on Zoological Nomenclature 1958, p. 373, for the genus-group name *Venustas* Finlay). Although the volume this paper appeared in was published on 10 March 1927, reprints and the subscript to the title in the published volume state clearly that reprints were "issued separately, December 23 1926". Under the present (1985) Code of Zoological Nomenclature, this paper was clearly published in 1926, and we can see no reason not to accept 1926 as its date of publication. The one possible nomenclatural change resulting from the change of date concerns *Maurea* Oliver, 1926 vs. *Venustas* Finlay, 1926, but this case is in fact not affected as the Commission (1958, p. 363) accepted the date of publication of *Maurea* Oliver as 20 December 1926.

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CHAPTER 2. MOLLUSCAN PALEOECOLOGY

Ecology is the study of the relationship organisms have with the physical environment and with each other. Paleocology attempts to infer such relationships for fossils on the basis of their similarity (taxonomic or morphological) to extant organisms, from evidence for behaviour (e.g. predation), from the manner of their preservation, and from sedimentological evidence (e.g. whether they lived on a hard or soft substrate). Paleocology should therefore, have both physical (i.e. non-biological) and biological components, but in practice most of what is called paleocology deals with attempts to infer the physical paleoenvironment, a subject of considerable interest to geologists. This type of study—which may have no paleontological input whatsoever—is best described as “paleoenvironmental analysis”.

PALEOENVIRONMENTAL ANALYSIS

Because of the high stratigraphic resolution that can be obtained from microfossils (chiefly foraminifera and coccoliths), molluscs have been relatively little-used in recent years for dating New Zealand Cenozoic rocks (except in the Late Miocene to Pleistocene). However, they have proved particularly useful for paleoenvironmental analysis. They have a marked

advantage over all other readily fossilisable invertebrate groups in having representatives in a wide range of terrestrial environments as well as in aquatic habitats, the latter ranging from fresh water through brackish water to virtually the whole of the marine realm. Because many molluscs are relatively large it is often possible for a paleontologist to give an “on-the-spot” assessment of the paleoenvironment rather than have to wait for laboratory preparation of the rock sample.

The reliability of paleoenvironmental analyses depends to a very large degree on the supposition that extinct species had similar ecological requirements to closely related or morphologically similar extant forms. This is not necessarily completely true as there is plenty of evidence to indicate that many groups of organisms have either changed considerably in their ecological preferences through time, or have become restricted to a small part of their former habitat. Nonetheless, it seems unlikely that all of the species in a diverse Cenozoic fossil assemblage will have had a significantly different habitat from their living relatives, so for maximum reliability paleoenvironmental analyses should be based on as many taxa as possible. In general, fossil molluscs can be ranked as follows in decreasing order of reliability for paleoecological interpretation.

1. Species that are still extant. The majority of molluscs in Pleistocene faunules fall in this category, but they become progressively less numerous with increasing age. Only a few Paleogene molluscs that are morphologically indistinguishable from extant species are known from New Zealand.
2. Species that are extinct but have congeners in the modern New Zealand fauna. Many, possibly the majority, of New Zealand Cenozoic molluscs are of this type. Some extant genera are richly speciose, with representatives in a wide range of environments, so it is necessary in such cases to compare the fossil species with what appears to be the most closely related living form. This invariably introduces some "noise" into paleoecological interpretation.
3. Species belonging in genus-group taxa that are extinct in New Zealand, but survive elsewhere. Many of the warm-water groups recorded from the Cenozoic in New Zealand belong in this category.
4. Species in genus-group taxa not known to be part of the modern fauna anywhere. Many of the extinct groups recorded in the New Zealand Cenozoic fauna were probably endemic to the New Zealand region, but others are more widely distributed. The only way in which taxa in this category can be used for paleoecological analysis is by noting their association with taxa of known ecological preferences.

In the following section we discuss the most important physical factors known to influence the distribution of molluscs, and give some examples from the New Zealand fauna.

AUTECOLOGICAL APPROACHES

1. Salinity

With relatively few exceptions the New Zealand Cenozoic molluscan record is one of aquatic species. Although a considerable number of species of land-snails have been recorded from late Pleistocene or Holocene sediments (particularly cave deposits), there are very few older records of the group. The most notable are from Pakaurangi Point, Northland (Otaian) (Climo and Maxwell, in prep.) and from the Upper Waipara River, North Canterbury (probably early Wanganui Series). The few species recorded constitute only a minute fraction of the total terrestrial molluscan fauna that must have existed in New Zealand during the Cenozoic.

a. Fresh-water

Fresh-water sediments of Cenozoic age are of restricted extent in New Zealand and those that are preserved seem to have been deposited under acidic conditions or have undergone post-depositional leaching, so molluscs are rarely present. The only widespread molluscs are bivalves of the family Unionidae ("fresh-water mussels"). Other constituents of the modern New Zealand fresh-water fauna (i.e., Sphaeriidae, Hydrobiidae, Thiaridae, Lymnaeidae, Planorbidae, Physidae, Latiidae and Ancyliidae (see Winterbourn 1973 for a concise summary)) are either unknown or are very rare in pre-Holocene beds.

Where they are recorded they are typically associated with estuarine or shallow-water marine molluscs, eg. the occurrences of the very widespread hydrobiid *Potamopyrgus antipodarum* in some Castlecliffian and Haweran faunules.

The best-known non-marine molluscan assemblages are from the Pomahaka Formation, Otago (Duntroonian ?) (see below). Most of the molluscs recorded from this unit were probably brackish-water, but others including hydrobiids, *Melanoides?* n.sp., *Planorbis?* sp. and *Neritoplica?* *pomahakaensis* are more likely to have lived in fresh water.

b. Brackish-water and estuarine facies

Because of the influx of fresh water and because circulation is relatively restricted, estuaries exhibit a considerable range in salinity, with fresh or brackish water at the head and water of normal or near-normal marine salinity at the mouth. Molluscan faunules of probable estuarine facies are recorded sporadically in the New Zealand cenozoic from Duntroonian onwards, but "pure" brackish-water assemblages (ie. without an admixture of molluscs from other environments) are much rarer than those that are inferred to have lived in the lower reaches of estuaries where salinity was appreciably higher. One of the most characteristic molluscs in the modern brackish-water fauna is *Melanopsis trifasciata* (also in fresh water according to Winterbourn (1973, p. 153))—this is common at Kaiti Hill, Gisborne (Haweran) where it occurs with another brackish-water species, the mussel *Xenostrobus securis* and with very abundant *Anadara trapezia*, an estuarine species now extinct in New Zealand (see below). *Melanopsis* (*Stilospirula?*) *pomahaka* is locally abundant in the Pomahaka Formation (Duntroonian?) and may have been an environmental analogue of *M. trifasciata*.

The middle and lower reaches of estuaries, particularly intertidal mud flats, support a more diverse but nonetheless rather restricted molluscan fauna that includes species of *Nucula*, *Solemya*, *Atrina*, *Cyclomactra*, *Macomona*, *Austrovenus*, *Notoacmea*, *Micrelenchus*, *Pisinna*, *Zeacumantus*, *Cominella*, *Xymene* and *Amphibola*. Some of these genera also have representatives in shallow-water marine facies, and all have a fossil record, particularly in the late Cenozoic—*Austrovenus* is first recorded from the Waitakian (Brydone, Mataura River), and may have ecologically replaced *Hinemoana acuminata*, which is abundant in some Pomahaka Formation assemblages. Several taxa that are extinct, or are no longer living in the New Zealand region, were probably also estuary-dwellers—these include *Crassostrea*, *Eumarcia*, *Barytellina*, *Batillona*, *Batillaria*, *Zefallacia*, *Taxonia* and *Pomahakia*. The highly distinctive species *Struthiolaria tuberculata* (Pl. 20 c,d) may have been restricted to an estuarine habitat—it is known definitely only from the Enys Formation (Altonian), Castle Hill Basin, Canterbury where it occurs locally in large numbers, associated with *Eumarcia* and *Batillaria*.

c. Normal salinity

The vast majority of New Zealand Cenozoic benthic molluscs seem to have lived in waters of normal salinity

and their distributional patterns are related primarily to factors such as substrate type, water depth and temperature. However, the greater diversity and abundance of planktonic species (particularly thecosome pteropods) in oceanic waters compared with in-shore waters probably reflects the normally somewhat lower salinity of the in-shore habitat.

2. Substrate

The nature of the substrate has a profound effect on benthic biotas, including molluscs—the faunule living on a rocky bottom differs greatly from that inhabiting soft silt in otherwise similar conditions. There is in fact considerable evidence to indicate that the larvae of many marine invertebrates actively select suitable substrates before settling and metamorphosing. For sediment substrates the coarseness and grain-size distribution are obvious properties that affect molluscan distribution; not only do they determine whether the substrate is firm or soft, but they also influence the quantity of nutrients trapped in the sediment. The general decrease in sediment size with increasing distance from shore at least partly accounts for the increase in the diversity and abundance of deposit-feeders with depth, as more nutrients are absorbed by silt and mud than by sand.

Biogenic substrates typically support very different faunules from surrounding sediments. The very rich fauna associated with coral reefs is an obvious and spectacular example, but other substrates (e.g. sea-grass, kelp, oyster-beds, water-logged wood and deep-sea coral thickets) are far more relevant to the New Zealand situation. Plant material usually decays without leaving direct evidence of its existence once it is buried, but the associated molluscs may be preserved, producing an assemblage that differs markedly from those living nearby.

a. Rocky-bottom substrates

Although rocky bottoms are most characteristic of very shallow waters, including the intertidal zone, they also occur down to the greatest depths and far from land, for example on the summits and flanks of volcanic seamounts, on canyon walls, etc. There is considerable irony in the fact that although the ecology of rocky shores has been studied in much greater detail than that of virtually any other marine environment, this facies is one of the most poorly represented in the fossil record. The modern New Zealand rocky shore and subtidal fauna includes mussels (*Mytilus*, *Aulacomya*, *Modiolus*, *Perna*), oysters (*Ostrea*, *Tiostrea*, *Saccostrea*), *Haliotis*, limpets (*Cellana*, *Patelloida*, *Notoacmea*, *Siphonaria*, etc.), trochids (*Diloma*, *Trochus*, *Melagraphia*), turbinids (*Turbo*, *Cookia*), *Nerita* (*Melanerita*), *Nodilittorina*, muricids (*Thais*, *Lepsiella*, *Haustrum*, *Neothais*) and many chitons, all of which have a poor fossil record. A small rocky shore faunule from Mt Luxmore, Fiordland (probably Duntroonian or Waitakian) includes *Haliotis*, *Cookia*, *Trochus* (*Thorista*), *Barbatia* and *Trichomya* (Lee et al. 1983); other faunules of similar facies are recorded from Kawau Island (Otaian) (Powell 1938a, p. 376), from Castle Hill Basin (Duntroonian or Waitakian) and from Mason River, North Canterbury (also Duntroonian or Waitakian).

Infaunal molluscs in the rocky shore zone are mostly restricted to rock-borers (e.g. *Zelithophaga*, *Barnea* (*Anchomasa*) and *Pholadidea* among the modern fauna, *Lithophaga* and *Parapholas* as fossils) or nestlers (e.g. *Hiatella*, *Irus*, *Leptomya*, *Kellia* and *Risellopsis*), but some burrowing bivalves (e.g. *Tucetona*, *Dosinia*, *Megacardita* and *Eucrassatella*) associated with fossil rocky shore faunules probably lived in subtidal gravel close by; at present *Pseudarcopagia disculus* and *Protothaca crassica* seem to live only in gravel on rocky shores.

Deeper-water rocky or firm-bottom assemblages are much more widely distributed than those of rocky shore facies in the New Zealand Cenozoic, and are recorded from volcanogenic rocks in the Oamaru district (e.g. Lorne, Bridge Point, Gees' Point), Waihao River, South Canterbury (Kapua Tuff), Castle Hill Basin (the "Fancoral bed"), Muriwai, Auckland and Chatham Islands (Red Bluff Tuff). Some of these assemblages are probably of shallow-water (inner or middle shelf) origin (e.g. the "Fancoral bed") but others probably lived at bathyal depths (e.g. the faunule from Muriwai described by Powell 1935). The assemblages typical of volcanogenic substrates vary greatly in composition but usually include representatives from at least some of the following groups—Arcacea (e.g. *Arca*, *Acar*, *Quadrilatera*), Pectinidae and Propeamussiidae (*Chlamys*, *Serripecten*, *Eburneopecten*, *Propeamussium*, *Parvamussium*), Limidae (*Lima*, *Limatula*, *Limea*, *Acesta*), Spondylus, Mytilidae (*Modiolus*, *Amygdalum*, *Septifer*), Glycymerididae, Carditidae, Verticordiidae, Pleurotomariidae, Trochidae (*Calliostoma*, *Conominolia*, *Spectamen*, *Calliotropis*), Turbinidae (*Bolma*, *Astraea*), Cassidae (*Galeodea*, *Echinophoria*), Ranellidae, *Xenophora*, Triviidae (*Trivia*, *Willungia*), Cypraeidae and Epitoniidae. Epifaunal species predominate—some of the above taxa (e.g., Carditidae, Verticordiidae, *Xenophora*) are more characteristic of soft substrates, whereas infaunal molluscs, (e.g., protobranchs, venerids, tellinids, mactrids and scaphopods) are absent or rare.

b. Level-bottom substrates.

The term "level-bottom" is preferred to "soft-bottom" for sands, silts and muds, for some of the latter may produce a relatively firm substrate.

The sediments included in this category vary greatly not only in size-grade and degree of sorting, but in stability, cohesiveness, nutrient availability and oxygen content, and it is difficult to give a concise account of the molluscan assemblages they support. In many cases it may be the non-preserved component of the original biota that has determined the diversity and abundance of some groups of molluscs, e.g. certain species of polychaetes that form the diet of most turrid gastropods.

Sedimentological factors such as overall size-grade and sorting influence infaunal and epifaunal molluscs alike. The nutrient content of sediments typically increases with decrease in size-grade, so deposit-feeding taxa are usually more diverse and abundant in silt and mud than in sand. Many epifaunal bivalves are, however, prevented from inhabiting fine-grained substrates by their lack of a means of cleaning the gills and mantle cavity. (A decrease in size-grade is of course typically correlated with an increase in depth, showing how difficult it can be to disentangle

the different factors that influence benthic molluscan distribution).

Cohesiveness—which depends on biogenic material content as well as mineralogy—is also of obvious importance. Large epifaunal molluscs, particularly gastropods, generally avoid “soupy” substrates unless they are specially adapted for such a mode of life (e.g. have a thin shell or some method of distributing their weight over a wide area). Semi-infaunal molluscs such as naticids or olivids which plow through the upper part of the sediment are much less affected, but Yochelson et al. (1983) have shown that predation by naticids on scaphopods (which are infaunal) is markedly less frequent in mud than in sand. They attribute this to the greater difficulty that naticids have in moving through sticky mud compared with sand.

Few molluscs can cope with living in or on an intermittently or perpetually shifting substrate such as an open sandy beach. Those that do are either rapidly burrowing infaunal species, or ones that can disintegrate themselves quickly. Modern New Zealand sandy beaches support relatively few but often numerically abundant bivalves from the families Mesodesmatidae (*Paphies*), Tellinidae (*Peronaea*, *Tellinota*, *Rexithaerus*), Psammobiidae (*Gari*), Mactridae (*Mactra*, *Spisula*, *Resania*), Veneridae (*Dosinia*) and Myochamidae (*Myadora*). All have at least some of the characters that facilitate rapid burrowing in bivalves, i.e. an antero-posteriorly elongate shell, a thin shell, a laterally compressed shell, sculpture of low relief or completely lacking, and a well defined posterior area (see Stanley 1970, an essential reference for anyone interested in the relationships between shell form and habitat in bivalve molluscs).

A well oxygenated environment is essential for most molluscs, and only a few species (mostly in the bivalve families Solemyidae, Lucinidae and Thyasiridae) can live in completely anoxic conditions through utilisation of sulphide-oxidising bacteria in their gut (see Reid and Brand 1986). Most marine sediments are oxygenated in the upper few centimeters and are strongly reducing beneath this zone. Many oxygen-requiring bivalves can nonetheless live in this anoxic zone so long as their siphons extend into oxygenated waters. Anoxic bottom conditions—which can exist beneath fully oxygenated surface waters—seem to have been widespread in New Zealand during the Paleocene when there was slow marine transgression over land of mostly low relief, and during the Late Eocene when a considerable thickness (up to 900 m) of grey or brown siltstone (Kaiata Formation) with very few macroinvertebrates accumulated in the Paparoa Trough in Westland and Nelson.

c. Biogenic substrates.

Some of the most diverse molluscan assemblages are those living on or in biogenic substrates such as other mollusc shells, bryozoans, corals, sponges, algae and wood. For some molluscs, this type of substrate serves merely as shelter or to provide a suitable place for attachment (e.g. many oysters and anomiid) or to bore into (e.g. *Pholadidea thomsoni* in oyster shells at Anthony Bay, Coromandel (Otaian), or *Lithophaga* and *Gastrochaena* in the coral *Madracis dodecachora* Squires, 1958 in the

South Branch, Waihao River (Mangaorapan)). For others the substrate is food as well as haven—cerithiopsids live on (or in) sponges, epitoniids feed on coelenterates (mainly corals and anemones), and teredinid bivalves infest wood. The presence of such molluscs in fossil assemblages is usually the only evidence that these substrates were originally present. Local concentrations of teredinid tubes with or without associated wood are not uncommonly found fossil—much rarer are the other molluscs known to be associated with water-logged wood, e.g. the limpet *Pectinodonta*, represented in the New Zealand Cenozoic by four known species, one of which has been found associated with carbonised wood (Marshall 1985). Other, more “exotic” substrates for deep-sea molluscs include squid-beaks, stone-crab carapaces, decaying kelp hold-fasts, and bone (Marshall 1983c, 1985; Hickman 1983). Molluscs associated with these particular substrates have not yet been found fossil in New Zealand, but there is a probable record of a Late Eocene species of the limpet genus *Addisonia* from Lorne, North Otago. At least some (and probably all) extant species of *Addisonia* live inside empty shark egg-cases (McLean 1985). Other small limpets of the family Lepetellidae, which live only on and in the narrow, horny tubes of the bathyal polychaete *Hyalonoecia*, occur quite commonly at some localities in the “*Modiolus* limestone” pods (Lillburnian) in the Gisborne district, suggesting that the limestone formed as deep-sea biogenic accumulations. Parasitic molluscs, particularly eulimids and pyramidellids, are present in many fossil assemblages and may give important clues as to the former presence of host organisms that are rarely, if ever preserved.

The biota living on a biogenic substrate is often much more diverse and qualitatively distinct from that inhabiting the surrounding area. Beu (1967a, p. 119-120) showed that the Pliocene molluscan faunule associated with the deep-water coral thicket at Palliser Bay differs radically from those in the immediately underlying and overlying siltstone. Some of the molluscs in the thicket were probably attached to the coral itself (e.g. *Limatula*, *Ctenoides*, *Pododesmus* (*Monia*), *Emarginula* and *Tugali*), but others seem to have lived on the sand trapped by the thicket.

3. Depth

The depth of deposition of a sediment is of considerable interest to geologists and as a consequence paleontologists are often called upon to provide paleobathymetric data, usually to the exclusion of other relevant ecological factors. In New Zealand, the use of molluscs to infer “paleodepth” seems to date from Marshall (1915, p. 380) who concluded that the faunule from the famous Target Gully Shellbed at Oamaru (Altonian) “appears to be characteristic of a depth of about 40 fathoms” (about 70 m).

Paleobathymetric determinations, of course, rest on the assumption that the extinct species had similar depth ranges to their living relatives. This is not necessarily true—the only extant New Zealand species of *Scaphander* is restricted to the upper bathyal zone (Dell 1956c, p. 143), but at least some of the fossil species lived in much shallower waters, including the inner shelf zone. Paleodepth determinations should, therefore, be based on as many taxa as possible.

A considerable number of physical properties are correlated with an increase in water depth, i.e. increase in hydrostatic pressure, decrease in bottom temperature, decrease in availability of sunlight, and decrease in mean sediment grain-size. The effects of these factors may be difficult, if not impossible, to distinguish, and anomalies (e.g. the presence of a relatively coarse substrate in deep water) may lead to problems in interpreting the associated biota. Nonetheless, there are well established patterns in the distribution of molluscs that give important clues to the probable depth of deposition of a fossil assemblage.

- a. Large molluscs, particularly those with thick shells, are characteristic of the shelf environment. Some species of the typically bathyal limid genus *Acesta* reach a large size, and certain deep-water gastropods (e.g. *Fusitriton*, some buccinids, some turrids) may be of comparable size to their shallow-water relatives, but they usually have a relatively thin shell, and are extremely sparsely distributed, and are more subject to dissolution than they are in shallower water. The presence in an assemblage of large specimens of Glycymerididae, *Limopsis*, *Cucullaea*, Crassatellidae, Carditidae, Veneridae, Mactridae, Turbinidae, Turritellidae or Naticidae is good evidence for a shallow-water environment.
- b. The following taxa typically have their greatest abundance or species-diversity on the modern New Zealand shelf, although most also have representatives in deeper waters—Arcidae, Glycymerididae, Ostreidae, Anomiidae, Pectinidae, Limidae, Mesodesmatidae, Tellinidae, Psammobiidae, Mactridae, Hiatellidae, Myochamidae, Lottiidae, Turbinidae, Trochidae, Turritellidae, Struthiolariidae, Calyptraeidae, Cassidae, Ranellidae, Muricidae, Columbelloidae, *Cominella*, *Buccinum*, *Penion*, *Amalda*, *Alcithoe*, Pyramidellidae and Polyplacophora. All have a fair to good fossil record in New Zealand. In addition, many taxa that are extinct (at least in the New Zealand region) seem primarily to have been shelf-dwellers, e.g. *Cucullaea* (sensu lato), *Limopsis* (sensu lato) (particularly the larger species), *Pinna*, “*Isognomon*”, *Crenostrea*, *Miltha*, “*Cyclocardia*”, *Megacardita*, *Glyptoactis* (*Fasciculicardia*), *Eucrassatella*, *Spissatella*, *Maoricardium*, *Hedecardium* (sensu lato), *Nemocardium* (*Varicardium*), *Solecurtus*, *Pyraxus*, *Magnatica* (sensu lato), *Paracomina*, *Nassicola*, *Zelandiella*, *Clifdenia*, *Morum* (*Oniscidia*), *Mauira*, *Austrotoma*, *Maorivetia* and *Scalptia*.
- c. With increasing water depth there is an increase in the diversity of protobranch bivalves (nuculids, nuculanaceans and solemyids) and of many Anomalodesmata (particularly the septibranchs Cuspidariidae, Poromyidae and Verticordiidae), but a decrease in pteriomorph (except Propeamussiidae) and heterodont diversity. Archaeogastropods (particularly scissurellids, skeneids, liotiids (on bryozoan and sponge substrates), seguenziids and some groups of limpets) and the neogastropod families Turridae and Cancellariidae increase in importance with depth, whereas mesogastropods (except for naticids) generally decline.

Dell (1956c) was the first to present a systematic survey of the New Zealand Recent “archibenthic” (upper bathyal) molluscan fauna on a regional scale and his work has formed the basis of several paleoecological studies on Neogene deep-water faunules (Beu 1967a, 1969, 1970c, 1979; Maxwell 1988a). Continuing work by B.A. Marshall (National Museum of New Zealand) has greatly augmented our knowledge of New Zealand deep-sea molluscs, and will ultimately lead to considerable refinement in paleobathymetric interpretation. Dell (1956c, p.189) showed that there is no abrupt change in the composition of modern molluscan faunas at the shelf-slope break, and identified a “transition zone” from c. 180–220 m. (The depth of the break is traditionally taken as being about 180m but it varies greatly—some workers have chosen a depth of 150m which corresponds to the average value for the base of the euphotic zone, i.e. the depth to which sunlight usable for photosynthesis penetrates). Some typical shelf species penetrate even deeper than 220 m, but they form a minor part of the bathyal fauna.

The studies on the Recent bathyal fauna, and those mentioned above on Neogene faunules have identified a large number of taxa that are restricted to, or are most common or most speciose in the bathyal zone. Those recorded fossil include *Brevinucula*, *Linucula*, *Deminucula*, *Zealeda*, *Austrotindaria*, *Pseudotindaria*, *Minormalletia*, *Bathyarca*, *Pectunculina*, *Propeamussiidae*, *Acesta*, *Bartrumia*, *Pholadomya*, *Procardia*, *Euciroa* (and probably most other verticordiids), *Cuspidaria*, *Pleurotomariidae*, *Pectinodonta*, *Cocculinidae*, *Pseudococculinidae*, *Calliotropis*, *Seguenziidae*, *Ihungia*, *Falsilunatia*, *Uberella* (*cicatrix* group), *Galeodea* sensu stricto (not uncommon in shelf assemblages prior to Late Miocene), *G.* (*Galeocorys*), *Sassia* (*kampyla* group), *Aeneator* (*Ellicea*), *Nassaria* (*Microfusus*), “*Pleia*”, *Pakaurangia*, *Exilia*, *Microvoluta* (“*Vexillita*” group), *Volutomitra*, *Hiwia*, *Iredalina*, *Mauithoe*, *Marshallena*, *Comitas*, *Cosmasyrinx*, *Gemmula*, *Paracomitas* (*Macrosinus*), *Splendrillia* (*Hauturua*), *Bathytoma*, *Eubela*, *Mioawateria*, *Thatcheria*, *Oamaruia* (*Zeadmete*), *Waipaoa*, *Ringicula* (*Ringiculina*), *Waikura* and *Striacadulus*. Many of these taxa are apparently extinct in the New Zealand region.

Most of the bathyal assemblages recorded from the New Zealand Cenozoic seem to have lived in the upper part of the zone (c. 200–800m), and there are very few records of molluscs (other than specimens probably redeposited from much shallower waters) from significantly deeper-water sediments. The small Altonian faunule recorded by Hayward (1979) from the Waitakere Range near Auckland includes the arcid genus *Bentharca* (originally identified as a species of *Notogrammatodon*), which is consistent with the depositional depth of 1000–2000m inferred on the basis of the associated foraminifera (Hayward 1979). The type species of *Bentharca*, *B. asperula* (Dall, 1881) has a recorded depth range of 430–3005m (Knudsen 1970, p. 75) but most records are from below 2000m. Sedimentological evidence indicates that the flysch from which the deep-water limpet *Pectinodonta waitemata* Marshall, 1985 was collected, was deposited at about 1600m (Ballance 1974). There can be little doubt that other fossil lower bathyal molluscs await discovery—as Marshall (1985, p. 277) suggests,

particular attention should be paid to any wood remains in deep-water sediments.

4. Temperature

Temperature is probably the most important single physical factor affecting the distribution of molluscs, and analysis of fossil assemblages can therefore, give valuable information on past climatic changes. At the present day the most important temperature gradients are latitudinal and bathymetric, although the simple patterns that might be predicted on the basis of these factors alone are upset by local surface current systems and by the upwelling of cold bottom water in some areas. Even in New Zealand—which has a latitudinal span of 12.5° Lat.—there is a marked difference between the molluscan faunas at opposite ends of the country, and there is evidence that this gradient has existed in the past as well.

There is abundant evidence—not only from molluscs but also from other fossil groups and from oxygen isotope measurements—to show that there have been major changes in sea temperatures in the New Zealand region during the Cenozoic. The gradual northwards drift of New Zealand following the breakup of Gondwana probably accounts for some of the overall warming that occurred from Early Paleocene to about early Middle Miocene, but superimposed on this are important temperature excursions, some of which probably relate to global events, others to more localised changes in oceanic current patterns in the south-west Pacific. Although the general picture is reasonably well known there are many details to fill in and studies on the distribution of Cenozoic molluscs will no doubt contribute to our understanding of these climatic changes.

In general, it has proved much easier to identify molluscs of probable warm-water affinity in the New Zealand Cenozoic fauna than those indicative of cooler conditions. The following taxa have extant representatives in warm (subtropical) waters, but are extinct in the New Zealand region or survive only in the northern part of the country—*Sarepta*, *Arca*, *Quadrilatera*, *Anadara*, *Glycymeris* (sensu stricto), *Limopsis*, *Cucullaea* (sensu lato), *Septifer*, *Trichomya*, *Lithophaga*, *Amygdalum*, *Pinna*, *Pteriidae*, *Isognomon*, “*Hinnites*”, *Spondylus*, *Plicatula*, *Dimyidae*, *Patro*, *Ctenoides*, *Miltha*, *Chama*, *Eucrassatella*, *Maoricardium*, *Trachycardium* (sensu lato), *Lutraria*, *Tellinella*, *Solecurtus*, *Proxichione*, *Placamen*, *Costacallista*, *Pitar* (*Hyphantosoma*), *Tapes*, *Gastrochaena*, *Parapholas*, *Clavagella*, *Peretrochus*, *Scutellastra*, *Bolma*, *Guildfordia* (sensu stricto), *Liotina*, *Bembicium*, *Pyrasmus*, *Triforis* (sensu lato), *Aclis*, *Korovina*, *Hipponix*, *Cheilea*, *Lachryma*, *Cypraeidae*, *Ovulidae*, *Eunaticina*, *Neverita*, *Polinices* (sensu stricto), *Rimella*, *Echinophoria*, *Linatella*, *Eudolium*, *Ficus*, *Colubraria*, *Mitrella*, *Retizafra*, *Pakaurangia*, *Chicoreus* (*Siratus*), *Rugotaphis*, *Typhis*, *Typhina*, *Coralliophilinae*, *Morum* (*Oniscidia*), *Lyria*, *Conidae*, *Marshallena*, *Cochlespira*, *Gemmula*, *Inquisitor*, *Bathytoma* (sensu stricto), *Cordieria*, *Microdrillia*, *Anacithara*, *Eubela*, *Thatcheria*, *Scalptia*, *Discotectonica*, *Granosolarium*, *Pseudomalaxis*, *Fimbriatella* and *Cryptoplax*. Nearly all of these taxa were present in the southern part of the South Island at some time or other during the Cenozoic. In addition there are numerous extinct taxa, most of them

apparently endemic to New Zealand, that disappeared at various times during the Late Miocene to Pleistocene. Some of these may have been warm-water taxa that became extinct as the result of late Cenozoic cooling—they include *Glycymerita* (sensu lato), *Phialopecten*, *Sectipecten*, *Serripecten*, *Lentipecten*, *Pteromyrtea*, *Spissatella*, *Nemocardium* (*Varicardium*), “*Isognomon*” (n.gen.), *Barytellina*, *Bartrumia*, *Kuia*, *Marama* (sensu stricto), *Dosinia* (*Raina*), *Eumarcia* (*Atamarcia*), *Conominolia*, *Sarmaturbo*, *Guildfordia* (*Opella*), *Taxonia*, *Zefallacia*, *Pareora*, *Struthiolaria* (*Callusaria*), “*Hespererato*”, *Magnatica* (sensu stricto), *Taniella*, *Polinices* (*Polinella*), *Semicassis* (*Kahua*), *Sassia* (*Haurokoa*), *Austrofusus* (*Neocola*), *Nassicola*, *Zelandiella*, *Falsiculus*, *Exilia*, *Clifdenia*, *Amalda* (*Spinaspira*), *Lamprodomina*, *Mauira*, *Spinomelon*, *Metamelon*, *Zeacuminia*, *Austrotoma*, *Zemacies*, *Mauidrillia*, *Etrempsopsis*, *Neoguraleus* (*Fusiguraleus*), *Rugobela*, *Notacirsa*, *Evelynella*, *Tibersyrnola* and *Waikura*.

The distribution of warm-water molluscs in the New Zealand Cenozoic indicates particularly warm conditions (subtropical but probably not fully tropical) during the Late Paleocene and Early Eocene (late Teurian—Mangaorapan), late Middle Eocene (Bortonian), Late Eocene (Kaiatan and Runangan), Early and Middle Miocene (Otaian-Clifdenian), and early and middle Pliocene (Opoitian and Waipipian).

Reliable evidence for the presence of cool-water molluscs is confined to the late Pliocene and Pleistocene. The species *Aulacomya ater maoriana*, *Chlamys patagonica delicatula*, *Stiracolpus symmetricus*, *Cominella nassoides* and *Argobuccinum pustulosum* all extended much further north than their modern range during cold periods at this time. The distributional history of *Chlamys patagonica delicatula* has been discussed in detail by Beu (1985a)—at the present day it is abundant only around the southern part of the South Island and islands to the south of New Zealand, but during the Nukumaruan it occurred abundantly as far north as the present area of inland Hawke's Bay (see below).

Cool-water molluscs have proved much harder to identify in pre-Late Miocene assemblages. *Laternula synthetica* Marwick from the Otahuhu brewery well (Waipipian) is very similar (if not identical) to the extant circumantarctic species *L. elliptica* (King and Broderip, 1831) (Mrs Solene Morris (British Museum (Natural History), pers. comm.), but the associated faunule includes species of *Acar*, *Patro*, *Divarilima*, *Lutraria*, *Eumarcia*, *Maoricardium*, *Hipponix*, *Polinices* and *Bedeve*, which indicate at least warm-temperate conditions. However, *Aulacomya* cf. *ater maoriana* is also recorded from Otahuhu so some mixing of cold and warm-water faunules may have taken place in this part of New Zealand. Although Laws (1950, p. 6-8) listed molluscs from two discrete beds in the well, there is no obvious difference between them in temperature regime.

Some of the distinctive molluscs in the Wangaloan fauna may have been species preferring cool conditions. A substantial fraction of the genus-group taxa recorded from the Wangaloan is not known from younger beds in New Zealand, and although this may partly reflect our poor knowledge of the molluscan fauna that existed in the period between the Wangaloan and the Bortonian,

it may also record the extinction of cool-water taxa as New Zealand moved into warmer climes. On the other hand, some characteristic Wangaloan taxa (i.e. *Lahillia*, *Perissodonta* and *Taioma*) persisted until the Late Eocene on Seymour Island, Antarctic Peninsula (which has remained in a high latitudinal position throughout the Cenozoic), and *Lahillia* is present in the Miocene of southern South America (Zinsmeister 1979, p.353). One genus in the Wangaloan fauna, *Perissodonta*, is restricted to the subantarctic islands of Kerguelan and South Georgia at the present day; the only other New Zealand record is in the poorly dated Otaio Gorge faunule, here rather arbitrarily assigned a Porangan age. However, the Wangaloan fauna includes *Electroma*, *Cucullaea*, *Miltha*, *Polinices*, and *Priscoficus*, and the Otaio Gorge assemblage contains *Costacallista*, *Polinices*, *Propesinum*, *Priscoficus* and *Athleta*, so there is no unambiguous evidence to suggest that conditions were particularly cool at either time.

Indirect evidence for cool periods during the Cenozoic is provided by the extinction of molluscs known or assumed to have been warm-water forms. One particularly notable group of extinctions occurred at or near the end of the Bortonian Stage, when such taxa as *Cubitostrea*, *Costacallista*, *Priscoficus*, *Fascioplex* and *Speightia* disappeared from the fossil record. Even more dramatic extinctions (possibly because they are better-documented) occurred at various times in the late Neogene from Waiauau onwards and are correlated with major negative temperature excursions indicated by oxygen isotope measurements (Beu 1987b). Evidence from microfossils and from oxygen isotope studies strongly suggest that there was a globally significant drop in bottom temperature at the Eocene–Oligocene (Runangan–Whaingaroan) boundary—this should have had a major effect on benthic molluscan faunas, but unfortunately New Zealand molluscs from the critical period are so far very poorly known.

B. SYNECOLOGICAL APPROACHES

The methods of paleoenvironmental interpretation described above have one thing in common—they are essentially autecological, i.e. they are based on the known or inferred ecological requirements of individual taxa, typically genera or subgenera. The two methods discussed below are synecological in that they involve the response of groups of molluscs (and by implication other organisms) to environmental factors. One of them, dependent on the concept of discrete bottom communities, has been widely used in paleoenvironmental studies in New Zealand, but the other ("taxonomic structure analysis") is relatively little known. Both have a potentially serious drawback (one that also applies in autecological analyses)—the composition of a fossil assemblage almost invariably differs markedly from the original biota that lived there, either because of mixing of assemblages or because various processes, both biological and physical, ensure that the major component of the biota escapes preservation. The study of these modifying processes (taphonomy) is becoming increasingly more important in paleontology because of the realisation that they introduce severe biases into paleoecological (and therefore, evolutionary) interpretations.

Mixing of assemblages is most prevalent in shallow-water environments where physical processes such as wave action (particularly during storms) and bottom currents can transport shells far from their original habitat, and may concentrate them in shell-banks along with specimens from radically different biotopes. Fossil assemblages from shallow-water facies not infrequently contain a mixture of brackish-water (or even fresh-water) and shallow marine species. For example, the small fresh-water gastropod *Potamopyrgus antipodarum* is nearly ubiquitous in Pleistocene shallow marine faunules. Shells from deeper water may also be introduced into shallow-water sediments through the action of large predators (particularly fish) or by hermit crabs. These processes may also move shallow-water molluscs into significantly deeper waters, but less common though very rapid processes such as turbidity currents or submarine slumps are generally more effective and may transport shells from the shelf into a bathyal or even an abyssal environment. Examples of such radical reworking are most common in areas where tectonic activity has been strong during sedimentation and where deposition has been particularly rapid, e.g. along much of the East Coast of the North Island, particularly in the Middle Miocene "Tutamoe conglomerate" facies of the Gisborne district.

The loss of soft-bodied organisms (in all except a few very unusual situations) is another obvious source of bias in paleoecology, but the effects of predators and scavengers on shelled organisms are also important, for they may not only remove prey from the habitat area, but also destroy them in the process. Taphonomic processes clearly complicate paleoecological interpretations and all the paleontologist can do is to try to estimate to what extent they have modified the assemblage being studied.

1. Bottom community analysis

In the early part of this century the Danish biologist C.J. Petersen introduced the concept of "bottom communities", recurring associations of benthic organisms usually dominated by one or two species, that could be recognised over wide areas of the sea-floor, and in many different parts of the world, albeit with some minor geographic variation in species composition. Physical factors such as salinity, substrate, water depth and current action were all thought to determine the nature of the particular community that existed in a given area. Powell (1937) carried out a survey of Auckland and Manukau Harbours and identified five distinct bottom "formations", some of which could be subdivided into two or more "associations". In most of these associations molluscs predominated among the "dominant" and "sub-dominant" species. Powell also noted that some of these communities could be recognised in the Pleistocene Wanganui section (Powell 1937, p. 399; 1939, p. 610), but it was Fleming (1953) who applied bottom community analyses to the entire Pliocene and Pleistocene section exposed between Waverley Beach and Wanganui.

In recent years considerable doubt has been placed on the whole idea of discrete bottom communities, as detailed numerical analysis has shown that they grade smoothly into one another. Rather than discrete entities, the "communities" seem primarily to be fortuitous

associations of species of similar ecological requirements. As Barnes and Hughes (1982, p.101) comment—"each local area of sediment supports an assemblage of species which differs in minor, and sometimes major, respects from all other such local areas, in part for historical reasons, in part as a result of biogeographical processes, in part because of ecological interactions *in situ*, and in part as a consequence of minor differences in the environment. Each local area therefore, supports its own community at any one time, and a limited number of stereotyped 'communities' do not occur in the sea, except in very broad terms". This of course does not necessarily invalidate paleoenvironmental conclusions based on the identification of fossil associations resembling modern "communities", but it seems unlikely that these can be recognised much earlier than the Pleistocene. However, a very broadly defined recurring association of molluscs seems to have been characteristic of shallow-water (inner shelf) sands throughout most of the Cenozoic in New Zealand; this includes representatives from at least some of the following taxa—*Glycymerididae* (*Glycymeris*, *Glycymerita*, *Tucetona*), *Cucullaea*, *Limopsis* (large species), *Pectinidae* (large species, particularly of *Lentipecten*, *Serripecten*, *Sectipecten*, *Pecten* and *Phialopecten*), *Cardiidae* (*Hedecardium* (sensu lato), *Maoricardium*, *Nemocardium* (*Varicardium*)), *Divaricella*, *Veneridae* (*Dosinia* (sensu lato), *Eumarcia* (*Atamarcia*), *Turia*, *Tawera*, *Kuia*, *Bassina*), *Tellinidae* (*Peronaea*, *Tellinota*), *Mactridae* (*Scalpomactra*, *Lutraria*, *Spisula* (sensu lato), *Resania*), *Gari*, *Panopea*, *Turritellidae* (*Zeacolpus* (*Leptocolpus*), *Tropicolpus*, *Amplicolpus*, most of them large to very large), *Pareora*, *Naticidae* (*Polinices* (sensu stricto), *Tanea*, *Magnatica* (sensu lato), *Buccinidae* (*Austrofusus*, *Nassicola*, *Cominella*, *Zelandiella*), *Austrotoma* and *Dentaliidae* (particularly large species of the *Fissidentalium solidum* group). The variation between individual faunules is so great however, that it would be very difficult to identify dominant or sub-dominant taxa that could be used to characterise a long-lived "bottom community".

2. Taxonomic structure analysis

Hickman (1974, 1984) pointed out the difficulties inherent in paleobathymetric analysis based on the known or inferred depth-ranges of individual taxa, i.e. changes in the ecological requirements of some taxa with time, and the problem of how to interpret the ecology of extinct taxa. As an alternative approach she introduced the concept of "taxonomic structure analysis", which is based on the observation that the relative proportions of major groups of bivalves and gastropods (calculated on the basis of the number of species rather than of individual specimens) are markedly different in the shelf, bathyal and abyssal zones in the modern fauna (Fig. 3). The major groups chosen by Hickman are protobranchs, pteriomorphs, heterodonts and septibranchs (here changed to the wider group Anomalodesmata) for bivalves, and archaeogastropods, mesogastropods, neogastropods and opisthobranchs (shelled species only) for gastropods.

Hickman claimed that taxonomic structure analysis is relatively insensitive to the problems that beset autecological analysis, but application of her technique

to some well-studied New Zealand Cenozoic faunules has given inconsistent results (Fig. 3). A detailed critique of taxonomic structure analysis was given by Maxwell (1988a)—the following discussion briefly outlines the major problems of the technique.

a. Collection Failure: Small molluscs may not be represented in a collection either because they have been overlooked (although this possibility is minimised if bulk samples are collected) or because they have been removed prior to burial (e.g. by current action) or by post-depositional solution. Very small molluscs (size range one to three mm) are not uniformly distributed among the major groups—gastropods of this size are predominantly archaeogastropods (e.g. Scissurellidae, Skeneidae) or mesogastropods (Rissoacea)—so their removal from a faunule may significantly alter its taxonomic structure.

b. Substratal Effects: The nature of the substrate may have a profound effect on taxonomic structure. The faunule from the coral thicket at Palliser Bay described by Beu (1967a) not only differs qualitatively from faunules from the surrounding siltstone, but has significantly higher proportions of pteriomorphs and mesogastropods and lower proportions of heterodonts and neogastropods than the latter (Maxwell 1988a, p.23).

As another example of the importance of substratal effects it is only necessary to point out that protobranchs and heterodonts, by virtue of their infaunal habitat, are far less common on hard substrates than on unconsolidated sediment. Only those species that are capable of boring into rock or are nestlers or crevice-dwellers will be represented. Pteriomorphs, on the other hand, will usually be over-represented on hard bottoms because many of them require a firm and stable substrate.

c. Sampling Errors: A faunule collected from a typical fossil locality is unlikely to be truly representative of the total fauna that lived in the general geographic area at that time, even within a reasonably restricted depth range. The bathyal assemblages from the Chatham Rise documented by Dell (1956c) differ from one another not only in species composition (as Dell noted) but also in taxonomic structure (Maxwell 1988a, p.24-25). Some of this variation may result from collection failure or from down-slope transport of dead shells, as Dell failed to distinguish between living specimens and empty shells, but it is probably largely a reflection of the patchy distribution of many deep-sea molluscs. It is obviously desirable to base taxonomic structure analyses on collections made from as many localities spread over a wide area as possible, and from comparable lithologies.

d. Geographic Variation: Hickman (1974) claimed that taxonomic structures of faunas from a given depth zone were essentially similar in different parts of the world, but this is not borne out by a comparison of upper bathyal faunas from Sagami Bay, Japan (30°48'-36°19' N) and from the Chatham Rise, New Zealand (43°14'-44°35' S) (Maxwell 1988a, p.25, table 8). The disparity is probably at least partly a reflection of differences in bottom temperatures (c. 3-9°C) between the two areas.

e. Temporal Variations: An underlying assumption of the taxonomic structure approach is that the structures of faunas from the major depth zones have changed relatively little with time. That this is not necessarily true

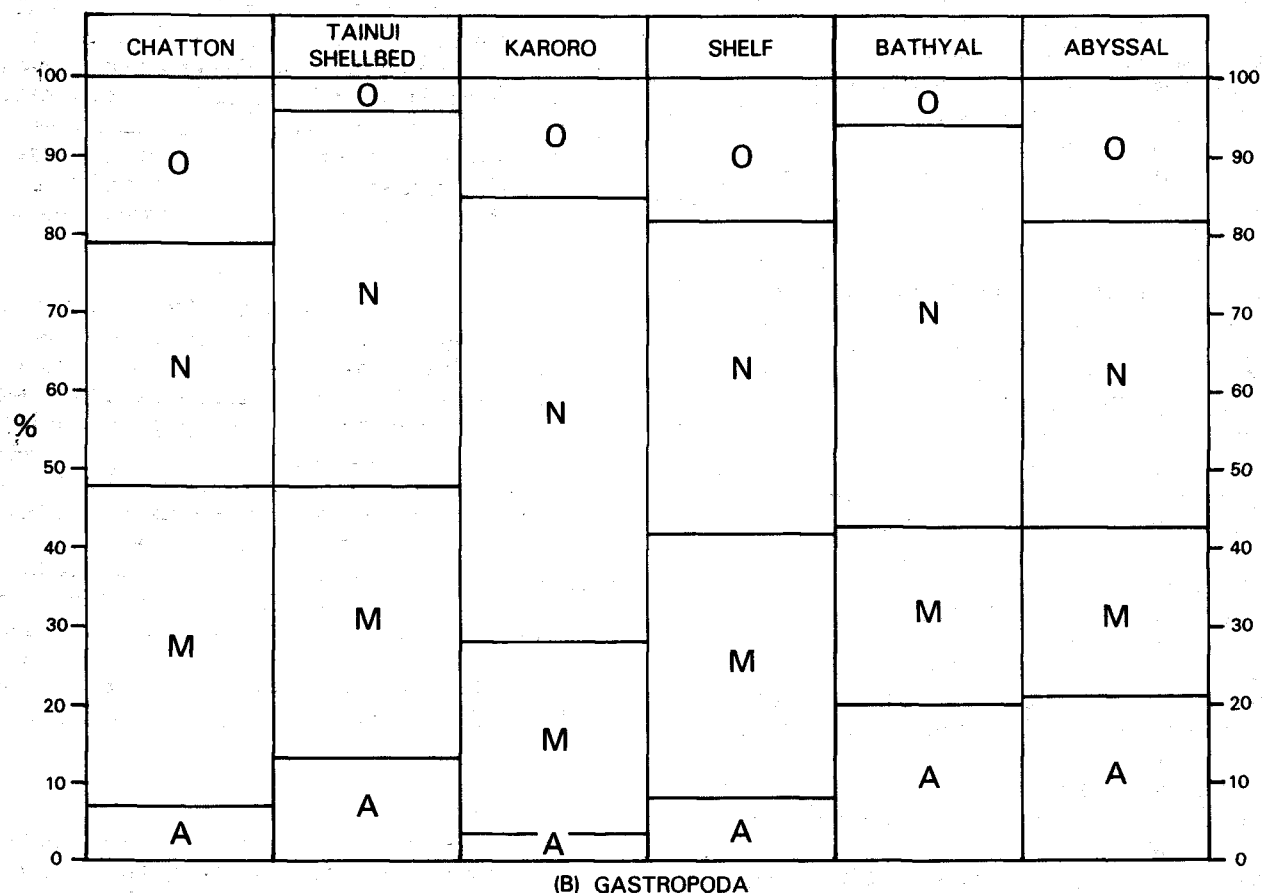
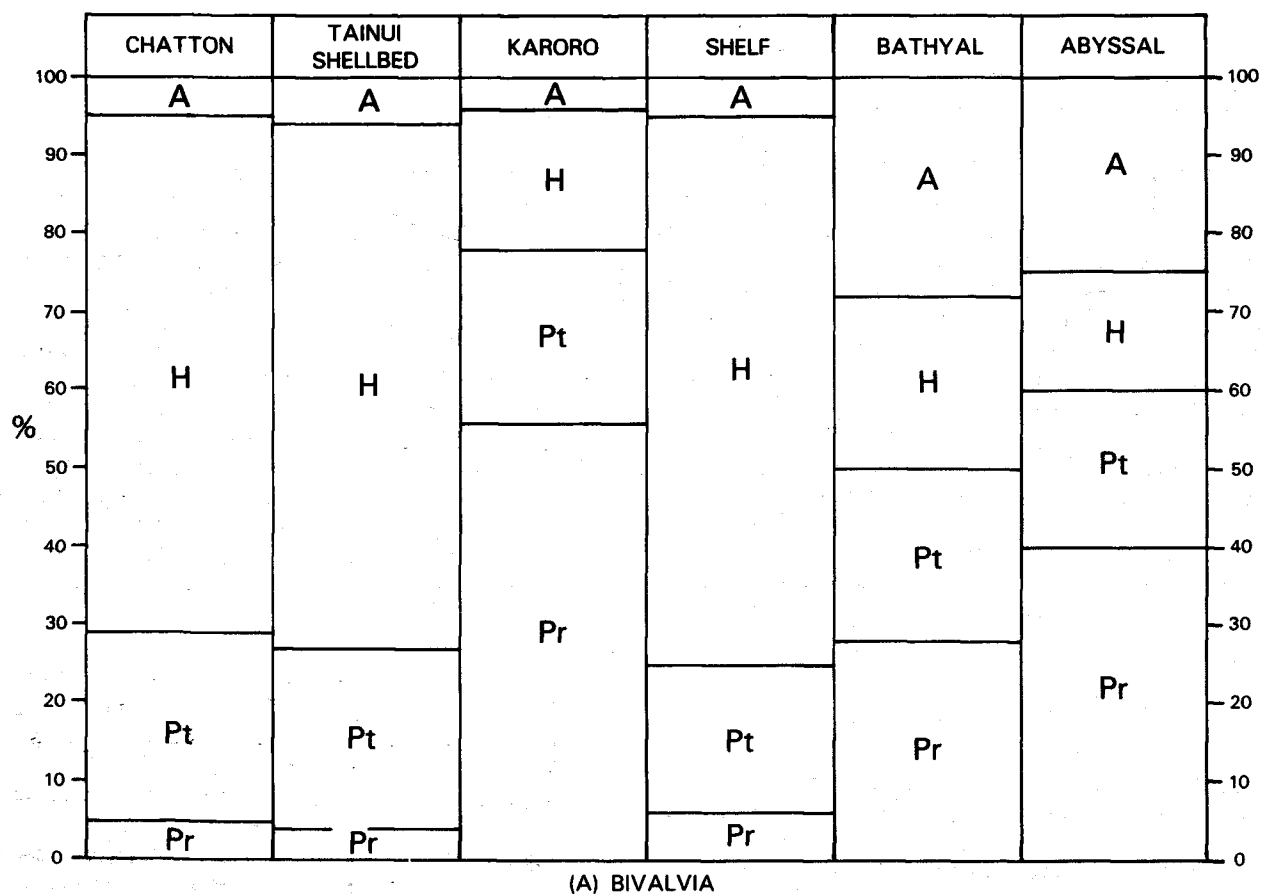


Figure 3 Taxonomic structures of three New Zealand Cenozoic molluscan faunules, compared with average taxonomic structures for the world extant shelf, bathyal and abyssal faunas (from Hickman 1974). New Zealand examples: Chatton Sand at Shell Gully, Chatton, Southland, Duntroonian (a shallow shelf faunule); Tainui Shellbed at Castlecliff, Wanganui, Castlecliffian (a mid to outer shelf faunule); and Stillwater Mudstone at Karoro Quarry, near Greymouth, Westland, Waiauian (an upper bathyal faunule; from Maxwell 1988a). Taxonomic symbols: Bivalvia—A = Anomalodesmata, H = heterodonts, Pr = pterobranchs, Pt = pteriomorphs; Gastropoda—A = archaeogastropods, M = mesogastropods, N = neogastropods, O = shelled opisthobranchs.

is shown by Hickman's own study on the molluscan fauna from the Late Eocene—Early Oligocene Keasey Formation of Oregon (Hickman 1974). The generic composition of this fauna (which is based on numerous collections from a large geographic area) indicates a bathyal depositional environment; the taxonomic structure of the gastropod fauna is in reasonable agreement with that of the modern bathyal fauna, but the bivalve fauna differs in its much higher protobranch diversity and lower proportion of anomalodesmatans. Hickman suggested that there has been a relatively recent increase in the diversity of true septibranchs (i.e. Poromyidae, Verticordiidae, Cuspidariidae). This is borne out by the admittedly sparse data provided by the New Zealand fossil record (Maxwell 1988a, p.25-26).

To summarise—taxonomic structure analysis is an interesting alternative to the traditional autecological approach to determining paleobathymetry, but it requires considerable refinement before it can be used with any confidence. It is probably of most use for interpreting Neogene faunas, and has limited applicability to Paleogene or older assemblages.

TROPHIC RELATIONSHIPS OF FOSSIL MOLLUSCS

Although neocologists pay due attention to the relationship between organisms and their physical environment, they are at least as interested in the relationships *between* organisms (usually expressed as a trophic web) in an ecosystem. The fossilisation process inevitably destroys most of the potentially useful information that neocologists take for granted, but paleoecologists whose interests range beyond paleoenvironmental assessment should make the attempt to apply trophic analysis to fossil assemblages. However, despite the wealth of suitable subjects for study there have been remarkably few attempts to carry out such analyses on New Zealand Cenozoic molluscan assemblages (Hayward 1976a; Maxwell 1988a).

Trophic analysis requires information on (a) the feeding habits of the organisms in an ecosystem and (b) the energy pathways between the organisms (i.e. knowing which is the consumer and which is the food).

Ecologists studying modern ecosystems expend a lot of time and effort in trying to quantify the energy flow between organisms (much more difficult in the marine environment than on land!), but paleoecologists are usually restricted to qualitative interpretations, because biomasses of fossils cannot accurately be calculated. (See Stanton et al. 1981, for an attempt to calculate biomasses of fossil molluscs on the basis of their shell volumes and, by inference, their biovolumes).

Inferences about the feeding habits of fossil molluscs are inevitably based on what is known about their closest extant relatives. For some groups there is surprisingly little reliable evidence of this kind and others have proven to be typically heterogeneous, so there will always be some uncertainty about assigning an extinct species to a particular trophic type. However, a considerable amount of information is available, and much of it has been usefully summarised in tabular form by Stanton and Nelson (1980, table 1) and by Taylor et al. (1980, table 1). The majority of molluscs fall into one or other of five feeding types.

1. Deposit-feeders (detritivores)

These obtain particulate food from the substrate (usually the sediment) either by swallowing it in bulk and digesting any organic material that may be present (non-selective deposit-feeding) or by utilising some physical property of the food such as size or density to remove it preferentially (selective deposit-feeding). Food may consist of living or dead microorganisms (e.g. bacteria, diatoms, foraminifera), comminuted remains of larger organisms, fecal pellets or organic material adsorbed on clay particles. Deposit feeders may be epifaunal or infaunal and may obtain their food from the sediment-water interface or from various depths within the sediment. Deposit feeding is best known in the bivalve superfamilies Nuculacea, Nuculanacea and Tellinacea (although some tellinids may also be suspension-feeders) and in the Scaphopoda, and is common in gastropods from the Trochacea and Rissoacea, in *Struthiolaria*, and among opisthobranchs. It is also reported in some species belonging to predominantly carnivorous groups.

2. Suspension-feeders

These feed on colloidal or dissolved organic matter, or on swimming or floating organisms. Some species exploit a narrow zone immediately above the sediment-water interface and consequently include in their diet resuspended detritus, but others sample the water mass an appreciable distance above the substrate.

The majority of extant bivalves are suspension feeders, as are many mesogastropods (e.g. Calyptraeacea, *Xenophora*, *Capulus*, some turritellids (Allmon 1988)). Suspension-feeding is rare in the Archaeogastropoda (although the normal mode in Trochidae Umboniinae) and is represented in the opisthobranchs by the thecosome pteropods. It is most common in shallow-water assemblages and decreases in frequency with increasing water depth. Most species are benthonic (epifaunal or infaunal), but the thecosome pteropods are planktonic.

3. Herbivores

This is a taxonomically diverse group that includes species that scrape micro-algae off the substrate (and therefore could also be classed as deposit-feeders) and those that browse on larger algae. Herbivores are well represented among the archaeogastropods (e.g. Haliotidae, Patellacea, many Trochacea, Neritidae), mesogastropods (Cerithiacea, many Rissoacea), opisthobranchs and pulmonates. Because of their reliance on plant material, marine herbivores are restricted to shallow waters where sunlight useful for photosynthesis can penetrate to the sea-bottom (typically less than 150 m). In deep waters water-logged wood may serve as a substrate for some gastropods but these seem for the most part to feed on associated bacteria rather than on the wood itself. Bivalves of the Teredinidae ("ship worms"), however, are able to digest wood.

4. Carnivores

This large category can be conveniently divided into three groups—grazers, predators and scavengers. Members of the first group have obvious analogies with herbivorous grazers, and include fissurellids, cerithiopsids, triphorids and some cypraeids (which live on sponges) and almost

all architectonicids and epitoniids (on coelenterates). Predators consume whole live prey and as a rule actively seek out their food, although sedentary species such as the septibranch bivalves presumably have some way of attracting prey. Scavengers of course, feed on carrion or moribund animals. In practice it may be impossible to tell if an extinct species was an active predator or a scavenger.

Carnivory has evolved in all extant molluscan groups except—as far as we know—Monoplacophora, but among the groups with a good fossil record, it is best known in the Gastropoda, particularly the Neogastropoda, most of which are predators on molluscs or other invertebrates. The following list includes the most important shell-bearing, carnivorous marine molluscs and their chief food source (information on predatory gastropods taken largely from Taylor et al. 1980, table 1). This list disguises the fact that many groups are dietarily more heterogeneous than it suggests—e.g. although nassariids are listed as primarily carrion-feeders, at least one extant species is known to be a deposit-feeder (Paine 1963).

Bivalvia

- Propeamussiidae—small crustaceans (mostly copepods and ostracods).
- “Septibranchs” (Verticordiidae, Poromyidae, Cuspidariidae)—polychaetes, small crustaceans.

Gastropoda

Archaeogastropoda

- Pleurotomariidae—sponges, carrion
- Fissurellidae—sponges
- Calliostomatinae—coelenterates, carrion, sponges

Mesogastropoda

- Cerithiopsidae/Triphoridae—sponges
- Epitoniidae—coelenterates
- Janthinidae—siphonophores
- Triviidae—ascidians
- Naticidae—gastropods, bivalves, scaphopods
- Cypraea—coelenterates, sponges
- Ranellidae—bivalves, ascidians, echinoderms, carrion
- Ficidae—echinoids
- Cassidae—echinoids
- Tonnidae—holothurians

Neogastropoda

- Buccinidae—bivalves, polychaetes, carrion
- Nassariidae—carrion
- Fasciolaridae—bivalves, gastropods, polychaetes
- Melongenidae—bivalves, gastropods
- Columbellidae—polychaetes, small crustaceans, carrion
- Turbinellidae—polychaetes
- Muricidae—bivalves, gastropods, cirripedes, corals
- Mitridae—sipunculids
- Marginellidae—bivalves
- Harpidae—decapod crustaceans
- Olividae—bivalves, gastropods, carrion
- Volutidae—bivalves, gastropods
- Conidae—gastropods, polychaetes, fish
- Terebridae—polychaetes
- Turridae—polychaetes
- Cancellariidae—gastropods, skates

Opisthobranchia

- Acteonacea—polychaetes, small crustaceans
- Philinacea—bivalves, polychaetes
- Bullacea—bivalves, gastropods
- Architectonica—coelenterates

Scaphopoda—relatively little is known about their diet, but at least some species eat small bivalves in addition to foraminifera.

Polyplacophora—most shallow-water species seem to be herbivores, but a few graze sponges, and predation on amphipods has been observed for the North American species *Placiphorella velata* Dall, 1879 (McLean 1962). A modern, undescribed species of *Placiphorella* is recorded from deep water around New Zealand, and may have a similar habit.

Cephalopoda—species of *Nautilus*, the only surviving genus of the Nautiloidea, feed on decapod crustaceans, including fresh moults.

5. Parasites

Endoparasitism (the more extreme form of parasitism in which the parasite is wholly internal and typically greatly simplified) is rare in the Mollusca, and no examples are known from New Zealand. By contrast, ectoparasitism (in which the parasite is largely or wholly external) is characteristic of two widespread gastropod families (Eulimidae and Pyramidellidae) and occurs in other, predominantly carnivorous, families (e.g. Epitoniidae). (The distinction between carnivory and parasitism is of course rather subtle). Eulimids are parasitic solely on echinoderms (echinoids, asteroids, ophiuroids, holothurians), but pyramidellids have a much wider variety of hosts, including bivalves, gastropods, chitons and polychaetes—some species seem to be host-specific, but others are relatively promiscuous in this respect. Eulimids have rather featureless shells and are difficult to classify, but pyramidellids are far more diverse in shape and sculpture and have received a considerable amount of attention from paleontologists; both families are well-represented in the New Zealand Cenozoic fauna.

Commensalism (which in some cases may represent an intermediate stage in the evolution of parasitism) is not uncommon in the Bivalvia. It is particularly characteristic of the Galeommatacea, some members of which live in sediment close to the host or in burrows formed by the host, or on the host itself. Hosts include other bivalves, echinoderms and polychaetes. Another form of commensalism is the association of micro-organisms with certain bivalves—this is best known for the “giant clams” (*Tridacna* spp.), which harbour algae (zooxanthellae) in their mantle and gills; a similar association is recorded for the cardiid *Fragum* and *Corculum*. More recently it has become apparent that some bivalves have a symbiotic relationship with sulphide-oxidising bacteria that allows them to live in anoxic conditions. This association was first noticed in bivalves living near deep-sea thermal vents (Vesicomyidae) and has now been recognised in members of the Solemyidae (some species of which are gutless), Mytilidae, Lucinidae and Thyasiridae (see summary by Reid and Brand 1986).

It should be emphasised that the feeding categories given here are not hard-and-fast if only because the first

two are descriptions of the way in which food is obtained, rather than the kind of food taken. Some molluscs fall into two categories, e.g., thecosome pteropods are both suspension feeders and herbivores and the common mud-snail *Amphibola crenata* is a herbivorous deposit feeder. Gastropods and scaphopods which devour foraminifera could be classed as deposit-feeders or as carnivores, although there is a tendency to restrict the latter term to species which devour metazoans. There are also some molluscs which undergo a change in dietary preferences during ontogeny.

Evidence of predation on molluscs

Molluscs are themselves preyed on by a wide variety of organisms, some of which conveniently leave evidence of their activities on the shell. Others leave no such evidence, or crush the shell into unrecognisable fragments during feeding. Two kinds of shell damage, drill-holes and shell-fracture, provide useful information on the nature and frequency of predation, and have received a considerable amount of attention from paleobiologists in recent years.

Drill-holes in molluscan shells can usually be attributed to predation by members of either the Naticidae or the Muricidae, although some holes may be produced by cassids or by octopods (see Boucot 1981; Carter 1968; Carricker and Yochelson 1968; Sohl 1969, for reviews of the subject). Naticid and muricid holes are "counter-sunk" (i.e. have a bevelled upper margin) but whereas the former are strongly concave (parabolic) below, muricid holes are more nearly cylindrical; this distinction unfortunately falls down in thin shells. Detailed studies on naticid predation on modern and fossil assemblages show that (a) drill-holes are often present in certain preferred areas of the shell rather than randomly distributed, and (b) there is a considerable degree of prey selection (i.e. some species suffer heavier predation than others). Prey selection is determined partly by size, with "cost-effectiveness" (i.e. the energy obtained from consumption of the prey *versus* that expended in drilling) being the over-riding factor (Kitchell et al. 1981), but it seems likely that a low frequency of naticid predation on some species (e.g. of opisthobranchs) may be attributable to effective escape behaviour or to an unpleasant taste (see Maxwell 1988a, p. 31-32). It should also be pointed out that naticids do not always need to drill through the shell to get at their prey; for example, they can attack gastropods through the aperture.

Predation by decapod crustaceans not only helps keep numbers of molluscs down, but according to the work of G. Vermeij and his colleagues (Vermeij 1977, 1978; Vermeij et al. 1980) it has had a significant effect on the evolution of marine gastropods. Modern decapods attack gastropods either by nipping off the apex ("decollators") or by breaking back the outer lip ("lip-peelers"). Such attacks are not always fatal, and gastropods are often able to recover and recommence shell growth, leaving distinctive scars (usually marked by interruption or off-setting of sculptural elements) as evidence of predation. Recognition of these growth-hiatuses can give useful information on the frequency of decapod predation in fossil assemblages, although some shell-breakage in high-energy environments could conceivably result from non-biological processes. A study of eight species of

gastropods from an upper bathyal assemblage at Karoro Quarry, Greymouth (Waiauian) showed that seven had shell-repair frequencies in the range 60-80% (some shells had two or more scars); the predator was probably the giant crab *Tumidocarcinus giganteus* Glaessner, 1960 (Maxwell 1988a, p.33-34). Decapods also attack bivalves, either by crushing the shell or by nipping at the margins. Traces left by the latter process may be difficult to distinguish from those produced by fish.

Starfish are important predators on molluscs (see Carter 1968, p 43-49 for a review of bivalve predation) but they usually leave little or no evidence of their activities on their prey. Complete or reasonably complete starfish are only very rarely found fossil in New Zealand, and isolated skeletal elements are usually the only direct evidence for their presence in a fossil assemblage. Some eulimids are parasitic on asteroids, but fossil species of the family are difficult to identify confidently, and it is usually impossible to come to firm conclusions about their probable hosts.

Many species of fish feed on molluscs (see Boucot 1981, table 4.18 for a lengthy list); some crush or break shells, others dissolve shells in their gut, and some excrete the shells entire. The presence of ray teeth (e.g. *Myliobatus*) in a fossil assemblage is good evidence for fish predation, but in most faunules the only evidence for the presence of fish is teleost otoliths, which are often difficult for the non-specialist to identify with any confidence. Other vertebrates, including seals, whales and birds, may also feed on molluscs, but their remains are much rarer than those of fish.

Trophic web reconstruction

Construction of a trophic web for a fossil ecosystem depends ultimately on how well studied the fossil assemblage is, which usually means paying attention to any representatives of non-molluscan groups that may be present, as molluscs occupy only the primary consumer and low-level carnivore levels. On the other hand, the presence of certain groups of molluscs may give valuable information on the non-preserved components of the original biota. Trophic reconstructions can be shown visually in a number of ways—the example given here (Fig. 4) adopts a hierarchical classification of trophic levels, but some ecologists prefer to present their conclusions in a non-hierarchical flow diagram, or even as a cartoon.

The account given here of molluscan paleoecology includes only some of the more obvious aspects of this fascinating branch of paleontology.

Many other topics that come into the domain of paleoecology deserve attention but have been little-studied in New Zealand—these include functional morphology (particularly the relationship of shell form to habitat—see Stanley 1970 for a classic study on bivalves), skeletal mineralogy, population structure (e.g. as a guide to reproductive "strategy"), diversity changes and their causes (e.g. the effects of changes in temperature or sea-levels) and paleobiogeography (particularly the relative importance of dispersal and vicariance). For anyone interested in paleoecology we recommend two very different works on the subject—Boucot (1981) and Dodd

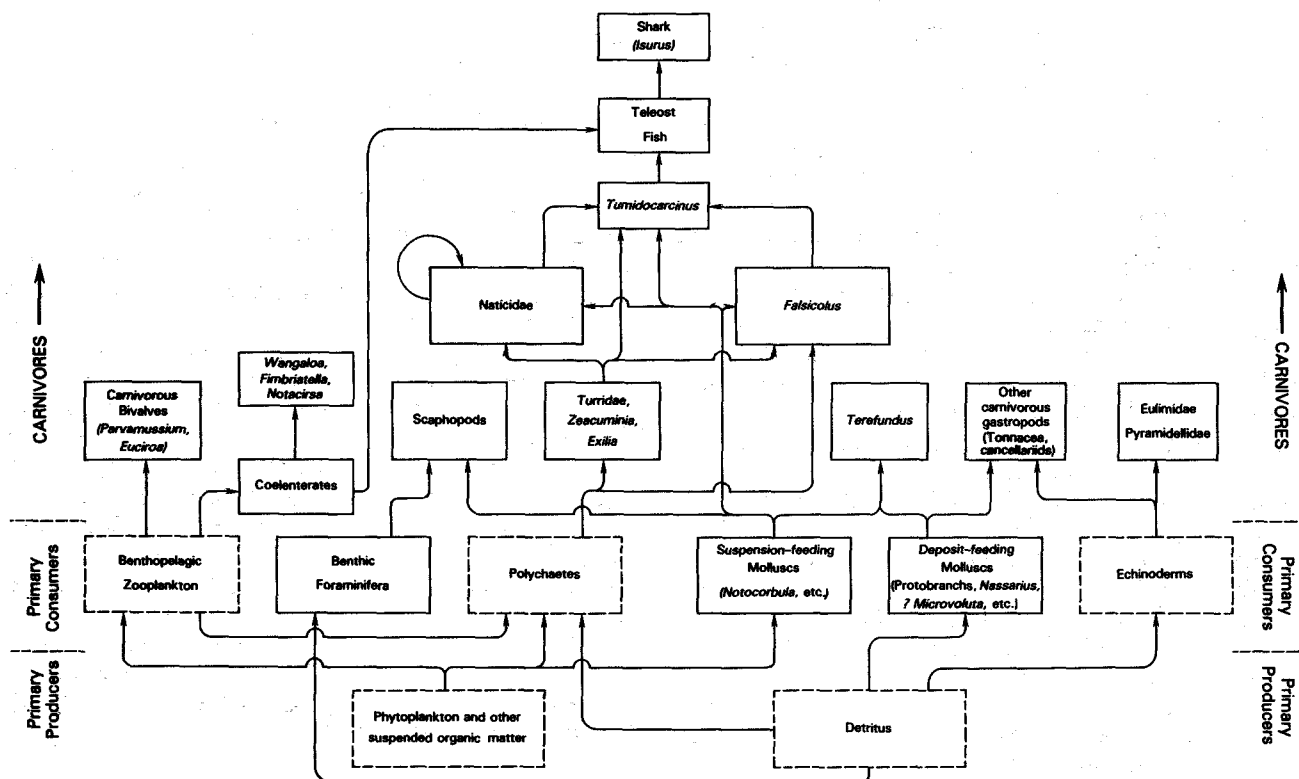


Figure 4 Partial reconstructed food-web for the Waiuan (late Middle Miocene) bathyal ecosystem represented by the faunule in the Stillwater Mudstone at Karoro, Greymouth (Maxwell 1988a, fig. 3), showing the more important inferred pathways between different trophic levels. Groups for which there is no direct fossil evidence are enclosed by dashed lines. The diagram is greatly simplified for the sake of clarity; teleost fish probably preyed on most molluscan groups present and on other organisms, and all groups contributed to the detritus, both in the form of fecal material and as decay products after death, with bacteria playing a vital part in the break-down of both detritus sources.

and Stanton (1981), as well as papers published in such journals as *Lethaia*, *Paleobiology* and *Paleogeography*, *Paleoclimatology*, *Paleoecology*. Barnes and Hughes (1982) give a concise account of modern marine ecology, and

Morton and Miller's book "The New Zealand Seashore" (1968) is quite indispensable for anyone attempting to interpret New Zealand Cenozoic shallow-water assemblages.

CHAPTER 3. MOLLUSCAN BIOSTRATIGRAPHY

One of the major roles of molluscan paleontology is the determination of the relative ages of rocks by biostratigraphy (stratigraphic ordering of the sequence of different life forms). Biostratigraphic sequences for the Cenozoic marine rocks of New Zealand have been pieced together for many different biological groups over more

than 120 years of geological research. As well as Mollusca, they are available in Foraminifera (both benthonic and planktonic), Ostracoda, calcareous nannofossils, pollen and spores, and dinoflagellates, and some research is being carried out on Radiolaria. During the last several decades much unravelling of New

Zealand's complexly deformed sequences, and of such complications as the existence of parallel but distinct warm-water and temperate biotas of Early Miocene age, has been enabled by the co-operation of paleontologists working together on different groups, particularly on Mollusca, Foraminifera and calcareous nannofossils. As noted in the introduction, Mollusca are much the most diverse of Cenozoic fossil groups in New Zealand, and are of some use for biostratigraphy wherever they occur as fossils; but they are much more diverse in shallow-water, near-shore facies and cannot provide a working biostratigraphy for the vast sequences of off-shore mudstone that are so characteristic of much of New Zealand (although the development of a biostratigraphy based on the planktonic gastropods grouped as "pteropods" holds some hope for a contribution from Mollusca to a biostratigraphy of deep-water facies in due course). For most practical biostratigraphy throughout the majority of the Cenozoic in New Zealand, the abundance of Foraminifera (particularly planktonic ones) makes them the pre-eminent group for biostratigraphy—a good population of each of many different species can be obtained easily by wet-seiving a sample of most mudstone units.

The major period when Mollusca continue to be at least as useful as Foraminifera for biostratigraphy is Pliocene and Pleistocene time. During this time (Opoitian to present), the number and frequency of extinction and evolutionary events decreased in Foraminifera (particularly after early Nukumaruan time), compared with earlier Cenozoic time, but increased sharply in Mollusca (no doubt partly because near-shore facies, with diverse Mollusca, are much better represented in progressively younger rocks than in older ones). Evolutionary sequences in rapidly evolving lineages of Mollusca, particularly in *Phialopecten* (Family Pectinidae) and the several lineages of *Pellicaria* (Struthiolariidae) and *Stiracolpus* (Turritellidae) together provide a fine subdivision of almost all near-shore to "shelf" facies of Pliocene to early Pleistocene age. Indeed, it is these three families, together with *Austrofuscus* and other closely related Buccinidae, which provide the most useful molluscan biostratigraphic guides throughout Cenozoic rocks.

Mention of the usefulness in biostratigraphy of evolutionary lineages of Mollusca introduces the topic of the different approaches to biostratigraphy. There are several different ways of compiling the time ranges of individual species (all of which are listed in our checklist) to arrive at useful biostratigraphic information. A glance at the main approaches in use for practical biostratigraphy will clarify the methodology used.

1. Time ranges of genera

The number of genus-group taxa of New Zealand Cenozoic Mollusca is so great (about 890 are included in our checklist, and perhaps another 200 are known to us but not recorded) that time ranges of genera are very useful in biostratigraphy. Combining first appearances and last appearances of groups of genera into a table to show the sequence of apparent arrivals and apparent extinctions through Cenozoic time (Figure 5) gives a clear appreciation of the way in which Cenozoic ages can be

determined from the ranges of genera. Not all genus-group taxa recorded from New Zealand have been included in Figure 5, but only those 410 taxa we consider to be of most use in biostratigraphy. Figure 6 is a table of the time ranges of these 410 genus-group taxa arranged in taxonomic order (i.e. the same order as in the checklist). Positions of individual taxa can be found in this taxonomically arranged table from the index.

An example of the usage of generic ranges is provided by the Kapitean-Opoitian boundary (approximately equivalent to the Miocene-Pliocene boundary). This boundary is readily recognisable by the use of Mollusca in "shelf" facies because it is marked by the permanent disappearance from the fauna of at least central and southern New Zealand (rocks of this age are not known in Northland) of many common, well known, middle Cenozoic genera such as *Aturia*, *Cucullaea*, *Lentipecten*, *Kuia*, *Notocorbula*, and large species of *Conus* and *Cypraea*. In a similar way, significant proportions of the generic composition of the molluscan fauna became extinct and newly appeared at most Neogene stage boundaries. In particular, marked extinctions of groups of genera allow easy recognition of the Pliocene stage boundaries and the Nukumaruan-Castlecliffian boundary in shallow facies (Beu 1987b).

2. Time ranges of species

A similar but still more finely subdivided biostratigraphy to that compiled for genera can be derived for time ranges of individual species. All species in our checklist have their known time ranges listed, but different species clearly differ in their biostratigraphic usefulness because of differing ecological tolerances, commonness or rarity, tested reliability, etc. We consider that the reliability of *all* molluscan biostratigraphy based on individual species before Duntroonian (Late Oligocene) time is low, because so few faunules have been described from most pre-Duntroonian stages and, indeed, the known faunal diversity is low for many Paleogene stages because of unsuitable facies (especially Teurian to Porangan, and Whaingaroan). The only apparent exception is the Bortonian Stage, widely represented by shallow facies in eastern Otago and in Northland, and characterised by several apparently restricted, common, rather exotic-looking species such as *Duplipecten waihaoensis* (Pl.5d), *Monalaria concinna* (Pl.6a,b), *Athleta necopinata* (Pl.6q) and *Speightia spinosa* (Pl.6s). However, the very poor knowledge of Porangan molluscan faunas, and the consequent possibility that no Bortonian species were originally restricted to that stage, makes the recognition of even Bortonian faunas of low reliability.

The continuous record of shallow-water faunas with diverse Mollusca begins in New Zealand with the onset of Duntroonian time, so we have compiled a detailed table (Figure 7) of the first and last appearances of species, in sequential order of stages, from Duntroonian time until present. Again, very far from *all* recorded species are included in Figure 7, as many are rare species known from only one or a few localities, and many others belong in taxonomically "difficult" groups and so have poorly known time ranges. The compilation of Figure 7 thus represents a distillation of our experience in Oligocene and Neogene biostratigraphy.

FIRST AND LAST APPEARANCES OF MAIN CENOZOIC GENERIC GROUPS

[illegible]

Figure 5a-c First and last appearances of the main Cenozoic molluscan genera. (Individual time ranges of these 410 genus-group taxa are shown in taxonomic order in Fig. 6). [Note: because of late corrections, numbers (89) and (120) have been deleted; *Ostrea* in number (26) is a combination of taxa now included in *Ostrea* (sensu lato) (Waipawan, Opoitian) and *Tiostrea* (Kapitean to Recent)].

STAGES		CRETACEOUS	WANGALOAN	TEURIAN	WAIPAWAN	MANGAORAPAN	HERETAUNGAN	PORANGAN	BORTONIAN	KAIATAN	RUNANGAN	WHAINGAROAN	DUNTROONIAN	WAITAKIAN	OTAIAN	ALTONIAN	CLIFDENIAN	LILLBURNIAN	WAIJUAN	TONGAPORUTUAN	KAPITEAN	OPOITIAN	WAIPIIAN	MANGAPANIAN	NUKUMARUAN	CASTLECLIFFIAN	HAWERAN	RECENT
TAXA																												
Duplipecten, Dicroloma, Carinacca (48)	48																											
Hyalocylis (49)	49																											
Waihaioia, Fusiaphera (50)	50																											
Borsonia, Tatara (51)	51																											
Callistotapes (52)	52																											
Typhis (53)	53																											
Pseudoportlandia, Magnatica, Mauira, Marshallena (s.s.) (54)	54																											
Lentipecten, Kuia, Hina (55)	55																											
Pseudotindaria (56)	56																											
Turehua (57)	57																											
Nucula, Jupiteria, Saccella, Parvamussium, Anomia, Divalucina, Scalpomactra, Peronaea, Austrodozinia, Offadesma, Eulima (s.l.), Tanea, Friginatica, Galeodea (s.s.), Austrofusus, Poirieria, Prototyphis, Volvarinella, Conus (s.l.), Bonellitia (s.l.), Granosolarium, Cirsotrema (s.s.), Eulimella, Turbonilla, Strioturbonilla, Dentalium (58)	58																											
Neverita (59)	59																											
Lirasyrinx (60)	60																											
Ficus, Microdrillia (61)	61																											
Hinnites, Varicardium, Willungia, Conilithes, Notacirsa (62)	62																											
Spissatella (63)	63																											
Haurokoa, Proximitra, Alocospira (64)	64																											
Cheilea,"Hespererato" (65)	65																											
"Marshallena" (n.gen.) (66)	66																											
Marama (67)	67																											
Ledella, Tucetona, Mesopeplum, Calliostoma, Lissotestella, Astraea, Argalista, Linemera, Xenophora, Trivia, Liratilia, Xymene, Pterynotus, Peculator, Puposyrnola, Tenuiactaeon, Fissidentalium (68)	68																											
Janupecten (69)	69																											
Lima, Cellana (70)	70																											
Pododesmus (71)	71																											
Propeamussium (72)	72																											
Neocola, Zelandiella (73)	73																											
Atamarcia (74)	74																											
Hinemanoa, Neritoplica, Pomahakia, Batillona (75)	75																											
Athlopecten, Proxichione, Guildfordia (76)	76																											
Megacardita, Pyrazus (77)	77																											
"Cyclocardia", Procominula, Costosyrnola (78)	78																											
Titanocardium, Clifdenia, Oniscidia (79)	79																											
Solecirtus, Fossacallista, Metamelon, Tomopleura, Etremopsis, Anacithara (80)	80																											
Tropicolpus, Echinophoria (81)	81																											
Notocorbula (82)	82																											
Myrtea, Callusaria, Mauidrillia, Evelynella (83)	83																											
Zefallacia, Spinomelon, Austrotoma, Scalptia (84)	84																											
Maoricardium (85)	85																											
Glycymeris (s.s.), Raina, Ringicula (86)	86																											
Fusiguraleus (87)	87																											
Linucula, Limaria, Neolepton, Tellinota, Dosina, Bassina, Dosinia (Asa), Myadora, Micrelenchus, Spectamen, Thoristella, Scrobs, Struthiolaria, Josepha, Zemitrella, Murexsul, Maoritomella, Scrinium, Neoguraleus, Oamaruia, Zeadmete, Scaphander, Retusa, Agatha, Terelimella (88)	88																											
		K	Mw	Dt	Dw	Dm	Dh	Dp	Ab	Ak	Ar	Ld	Lw	Po	Pl	Sc	Sl	Sw	Tt	Tk	Wo	Wp	Wm	Wn	Wc	Wq	r	

Fig. 5b

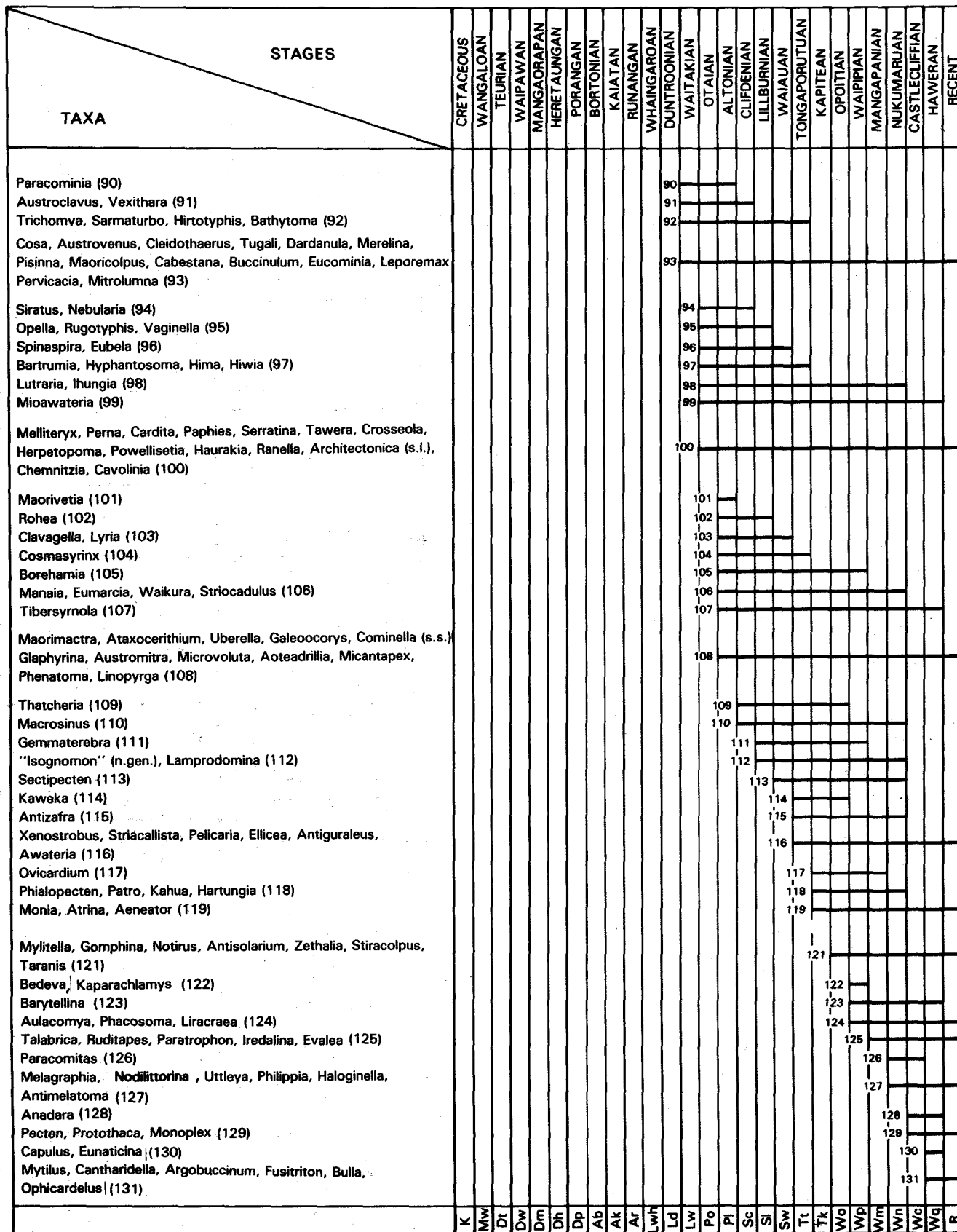


Fig. 5c

TIME RANGES OF MAIN CENOZOIC GENERIC GROUPS

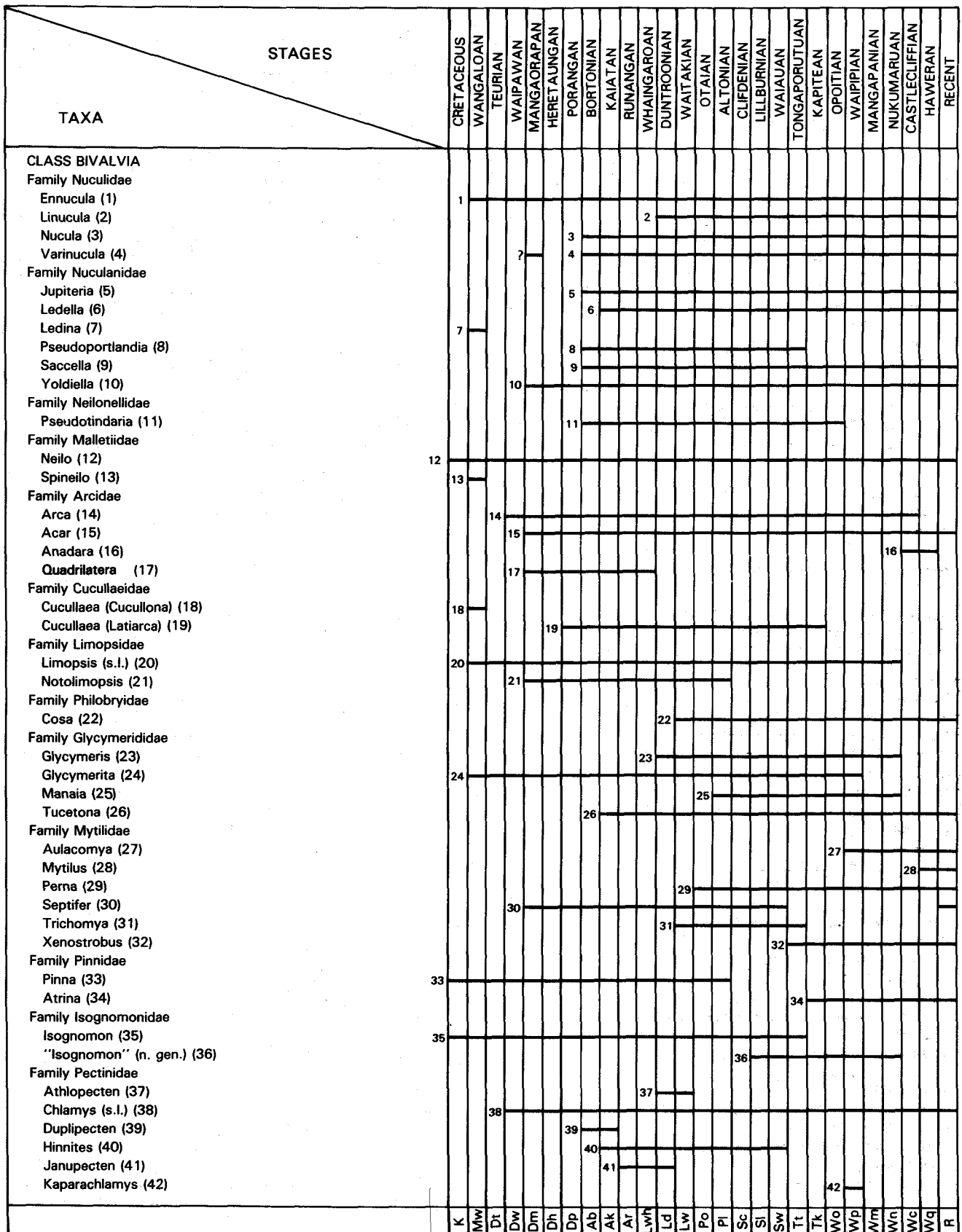


Figure 6a-j Time ranges of the 410 Cenozoic molluscan genus-group taxa used to compile Fig. 5, in taxonomic order (their position can be found alphabetically from the index). [Note: *Heterotermia* (252), *Tudicilana* (253) and *Fyfea* (255) have been transferred to Family Turbinellidae in the text and checklist; *Ostrea* (65) is a combination of taxa now included in *Ostrea* (sensu lato) (Waipawan, Opoitian) and *Tiostrea* (Kapitean-Recent)].

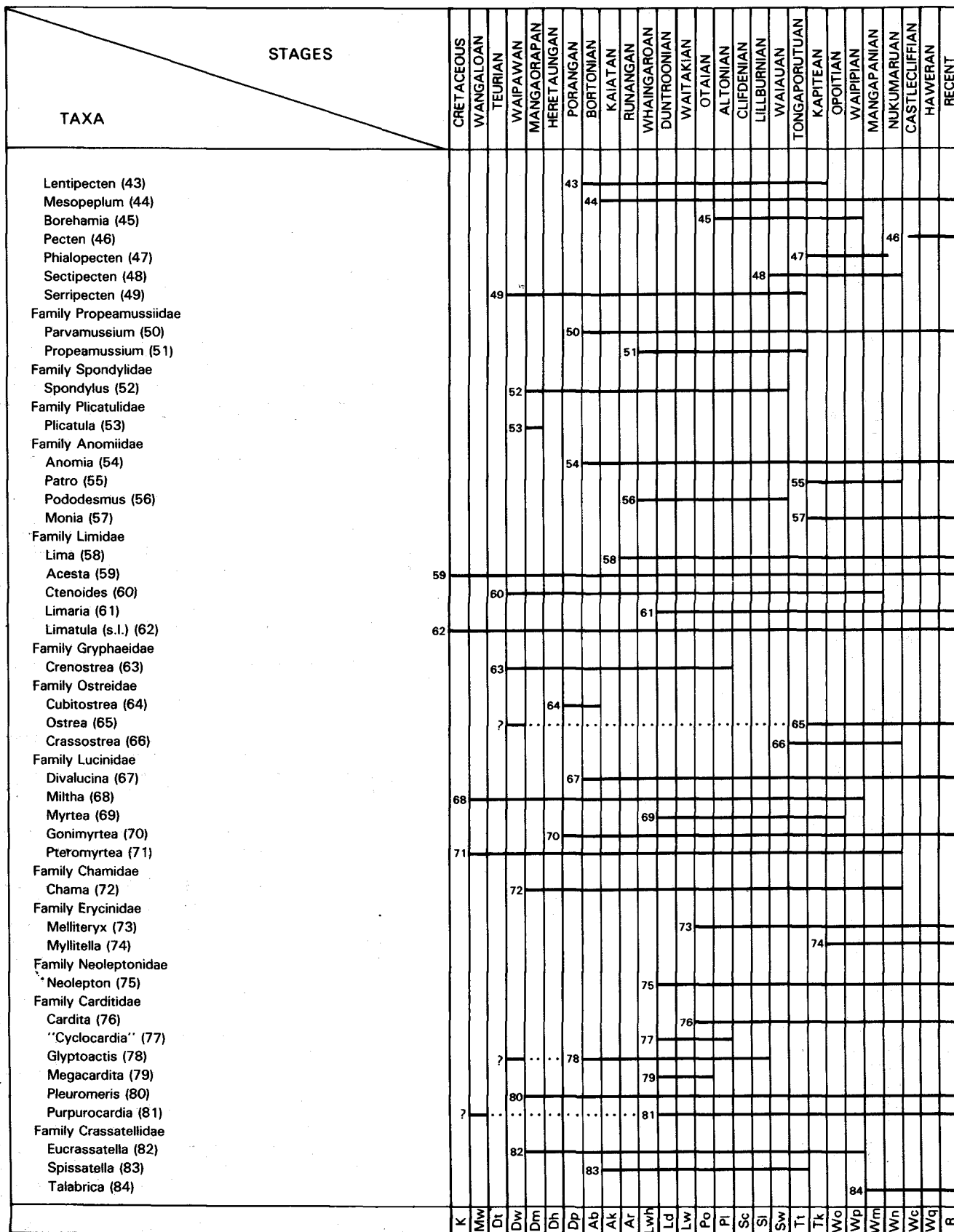


Fig. 6b

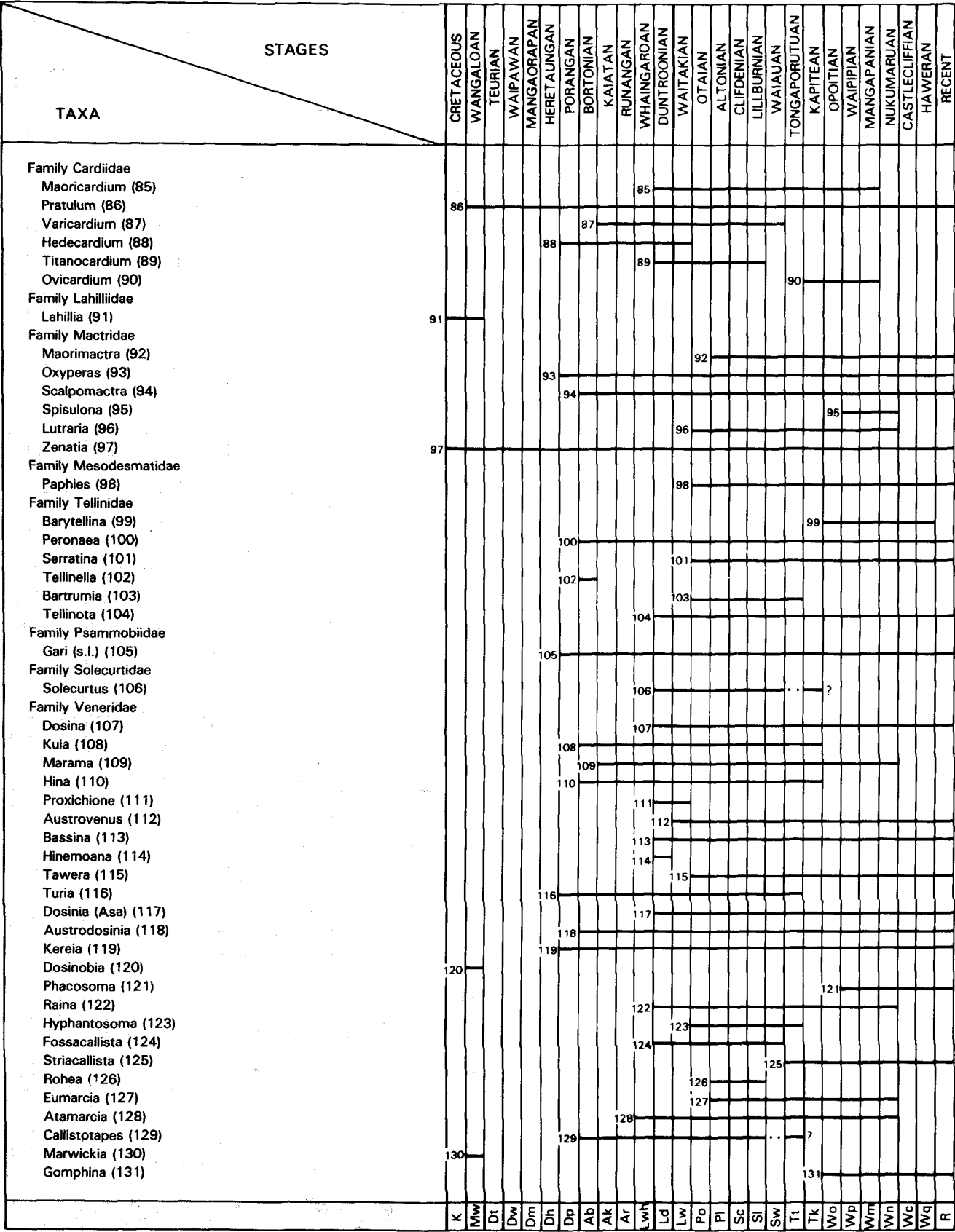


Fig. 6c

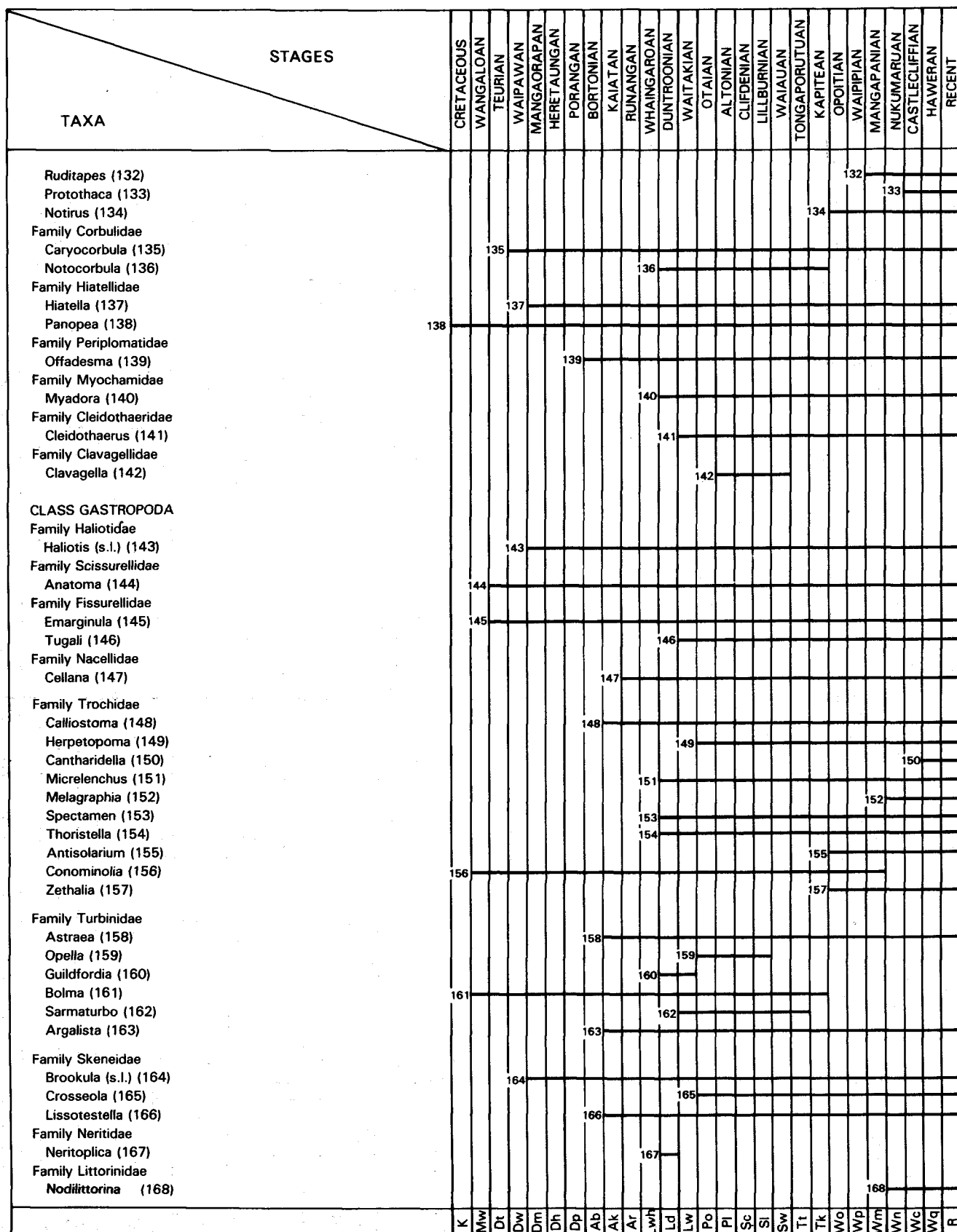


Fig. 6d

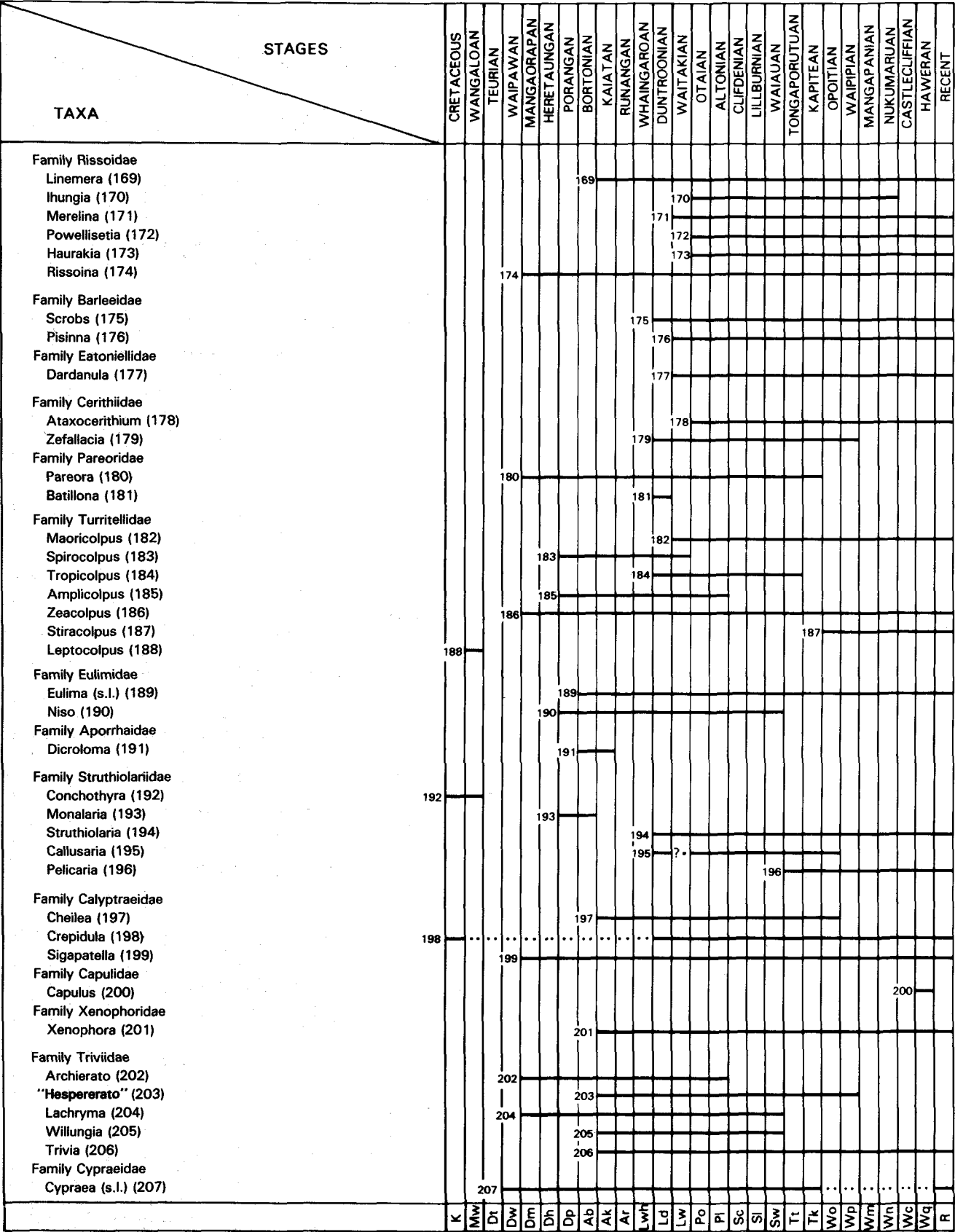


Fig. 6c

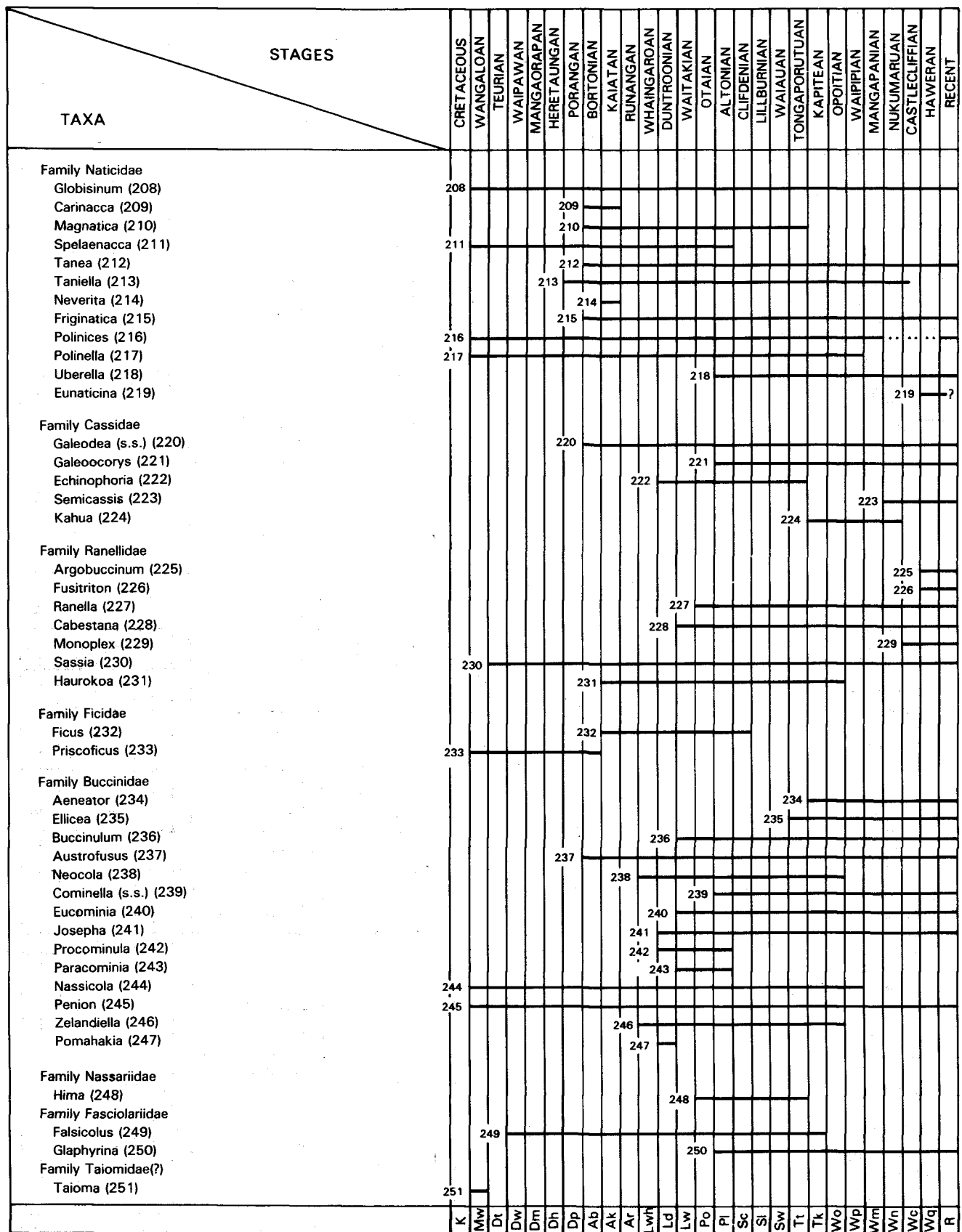


Fig. 6f

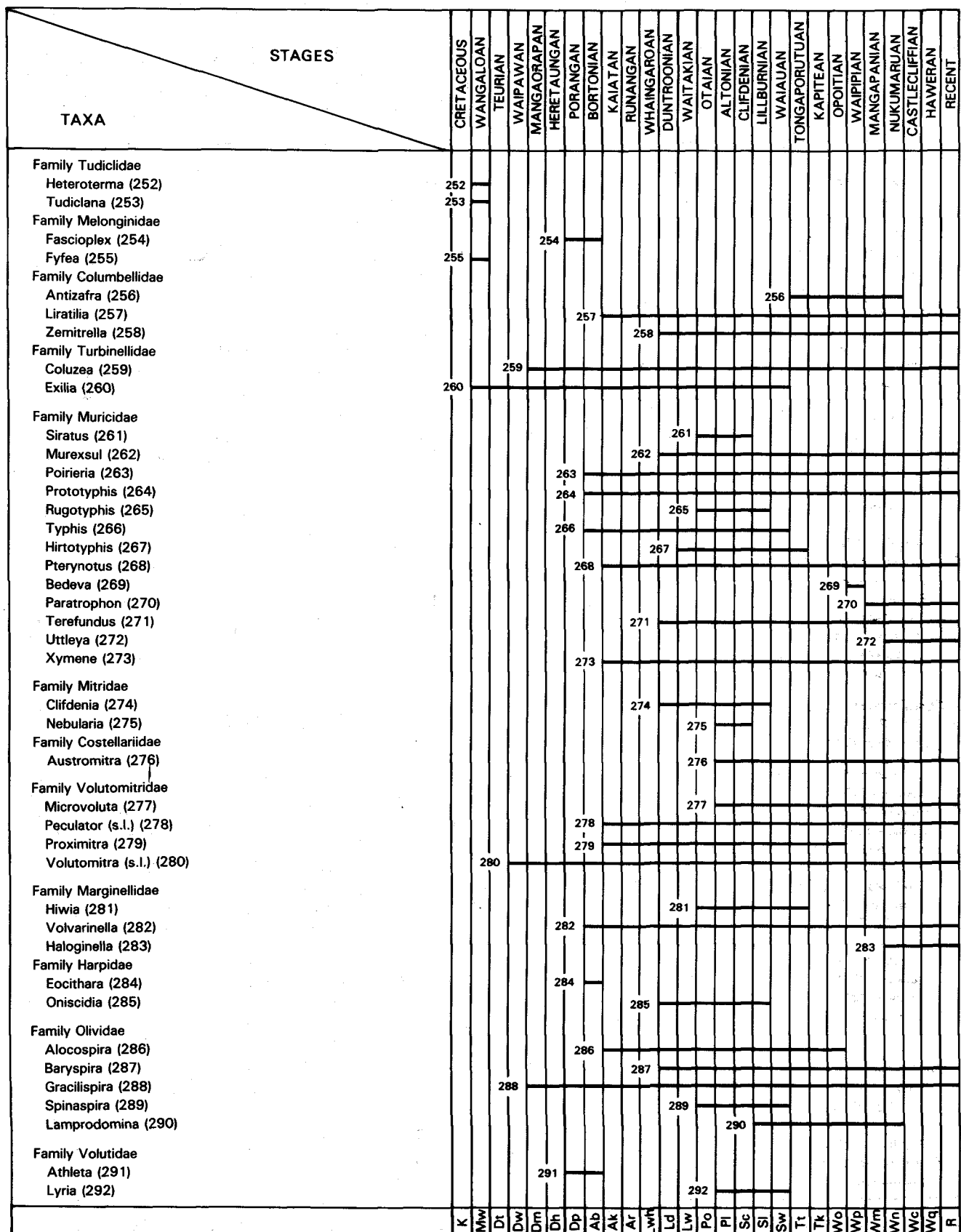


Fig. 6g

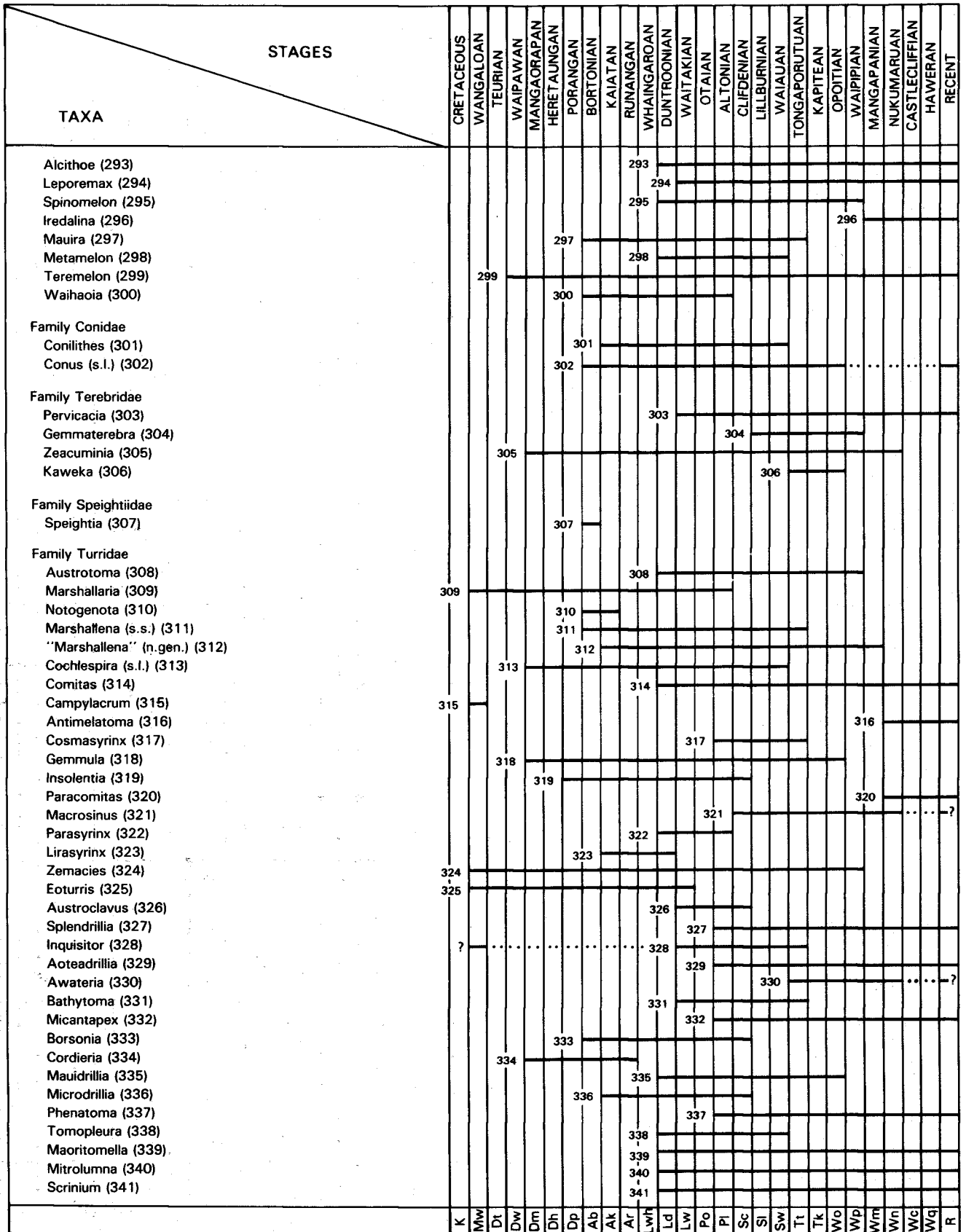


Fig. 6h

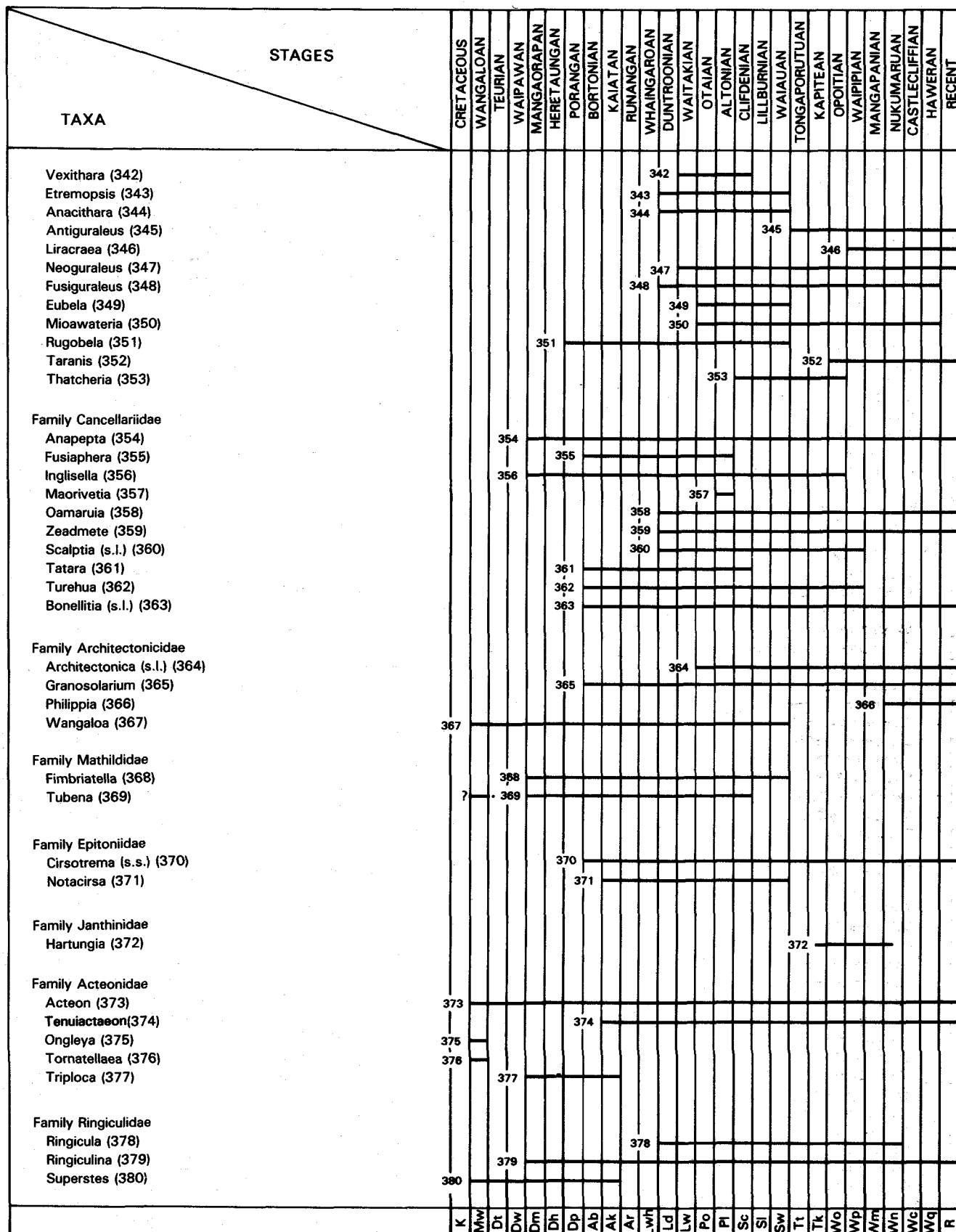


Fig. 6i

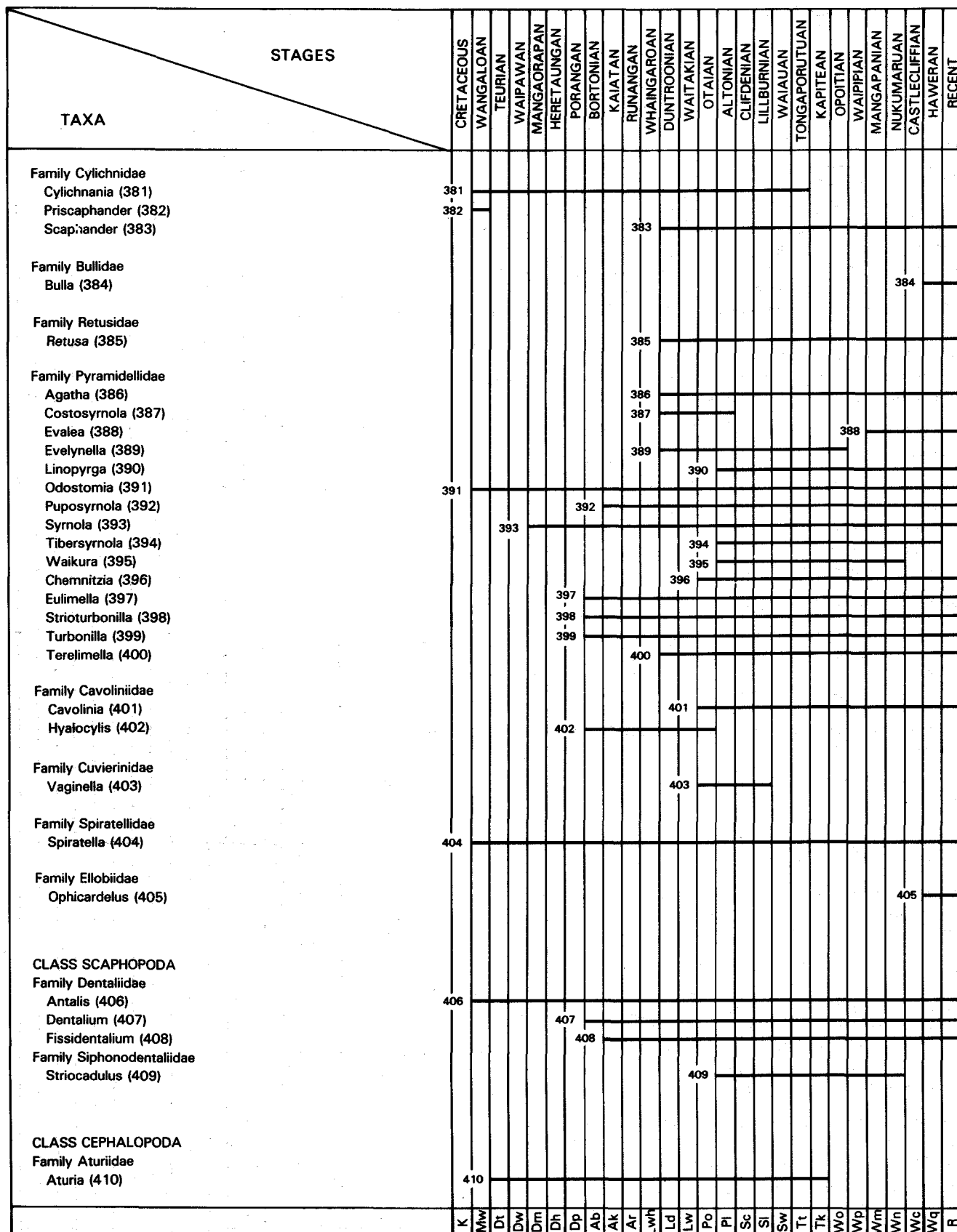


Fig. 6j

OLIGOCENE (DUNTROONIAN) TO PLEISTOCENE FIRST AND LAST APPEARANCES OF SPECIES

TAXA	STAGES	OLDER	DUNTROONIAN	WAITAKIAN	OTAIAKIAN	ALTONIAN	CLIFDENIAN	LILLBURNIAN	WAIKUAN	TONGAPORUTUAN	KAPITEAN	OPOITIAN	WAIPIAN	MANGAPANIAN	NUKUMARUAN	CASTLECLIFFIAN	HAWERAN	RECENT
<i>Zeacolpus wharekuriensis</i> (1)	1																	
<i>Chlamys chathamensis</i> , <i>Janupecten subteres</i> , " <i>Cyclocardia</i> " <i>christiei</i> , <i>Megacardita ponderosa</i> , <i>Spissatella subobesa</i> , <i>Maoricardium strangi</i> , <i>Hedecardium olssoni</i> , <i>H. waitakiense</i> , <i>Oxyperas leda</i> , <i>Tapes parki</i> , <i>Tropicolpus brycei</i> , <i>T. chattonensis</i> , <i>T. harringtoni</i> , <i>T. (Amplicolpus) healyi</i> , <i>Austrofusus precursor</i> , <i>Cominella (Procominula) praecox</i> , <i>C. propinqua</i> , <i>Falsiculus allani</i> , <i>Coluzea maoria</i> , <i>Amalda (Alocospira) electa</i> , <i>Austrotoma inaequabilis</i> , <i>Lirasyrinx anomala</i> , " <i>Scalptia</i> " <i>christiei</i> (2)	2																	
<i>Neilo sinangula</i> , <i>Athlopecten athleta</i> , <i>Lentipecten hochstetteri</i> (sensu stricto), <i>Serripecten</i> n. sp. aff. <i>hutchinsoni</i> , <i>Crenostrea wuellerstorfi</i> , <i>Flemingostrea wollastoni</i> , <i>Globisium crassiliratum</i> , <i>Sassia minima</i> , <i>Parasyrinx subalta</i> (3)	3																	
<i>Magnatica planispira</i> , <i>Sassia maoria</i> , <i>Amalda (Baryspira) robusta</i> , <i>Comitas fusiformis</i> (4)	4																	
<i>Limopsis catenata</i> , <i>Nemocardium (Varicardium) patulum</i> (5)	5																	
<i>Eucrassatella ampla</i> , <i>Bassina speighti</i> , <i>Friginatica vaughani</i> (6)	6																	
<i>Notocorbula humerosa</i> (7)	7																	
<i>Poirieria primigena</i> (8)	8																	
<i>Crepidula radiata</i> (9)	9																	
<i>Dosinia (Asa) lambata</i> (10)	10																	
<i>Lima paleata</i> , <i>Cirsotrema lyratum</i> (11)	11																	
<i>Cucullaea worthingtoni</i> , " <i>Cyclocardia</i> " <i>marama</i> , <i>Dosinia uttleyi</i> , <i>Maoricolpus doni</i> , <i>Tropicolpus hornibrooki</i> , <i>T. mackelleri</i> , <i>Zeacolpus flemingi</i> , <i>Z. greggi</i> , <i>Austrofusus affiliatus</i> , <i>Cominella (Procominula) denselirata</i> , <i>Amalda (Alocospira) cuppedia</i> , <i>Austrotoma eximia</i> , <i>Eoturris uttleyi</i> (12)	12																	
<i>Tropicolpus gittosinus</i> , <i>Zeacolpus woodhouseae</i> , <i>Austrofusus (Neocola) apudalpha</i> , <i>Austrotoma finlayi</i> (13)	13																	
<i>Limopsis zealandica</i> , <i>Pododesmus incisurus</i> , <i>Kuia vellicata</i> , <i>Globisium miocaenicum</i> , <i>Metamelon inermis</i> , <i>Spinomelon benitens</i> , <i>Teremelon tumidior</i> (14)	14																	
<i>Limatula suteri</i> , <i>Cleidotheraerus albidus</i> (15)	15																	
<i>Gegania (Tubena) olssoni</i> (16)	16																	
<i>Parapholas aucklandica</i> , <i>Sarmaturbo superbus</i> , <i>Tropicolpus tetleyi</i> , <i>Struthiolaria lawsi</i> , <i>S. (Callusaria) otaioica</i> , <i>Cominella (Procominula) pulchra</i> , <i>Penion finlayi</i> , <i>Zeacuminia biplex</i> , <i>Austrotoma lawsi</i> , <i>Zemacies lividorupis</i> , <i>Bathytoma hokianga</i> , <i>Cavolinia pycna</i> (17)	17																	
<i>Neilo awamoana</i> , <i>Cucullaea australis</i> , <i>Pinna distans</i> , <i>Spissatella trailli</i> , <i>Guildfordia (Opella) subfimbriata</i> , <i>Tropicolpus (Amplicolpus) cavershamensis</i> , <i>Zeacolpus lawsi</i> , <i>Chicoreus (Siratus) komiticus</i> , <i>Austrofusus (Neocola) flexuosus</i> , <i>Nassarius (Hima) separabilis</i> , <i>Falsiculus corrugata</i> , <i>F. kaiparaensis</i> , <i>Coluzea dentata</i> , <i>Proximitra rutidolomum</i> , <i>Amalda (Spinaspira) spinigera</i> , <i>Alcithoe turrita</i> , <i>Spinomelon parki</i> , <i>Conus armoricus</i> , <i>Zeacuminia fluctuosa</i> , <i>Austrotoma excavata</i> , <i>Bathytoma bartrumi</i> , <i>B. haasti</i> , <i>Vaginella torpedo</i> , " <i>Lornia</i> " <i>marwicki</i> (18)	18																	
<i>Spondylus aucklandicus</i> , <i>Echinophoria pollens</i> , <i>Sassia zealta</i> (19)	19																	
<i>Glyptoactis (Fasciculicardia) subintermedia</i> , <i>Oniscidia finlayi</i> (20)	20																	
<i>Septifer torquatus</i> , <i>Lima colorata</i> , <i>Notocorbula inerrans</i> (21)	21																	
<i>Ledella pakaurangiensis</i> , <i>Serripecten hutchinsoni</i> , <i>Maoricolpus ongleyi</i> , <i>Hiwia amplificata</i> (22)	22																	
			Ld	Lw	Po	Pl	Sc	Sl	Sw	Tt	Tk	Wo	Wp	Wm	Wn	Wc	Wq	R

Figure 7a-d First and last appearances of the main biostratigraphically useful species of Duntroonian (Late Oligocene) to Haweran (late Pleistocene) Mollusca.

TAXA	STAGES	OLDER	DUNTRONIAN	WAITAKIAN	OTAIAN	ALTONIAN	CLIFDENIAN	LILLBURNIAN	WAIUAN	TONGAPORUTUAN	KAPITEAN	OPOTIAN	WAIPIAN	MANGAPANIAN	NUKUMARUAN	CASTLECLIFFIAN	HAWERAN	RECENT
		Ld	Lw	Po	Pl	Sc	Si	Sw	Tt	Tk	Wo	Wp	Wm	Wn	Wc	Wq	R	
<i>Lentipecten</i> n. sp. aff. <i>hochstetteri</i> , <i>Aturia cubaensis</i> (23)	23																	
<i>Crepidula monoxyla</i> (24)	24																	
<i>Trichomya huttoni</i> , "Hinnites" <i>trailli</i> , <i>Dosinia</i> (<i>Austrodosinia</i>) <i>magna</i> , <i>Eumarcia pareoraensis</i> , <i>E. (Atamarcia) curta</i> , <i>Tropicolpus abscisus</i> , <i>Zeacolpus awamoensis</i> , <i>Crepidula densistria</i> , <i>Galeodea apodemetes</i> , <i>Cirsotrema caelicola</i> , <i>Austrofusus spiniferus</i> , <i>A. (Neocola) alpha</i> , <i>A. beta</i> , <i>A. n. sp. aff. apudalpha</i> (Oamaru), <i>Cominella (Procominella) pukeuriensis</i> , <i>Nassicola finlayi</i> , <i>Penion marwicki</i> , <i>Falsicolus</i> n. sp. (<i>Parengarenga</i>), <i>Nassarius (Hima) socialis</i> , <i>Proximitra apicalis</i> , <i>Amalda (Alocospira) hebera</i> , <i>Alcithoe (Leporemax) bathgatei</i> , <i>A. lepida</i> , <i>A. scopi</i> , <i>Spinomelon henryi</i> , <i>S. mira</i> , <i>S. speighti</i> , <i>Conilithes wollastoni</i> , <i>Gemmula</i> n. sp. (<i>Clifden</i> , <i>Parengarenga</i>), <i>Austrotoma minor</i> , <i>A. nervosa</i> , <i>A. n. sp. (Clifden, Parengarenga)</i> , <i>Bathytoma</i> n. sp. (<i>Parengarenga</i>), <i>Parasyrinx alta</i> , <i>Inquisitor awamoensis</i> . <i>I. n. sp. (Parengarenga)</i> , <i>Maorivetia brevirostris</i> , <i>Gegania (Tubena) viola</i> (25)	25																	
<i>Glycymerita robusta</i> , <i>Spissatella clifdenensis</i> , <i>Coluzea kiosk</i> , <i>Alcithoe (Leporemax) phymatias</i> , <i>Austrotoma clifdenica</i> , <i>A. n. sp. aff. echinata</i> (Karamea), <i>Zemacies elatior</i> (26)	26																	
<i>Maoricardium gudexi</i> , <i>Solecurtus bensoni</i> , <i>Dosina firmocosta</i> , <i>Clavagella oamarutica</i> , <i>Xenophora flemingi</i> , <i>Austrofusus magnificus</i> , <i>Falsicolus inurbana</i> , <i>Clifdenia turneri</i> , <i>Metamelon clifdenensis</i> , <i>Bathytoma finlayi</i> (27)	27																	
<i>Purpurocardia perscrupulosa</i> , <i>Dosinia (Raina) bensoni</i> , <i>Maoricolpus horni</i> , <i>Zeacolpus pukeuriensis</i> , <i>Struthiolaria calcar</i> , <i>S. (Callusaria) spinosa</i> , <i>Amalda (Spinaspira) stortha</i> (28)	28																	
<i>Bartrumia tenuiplicata</i> , <i>Tropicolpus milleri</i> (29)	29																	
<i>Glycymerita (Manaiia) huttoni</i> , <i>Cypraea (Notadusta) clifdenensis</i> (30)	30																	
<i>Pareora striolata</i> (31)	31																	
<i>Polinices (Polinella) obstructus</i> (32)	32																	
<i>Leptochiton inquinatus</i> , <i>Nucinella maoriana</i> , <i>Offadesma angasi</i> (33)	33																	
<i>Trachycardium (Regozara) delectabile</i> , <i>Galeodea</i> n. sp. (<i>Clifden</i>), <i>Conus</i> n. sp. (<i>Karamea</i>) (34)	34																	
<i>Struthiolaria</i> n. sp. (<i>Wairarapa</i>), <i>Austrotoma echinata</i> , <i>Zemacies simulacrum</i> (35)	35																	
<i>Varinucula crepida</i> , <i>Yoldiella stimulea</i> , <i>Cucullaea ponderosa</i> , <i>Pododesmus paucicostatus</i> , <i>Taniella mima</i> , <i>Zeacolpus willetti</i> , <i>Eremopsis erecta</i> , <i>Leucosyrinx climoi</i> (36)	36																	
<i>Struthiolaria (Callusaria) callosa</i> , <i>Sassia pahaoensis</i> , <i>Austrofusus (Neocola) gamma</i> , <i>Cominella hendersoni</i> (37)	37																	
<i>Glycymerita rangatira</i> (38)	38																	
<i>Hedecardium (Titanocardium) marwicki</i> , <i>Cosmasyrinx latior</i> (39)	39																	
<i>Saccella andrewi</i> , "Hinnites" <i>marwicki</i> , <i>Zeacolpus fyfei</i> , <i>Austrofusus (Neocola) demissus</i> , <i>Nassicola contracta</i> , <i>Austrotoma gemmulata</i> (40)	40																	
<i>Polinices intracrassus</i> , <i>Penion crawfordi</i> , <i>Zelandiella calcarata</i> , <i>Mauira washburnei</i> (41)	41																	
<i>Resania elongata</i> (42)	42																	
<i>Gemmaterebra bicorona</i> (43)	43																	
<i>Maoricardium spatiosum</i> (44)	44																	

Fig. 7b

TAXA	STAGES																OLDER	DUNTRONIAN	WAITAKIAN	OTAIAN	ALTONIAN	CLIFDENIAN	LILLBURNIAN	WAIUAN	TONGAPORUTUAN	KAPITEAN	OPOITIAN	WAIPIIAN	MANGAPANIAN	NUKUMARUAN	CASTLECLIFFIAN	HAWERAN	RECENT	
<i>"Isognomon" zealandicum</i> , <i>Lamprodomina neozelanica</i> (45)																																		
<i>Zealeda crassicostata</i> , <i>Mesopeplum</i> (<i>Borehamia</i>) n. sp. (N. Canterbury), <i>Sectipecten diffusus</i> , <i>Zeacolpus nissen</i> , <i>Mauithoe insignis</i> , <i>Austrotoma obsoleta</i> , <i>Comitas gagei</i> , <i>C. nana</i> , <i>Nassarius</i> (<i>Hima</i>) <i>karoroensis</i> (46)																																		
<i>Glycymerita</i> (<i>Manaia</i>) <i>hurupiensis</i> , <i>Struthiolaria</i> n. sp. small (N. Canterbury), <i>Polinices</i> (<i>Polinella</i>) <i>scalptus</i> , <i>Zelandiella fatua</i> , <i>Falsiculus tangituensis</i> , <i>Zeacuminia orycta</i> (47)																																		
<i>Kuia maddocki</i> , <i>Austrofusus valedictus</i> (48)																																		
<i>Polinices propeovatus</i> , <i>Sassia</i> (<i>Haurokoa</i>) <i>woodi</i> , <i>Mioawateria personata</i> (49)																																		
<i>Neojanacus perplexus</i> (50)																																		
<i>Sectipecten grangei</i> , <i>Marama hurupiensis</i> , <i>Zeacolpus taranakiensis</i> , <i>Struthiolaria praenuntia</i> , <i>Pellicaria nana</i> , <i>Austrofusus cliftonensis</i> , <i>Amalda</i> (<i>Baryspira</i>) <i>tirangiensis</i> , <i>Alcithoe hurupiensis</i> , <i>Mauithoe strongi</i> , <i>Austrotoma hurupiensis</i> , <i>Dentalium otamaringaense</i> (51)																																		
<i>Cucullaea hamptoni</i> , <i>Conus hendersoni</i> (52)																																		
<i>"Ennucula" otamaringaensis</i> (53)																																		
<i>Nemocardium</i> (<i>Pratulum</i>) <i>quinarium</i> (54)																																		
<i>Crassostrea ingens</i> (55)																																		
<i>Cabestana tabulata</i> (56)																																		
<i>Sectipecten wollastoni</i> , <i>Phialopecten tolagaensis</i> , <i>Notocallista</i> (<i>Striacallista</i>) <i>kapitea</i> , <i>Struthiolaria nexa</i> , <i>Pellicaria lacera</i> , <i>Aeneator huttoni</i> , <i>Austrofusus coerulescens</i> , <i>Comitas kennetti</i> (57)																																		
<i>Mesopeplum</i> (<i>Borehamia</i>) <i>toaense</i> , <i>Struthiolaria</i> (<i>Callusaria</i>) <i>obesa/arthritis</i> , <i>Semicassis</i> (<i>Kahua</i>) <i>kaawaensis</i> (58)																																		
<i>Nemocardium</i> (<i>Pratulum</i>) <i>finlayi</i> , <i>Eucrassatella marshalli</i> , <i>Maorimactra chrydaea</i> , <i>Zeacolpus kanieriensis</i> , <i>Hartungia typica</i> , <i>Antalis pareoraensis</i> (59)																																		
<i>Patrö undatus</i> , <i>Trachycardium</i> (<i>Ovicardium</i>) <i>rossi</i> , <i>Marama murdochi</i> , <i>Eumarcia</i> (<i>Atamarcia</i>) <i>benhami</i> , <i>Sassia pusulosa</i> (60)																																		
<i>Chlamys gemmulata</i> , <i>Atrina pectinata zelandica</i> , <i>Tiostrea chilensis lutaria</i> , <i>Dosinia</i> (<i>Kereia</i>) <i>greyi</i> (61)																																		
<i>Phialopecten ongleyi</i> , <i>Zethalia russelli</i> , <i>Zeacolpus opoitius opoitius</i> , <i>Stiracolpus kaawaensis</i> , <i>S. procellosus</i> , <i>Struthiolaria illepida</i> , <i>Pellicaria parva</i> , <i>Austrofusus</i> (<i>Neocola</i>) <i>ngatuturaensis</i> (62)																																		
<i>Pellicaria canaliculata</i> , <i>"Marshallena" decens/impar</i> (63)																																		
<i>Polinices waipiensis</i> , <i>Semicassis</i> (<i>Kahua</i>) <i>fibrata</i> , <i>Austrofusus pagoda</i> , <i>Clavatoma pulchra</i> , <i>Zeacuminia murdochi</i> (64)																																		
<i>Pteromyrtea dispar</i> , <i>Stiracolpus huttoni</i> (65)																																		
<i>Perna canaliculus</i> , <i>Maoricolpus roseus</i> , <i>Zeacolpus vittatus</i> (66)																																		
<i>Phialopecten marwicki</i> , <i>Kaparachlamys hectori</i> , <i>Mesopeplum</i> (<i>Borehamia</i>) <i>crawfordi</i> , <i>Dosina</i> n. sp. (<i>Waipipi</i>), <i>Calliostoma hawera</i> , <i>C. waiparaense</i> , <i>Struthiolaria errata</i> , <i>Pellicaria incrassata</i> , <i>P. zelandiae</i> , <i>Zemacies prendrevillei</i> , <i>Austrotoma ampla</i> (67)																																		
<i>Glycymeris waipiensis</i> , <i>Bassina katherinae</i> , <i>Zethalia coronata</i> , <i>Zeacolpus opoitius takapauensis</i> , <i>Austrofusus pliogenicus</i> , <i>Coluzea spectabilis</i> (68)																																		
	Ld	Lw	Po	Pl	Sc	Sl	Sw	Tt	Tk	Wo	Wp	Wm	Wn	Wc	Wq	R																		

Fig. 7c

TAXA	STAGES																OLDER	DUNTRONIAN	WAITAKIAN	OTAIAIAN	ALTONIAN	CLIFDENIAN	LILLBURNIAN	WAIATAIAN	TONGAPORUTUAN	KAPITEAN	OPOITIAN	WAIPIIAN	MANGAPANIAN	NUKUMARUAN	CASTLECLIFFIAN	HAWERAN	RECENT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
<i>Glycymerita (Manaia) manaiaensis</i> , <i>Mactra (Mactrona) mula</i> , <i>Eumarcia plana</i> , <i>Lutraria solida</i> , <i>Zeacuminia planitas</i> (69)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			

Fig. 7d

LINEAGES IN SOME MAJOR BIOSTRATIGRAPHICALLY USEFUL FAMILIES

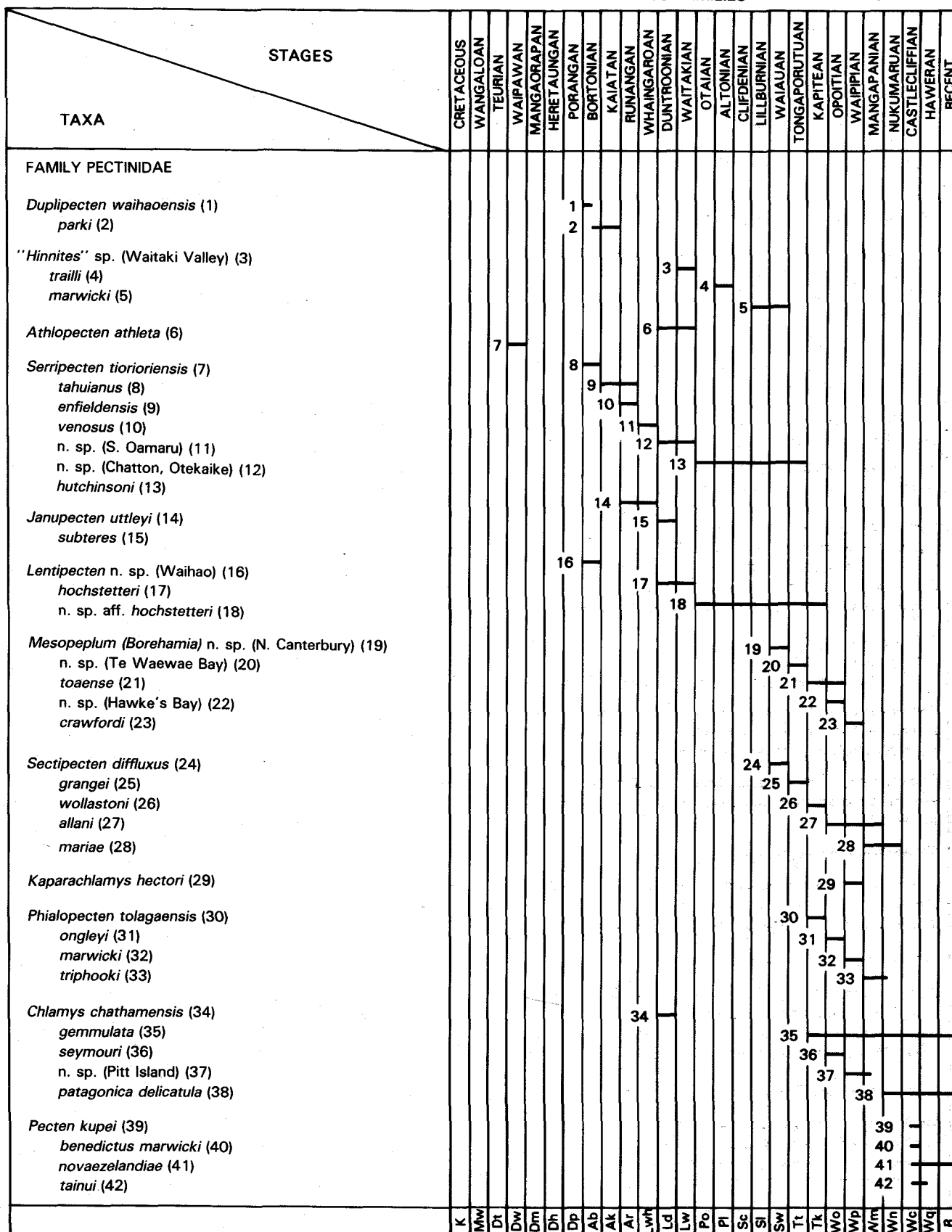


Figure 8a-d Examples of evolutionary lineages in the main biostratigraphically useful families of New Zealand Cenozoic Mollusca.

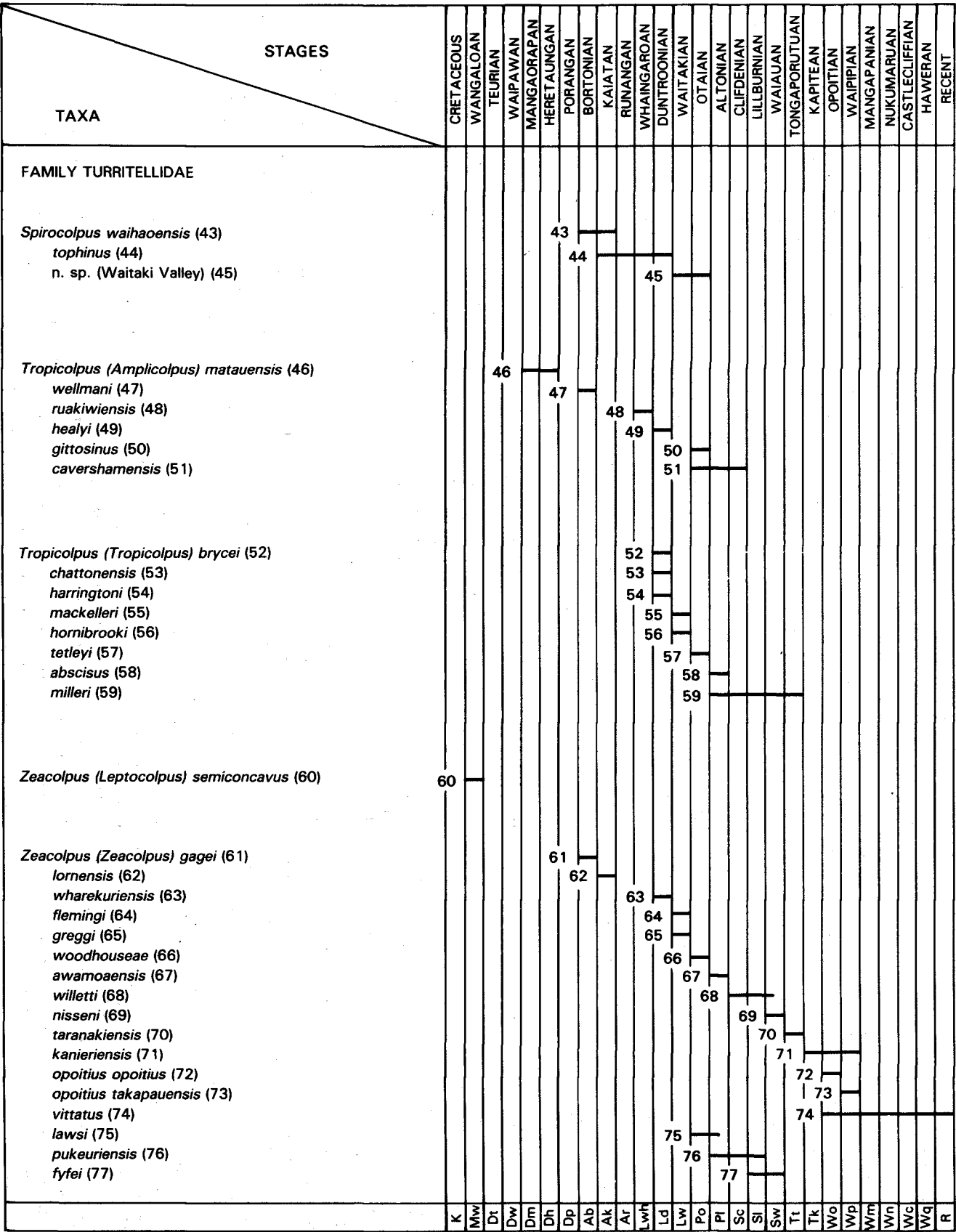


Fig. 8b

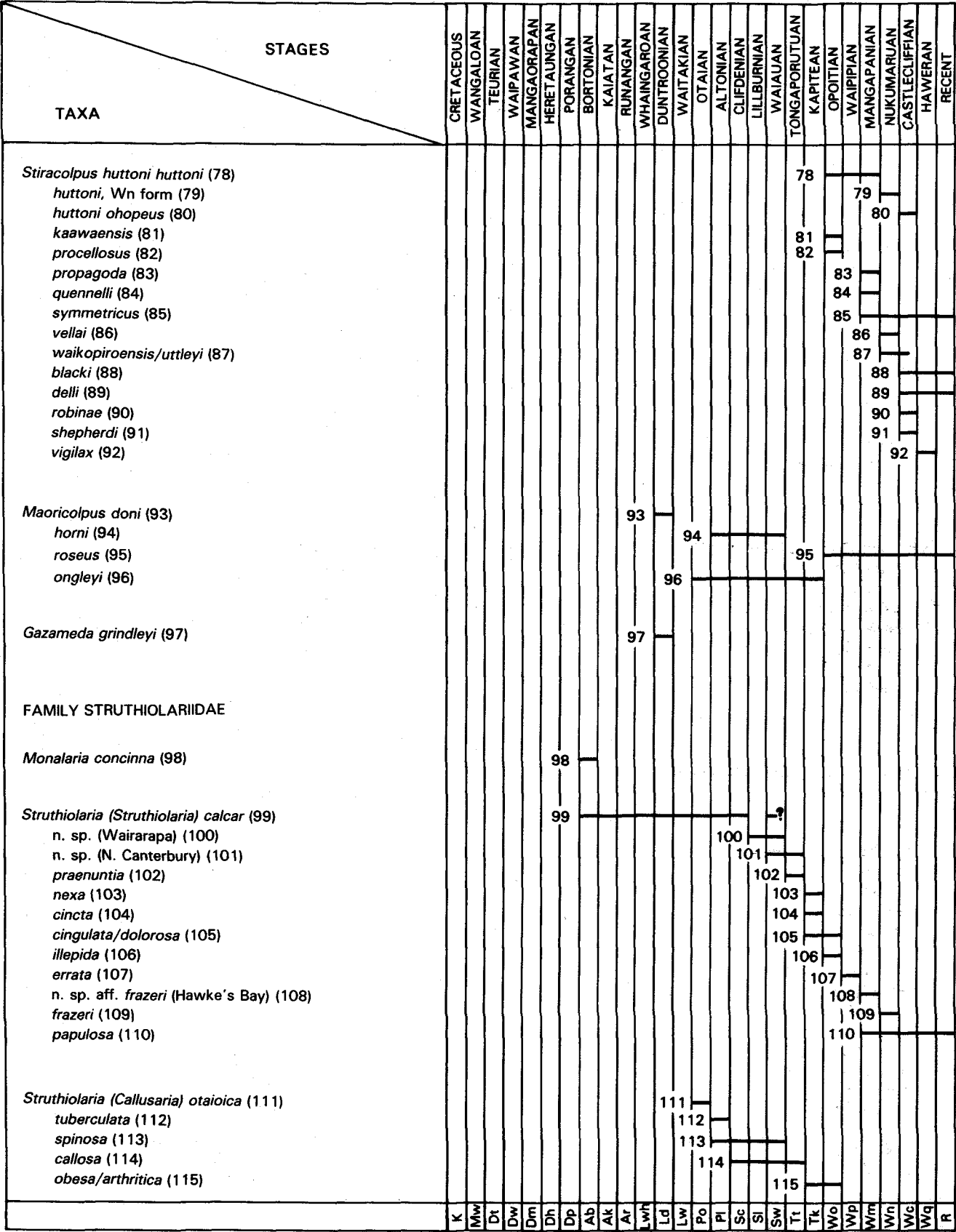


Fig. 8c

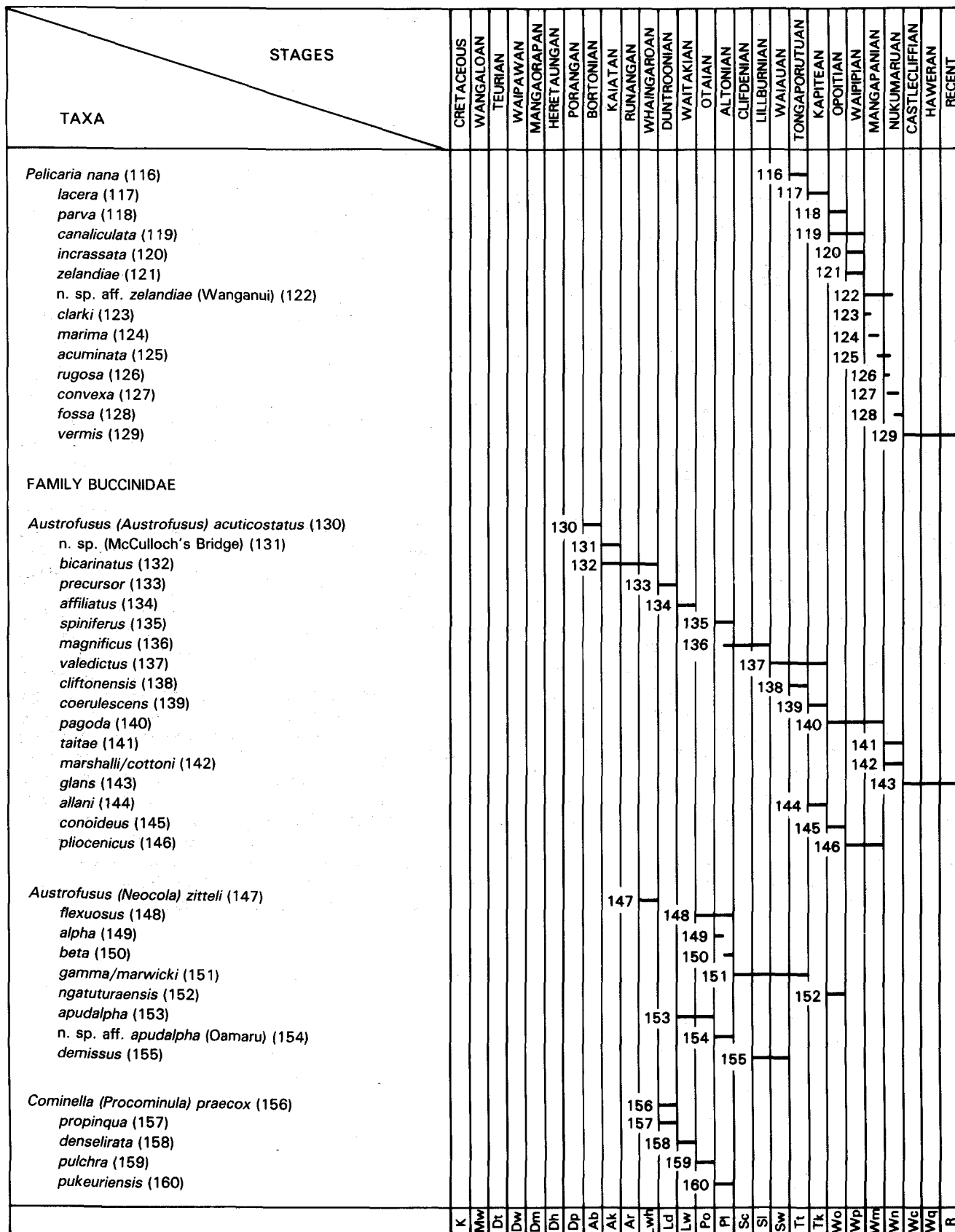


Fig. 8d

3. Evolutionary lineages

As noted above, particularly fine subdivision of Pliocene and Pleistocene time is possible because frequent oceanographic changes and, in New Zealand, rapid tectonic (and hence paleogeographic) changes caused frequent evolutionary changes in some molluscan genera, most notably *Phialopecten* (Pectinidae), *Pellicaria* (Struthiolariidae) and *Stiracolpus* (Turritellidae). These changes in sequences of evolving species (lineages) provide the most reliable of biostratigraphic data, because (1) the changes are much more likely to be coeval from area to area (basin to basin or, in the case of *Pellicaria*, in which different lineages occurred in some of the different sedimentary basins, one part of a basin to another) than are those caused by the extinction or appearance of a species or genus, which may have been caused in turn by external factors such as progressive temperature change (and so, for example, a species might become extinct earlier in the south of New Zealand than in the north); and (2) being able to compare the ancestral species with its descendant provides a much more reliable datum than one based on presence and absence data. Obviously, much of the testing of presence and absence data (such as appearances and extinctions of genera or species) is concerned with the possibility that the event may have been caused by a local facies change rather than a real extinction or appearance. The continual refinement of biostratigraphy therefore, involves two distinct lines of research: (a) taxonomic refinement of evolutionary lineages (in other words, trying to understand which are the real, reliable species, what is merely phenotypic variation of a single species, and so which changes are really evolutionary), and (b) continual re-evaluation of the timing of appearances and extinctions in different parts of the country, both by comparison of molluscan data with each other, and by comparison with other (particularly planktonic) fossil groups. A good example is discussed briefly below (in the section on Nukumaruan faunas, under *Pellicaria fossa* and *P. convexa*) of an apparent evolutionary lineage in late Pliocene-early Pleistocene rocks of Hawke's Bay that proved to be the result of facies changes rather than evolution.

Phialopecten, *Pellicaria* and *Stiracolpus* are but three examples of the many groups of evolutionary lineages of Mollusca displayed in New Zealand Cenozoic rocks. The many evolutionary changes seen in Mollusca allow a very reliable biostratigraphy of shallow-water marine rocks as, besides the advantages mentioned above, most evolutionary changes in New Zealand Mollusca are rapid, conforming to the punctuation/stasis model, as is expected in the normal mode of allopatric speciation. Examples of evolutionary lineages in Pectinidae, Turritellidae, Struthiolariidae and Buccinidae (the most biostratigraphically useful families) are shown in the fourth time-range table (Figure 8).

Some of the most important lineages (because they have proved reliable in biostratigraphy) are illustrated, at least in part, in our plates. Some major examples of confirmed first-order biostratigraphic reliability are (1) *Cucullaea* (*Latiarca*) *waihaoensis-worthingtoni* (Pl.10e,j) – *australis-ponderosa-hamptoni* (Porangan?-Kapitean; distinctions between some supposed taxa uncertain); (2) *Phialopecten tolagaensis-ongleyi-marwicki-triphooki* (Pl.33; Kapitean-early Nukumaruan); (3) *Sectipecten diffusus-grangei-wollastoni-allani* (Pl.28, Pl.33; Waiau-Mangapanian); (4) *Zeacolpus pukeuriensis-willetti-nisseni-taranakiensis* (Pl.20, Pl.29; Altonian-Tongaporutuan, merely one example of a plexus of *Zeacolpus* lineages and of many in the Turritellidae); (5) *Pellicaria canaliculata-clarki-marima-acuminata* (Pl.36, Pl.42; Waipipian-early Nukumaruan, but again merely an example from a plexus of lineages); (6) *Struthiolaria* (*Callusaria*) *otaioica-spinosa-callosa-obesa* (Pl.20, Pl.29, Pl.36; Otaian-Opoitian); (7) *Hartungia typica-chavani* (Pl.37; Kapitean-early Nukumaruan, a world-wide lineage of planktonic gastropods); (8) *Austrofuscus* (*Neocola*) *alpha-beta-gamma-marwicki-ngatuturaensis* (Pl.25, Pl.37; Altonian-Opoitian; the most useful of several lineages in *Austrofuscus* and related Buccinidae); and (9) *Parasyrinx subalta*-n.sp.-*alta* (Pl.15, Pl.22; Duntroonian-Altonian; one of many useful lineages in the huge family Turridae).

A larger time-range table demonstrating these and many other lineages of Cenozoic Mollusca (Beu and Maxwell in Hoskins 1982, table 11) has been significantly modified and corrected in the compilation of Figures 5-8.

CHAPTER 4. GLOSSARIES

GLOSSARY OF TERMS APPLIED TO MOLLUSCA

Definitions have been adapted largely from the "Treatise on Invertebrate Paleontology". Symbols: B = term applies to bivalves, G = gastropods, N = nautiloids, P = Polyplacophora (chitons), S = scaphopods.

Abapertural (G)—away from the aperture (in the direction of whorl coiling) (opposite: adapertural).

abapical (G)—away from the apex (equivalent to anterior in high-spired taxa) (opposite: adapical).

adapertural (G)—towards the aperture (in the direction of whorl coiling) (opposite: abapertural).

adapical (G)—towards the apex (equivalent to posterior in high-spired taxa) (opposite: abapical).

adductor muscle (B)—a muscle joining and closing the two valves, working in opposition to the ligament; two present in most bivalves (said to be dimyarian) but only one in some (monomyarian); attached to a depressed (or, in a few taxa, elevated) area in each valve called an adductor muscle scar.

alate—winged (see wing).

anal sinus (G)—notch, slot or embayment in the outer lip, typically at or above the periphery, to allow excretion of waste products. Its position and shape are of considerable taxonomic significance in some groups, particularly the Turridae (see turrid sinus).

angulation (G)—a ridge (usually spiral) between two meeting surfaces; commonly at the shoulder (ie. abapical margin of the sutural ramp) and/or a peribasal angulation.

anterior—in the direction in which the living animal moves.

anterior lateral tooth (B)—a lateral hinge tooth in front of the beak.

anterior tubules (B)—in Clavagellidae, tubules around the anterior end of the sac, for passage of water.

anterior valve (P)—the head valve; the anteriormost of eight valves (or plates) in a chiton shell, commonly semicircular.

anterodorsal margin (B)—the dorsal margin in front of the beak.

aperture (G, N)—the single, large opening through which the head-foot is extruded.

aperture (S)—anterior orifice or aperture; the broader, anterior end of a scaphopod shell, through which the foot and captacula (feeding "tentacles") are extruded (see apex). In Dentaloida the shell is widest at the aperture, but in most Gadiloida it is widest some distance behind the aperture.

apex (G)—the tip, or summit, of the spire, bearing a protoconch in most taxa; the summit of cap-shaped taxa ("limpets").

apex (S)—the posterior orifice or aperture; the narrow, posterior end of the scaphopod tube (see aperture). A simple opening in some species, but modified by slits, slots or notches in others. Some species have a narrower, short tube (terminal pipe) protruding beyond the apex.

apophysis (B)—a long, narrow, usually curved, ligament-support structure in the centre of the hinge (protruding into the central cavity of articulated shells) in some edentulous bivalves, notably Pholadidae.

articulamentum (P)—the inner, relatively hard, dense, semiporcellaneous shell layer of chiton valves, extended beyond the tegmentum (which see) to form the insertion plates and sutural laminae (sometimes now subdivided into two layers, the articulamentum (sensu stricto), the outer (more dorsal) of the two, and the hypostracum, the inner (more ventral) of the two).

auricle (B)—ear; an anterior or posterior area adjacent to the dorsal margin, marked off from the disc by a hollow, groove, ridge or slight angulation (most commonly in Pectinacea).

auricular crus (B)—in Pectinacea, a low ridge, nodule or flat-surfaced, elevated area on the shell interior, near the base of the auricle, where valve internal surfaces meet (plural, crura).

axial (G)—of sculpture, parallel or nearly parallel to the axis of coiling. The more general term for the common sculpture crossing the spiral sculpture of gastropods nearly at right angles, although the special term "collabral sculpture" is preferable when applicable (although nearly all axial sculpture is collabral, ie., parallel to the outer lip, non-collabral axial sculpture, when the axial sculpture crosses the growth lines at a low angle, occurs in a few taxa of Buccinacea and Trochacea, in all Cancellariidae Plesiotritoninae, and probably in a few other taxa).

axis (G)—an imaginary line through the shell apex, about which the shell is coiled.

basal cord (G)—any spiral cord on the base; sometimes used in the sense for which "peribasal cord" is preferred here.

basal fasciolar band (G)—see fasciolar bands.

basal groove (G)—in Olividae Ancillinae, a deep narrow groove separating the fasciolar bands from the columellar lip.

base (G)—differently defined in different groups; in conispiral shells, that part of the surface abapical (and, in many taxa, anterior) to the extension of the suture around the last whorl; in limpets, the aperture, or apertural side; in Cypraea and Lamellariacea ("cowries"), the flattened apertural side.

beak (B)—the proximal portion of the umbo; a nose-like, usually protruding angle, along or above the hinge, where the growth of the valve commenced; the point of maximum curvature.

body chamber (N)—the large, non-septate final portion of a cephalopod shell, occupied by the body of the animal.

body whorl (G)—the last whorl (commonly used in older descriptions, but now replaced by "last whorl").

broad band (G)—in Olividae Ancillinae, the broad, spiral band around the mid-whorl area, posterior to the depressed band and anterior to the spire callus.

- bucciniform (G)—shaped as in *Buccinum*, i.e., with moderately tall spire, short last whorl, moderately and evenly inflated whorls, and only a short but (in most) widely open siphonal canal.
- byssal fasciole (B)—in Pectinacea, the trace of the former byssal notch positions, extending from the beak to the present byssal notch.
- byssal foramen (B)—an opening in the right valve of Anomiidae for the passage of the calcified byssus (also for passage of the conchiolin byssus in *Pulvinites*).
- byssal gape (B)—an opening between the shell margins for passage of the byssus.
- byssal notch (B)—an indentation in the valve margin below the right auricle of many Pectinacea and Pteriacea for passage of the byssus.
- byssus (B)—a bundle of hair-like conchiolin strands for attachment of the shell to various hard substrates; secreted by a gland at the base of the foot. In Anomiidae, cemented into a single calcified rod or pad.
- callum (B)—a secondary calcareous anterior structure in some Pholadidae, closing the pedal gape in adults.
- callus (G)—shelly substance composing the inductura, in the parietal region, or extending over the inner lip, over the base, into the umbilicus, or (in many Olividae Ancillinae) over the spire.
- camera (N)—chamber; the space enclosed between two adjacent septa.
- campanulate (G)—in Turritellidae, a whorl profile with a rounded, protruding angle below the upper suture, a more strongly protruding, strongly angled ridge above the lower suture, and a concave zone between the two ridges.
- Camptonectes* microsculpture (B)—in Pectinacea, external sculpture of fine to very fine “radial” striae or lirae, remaining normal to the valve margins at all stages of growth, and therefore curved outward distally, and diverging distally from a near-central radial line on the disc.
- canal (G)—a narrow, semitubular extension of the aperture; an anterior (siphonal) canal is present in most higher gastropods, and a posterior (anal) one in some, particularly in Bursidae.
- cancellate—sculptured with intersecting spiral and axial (in gastropods) or radial and commarginal (in bivalves) costae, costellae, cords or threads.
- cardinal area (B)—a flat or slightly concave, commonly triangular surface between the beak and the hinge margin in some bivalves (mainly Pterioidea), partly or wholly bearing the external ligament.
- cardinal crura (B)—narrow ridges or teeth (low, straight and simple in most taxa) radiating from the apex of the ligamental pit in some Pectinacea (singular: crus).
- cardinal tooth (B)—a hinge tooth radiating from beneath the beak.
- carina—a prominent ridge or keel.
- central area (P)—part of the upper surface of the tegmentum on intermediate valves, on either side of the jugum, marked off from the pleural (= lateral) areas by a ridge, and/or by bearing distinctive sculpture.
- cerithiiform (G)—shaped as in *Cerithium*, i.e., with tall spire, small aperture, and short, twisted siphonal canal.
- chamber (N)—see camera.
- chevron groove (B)—a V-shaped groove (angled below the beak) on the cardinal area, in which the external ligament is attached.
- chomata (B)—in “oysters” (Gryphaeidae and Ostreidae), small tubercles or radial ridges on the margins (meeting faces) of the valves, present below the hinge on both anterior and posterior margins of most oysters, and around the entire margin of a few; also known as anachomata on the right valve, and catachomata on the left valve. Particularly large, prominent chomata in some species of *Pycnodonte* are known as pycnodonteine lath chomata.
- chondrophore (B)—a resilifer that projects below the margin of the hinge.
- circumbilical (G)—bordering the umbilicus. Some gastropods have a strongly differentiated circumbilical ridge or cord.
- clathrate (G)—net-like sculpture produced by the intersection of spiral and orthocline elements (i.e., more-or-less at right angles to each other; in practice, frequently used as synonymous with reticulate, which see).
- coeloconoid (G)—applied to gastropod spires of approximately conical form but with a concave outline (see cyrtconoid).
- collabral (G)—parallel to the outer lip, i.e., the more precise term for “axial” sculpture, which in most cases is not truly axial. In the great majority of gastropods, “axial” sculpture, although prosocline, orthocline, or opisthocline, remains collabral; but in a few taxa, “axial” sculpture is non-collabral, and crosses the growth lines at a low angle (see “axial”).
- columella (G)—the pillar forming the axis of coiled shells; commonly used for the exposed portion, below the parietal area of the inner lip.
- columellar teeth (G)—in Cypraea and Lamellariacea (“cowries”), the narrow, closely spaced, transverse ridges on the inner lip.
- cominelliform (G)—shaped as in *Cominella*; similar to bucciniform, but more truncate anteriorly.
- commarginal (B)—sculpture parallel to the valve margins, i.e., the preferred term for “concentric” sculpture.
- commissure (B)—the line of meeting of the two valves of a single bivalve shell.
- compressed—somewhat flattened.
- conchiolin—proteinaceous material composing the periostracum, the ligament, the byssus, most opercula, and the organic matrix of the calcareous shell.
- conspiral (G)—coiled so that the spire projects as a cone or conoid.
- convexity (B)—the degree of inflation.
- convolute (G,N)—with the last whorl completely enveloping and enclosing the earlier whorls; as involute, but lacking umbilici.
- cord (B)—a spiral ridge or costa.

- costa—a spiral, axial, radial or commarginal ridge; usually used for the radial ridges of bivalves and the axial ridges of gastropods (diminutive, costella).
- crenulate (B)—with the inner ventral margin bearing alternate ridges and notches.
- crus (B)—plural, crura; see cardinal crura.
- ctenolium (B)—in Pectinacea, a comb-like row of small teeth along the lower edge of the byssal notch or fasciole.
- cyrtocooid (G)—applied to gastropod spires of approximately conical form but with a convex outline (see coeloconoid).
- decollate (G)—losing the early spire whorls (deliberately; restricted to a few groups of tall conispiral shells).
- decussate (G)—net-like sculpture produced by the intersection of prosocline and opisthocline elements (ie., “diagonally” clathrate or reticulate); the usual protoconch sculpture in the turrid subfamily Daphnellinae and in some Cerithiopsidae.
- dentition (B)—a collective term for the hinge teeth and sockets.
- depressed (G)—with a low or flat spire.
- depressed band (G)—also known as an ancillid band; in Olividae Ancillinae, a relatively narrow spiral band just anterior to the mid-whorl and immediately anterior to the broad band, depressed below the rest of the whorl surface, and usually distinctively coloured; generated in many taxa by a small denticle low on the outer lip.
- deviated (G)—of the protoconch, with its coiling axis at a distinct angle to that of the teleconch; of the columella, bent or curved away from its expected, nearly straight course.
- dextral (G)—right-handed; ie., with the aperture on the observer’s right, or coiling clockwise when viewed from the spire apex (actually to be determined from both shell and anatomy; a few hyperstrophic dextral gastropods are known in which, with the aperture to the observer’s right, the spire protrudes downwards) (opposite: sinistral).
- diameter (G)—the distance between two planes parallel to and just touching the sides of conispiral shells (parallel to the coiling axis).
- disc (B)—in Pectinacea, the main area of the valve, ie., not including the auricles.
- dissoconch (B)—the shell formed after the embryonic stage (the embryonic shell is the prodissoconch).
- distal—the last-formed part of the shell.
- divaricate (B)—sculpture of lines or ridges with a marked angle, arranged so the lines or ridges diverge from a (commonly central or subcentral) line radiating from the beak (eg., in *Divaricella* and *Ctenoides*).
- dorsal—towards the back (dorsum) as the living animal moves (opposite of ventral); in bivalves, the margin bearing the hinge.
- dorsal face (S)—normally the concave face of a scaphopod shell; in some species of *Cadulus* the dorsal face is somewhat convex although less so than the ventral face.
- ear—see auricle.
- edentulous (B)—without hinge teeth.
- embryonic shell—the shell formed before emergence from the egg, and in some taxa, during planktonic larval life (in gastropods, the protoconch; in bivalves, the prodissoconch).
- entire (B)—of the pallial line: without a pallial sinus (= integripalliate).
- equilateral (B)—with the parts of the shell anterior and posterior to the beak approximately equal in length.
- equivalve (B)—with the two valves of the same shape and size (opposite: inequivalve).
- escutcheon (B)—a differentiated posterodorsal area margining the external ligament, typically lozenge-shaped in articulated shells, marked off by a ridge in many taxa, but merely by a sculptural difference in some, and not differentiated at all in a few.
- evolute (G,N)—coiled with the whorls not in contact (gastropods) or just touching, producing very wide umbilici (cephalopods).
- fasciolar bands (G)—in Olividae Ancillinae, narrow, flat-surfaced bands around the fasciole, anterior to the depressed band and posterior to the basal groove; in many taxa, divided into three (to varying degrees of clarity) by low ridges between them: the top fasciolar band is the posteriormost (anterior to the depressed band), the mid fasciolar band is central, and the basal fasciolar band is the anteriormost (just posterior to the basal groove).
- fasciole (G)—an anterior (abapical) spiral band or zone, demarcated by a margining ridge and/or by lamellose sculpture, generated by the siphonal notch of siphonostomatous gastropods.
- flank (B)—the median part of the surface of the valve; limited posteriorly by an umbonal-ventral ridge or by a sculptural difference in some taxa.
- fold (B,G)—(1) of sculpture, a prominent axial costa (in gastropods), radial costa or commarginal ridge (in bivalves, eg., radial folds of Pectinidae), affecting the whole thickness of the shell; (2) on the gastropod columella, a plait or plica, a spiral ridge to aid attachment of the columellar muscle.
- foot—of gastropods and chitons, the large muscle mass on which the animal moves; of bivalves, wedge-shaped and used for burrowing in most, but reduced to a small mantle-cleaning and/or byssus-secreting structure in many Pterioidea; of scaphopods, a narrow burrowing organ similar to that of burrowing bivalves; of cephalopods, subdivided into the arms.
- fossette (B)—a shallow socket or ligamental hollow; used also of a triangular resilifer in the cardinal area, e.g., in *Limopsis*.
- fossula (G)—in Cypraeacea and Lamellariacea (“cowries”), a shallow depression or groove on the anterior part of the inner lip, just inside the aperture, margined internally by a low ridge.
- frustate (G)—in Turritellidae, a whorl profile in which each whorl is flat-sided apart from a prominently projecting basal angle, ie., each whorl tapers regularly inward from the basal angle to the upper suture.

- funicle (G)**—a spirally coiled ridge extending into the umbilicus from the inner lip, as in many Naticidae; particularly used for the outer (apertural) face of the ridge.
- fusiform (G)**—shaped as in "*Fusus*" (i.e., *Fusinus*), narrowly spindle-shaped, with a tall spire and a long siphonal canal.
- gape (B)**—an opening remaining between the two valve margins of a closed, articulated shell (commonly for the passage of the byssus, foot or siphons).
- girdle (P)**—a flexible muscular integument, surrounding the valves, and in which they are embedded; the girdle may be smooth ("leathery") or bearing a variety of spicules or scales.
- gradate (G)**—of the spire; regularly stepped.
- granulate**—sculptured with many small granules, nodules or beads.
- growth line angle (G)**—in Turritellidae, the growth line angle, "a", is the angle between the axis of coiling (i.e., a truly axial imaginary line on the whorl surface) and a line subtended by a growth line (commonly prosocline; see diagram in Fig. 9h).
- growth lines**—surface sculpture, commonly not prominent, generated during shell secretion, and so parallel to the outer lip (in gastropods) or to the valve margins (in bivalves).
- head valve (P)**—see anterior valve.
- height**—of bivalves, the distance between the extremities of the ventral and dorsal margins, in the plane of the commissure; of gastropods, the distance between two planes perpendicular to the coiling axis and just touching the adapical and abapical ends (except in Cypraeaacea and Lamellariacea ("cowries"), where it is used for what would be termed the "minimum diameter" in other gastropods—the distance between two planes parallel to and just touching the base and dorsum, i.e., between the extremities of the apertural and abapertural sides).
- heterodont (B)**—with distinctly different cardinal and lateral teeth; hence also used for the taxonomic group with such a hinge, "heterodonts", i.e., the Subclass Heterodonta.
- heterostrophic (G)**—of the protoconch, coiled in the opposite sense to the teleoconch; the normal situation in Architectonicidae, Mathildidae, Pyramidellidae, and many other opisthobranchs (see orthostrophic).
- hinge (B)**—structures of the dorsal region (including the ligament, resilifer or chondrophore, hinge teeth and sockets, and lithodesma), mostly near the beak, that articulate the dorsal margins of the two valves of one shell.
- hinge axis (B)**—an imaginary straight line about which the two valves of one shell are hinged.
- hinge plate (B)**—an internal platform below the beak, parallel to the plane of the commissure, bearing the hinge teeth and sockets, chondrophore, lithodesma, etc.
- hinge tooth (B)**—a structure in the hinge (one of several in most bivalves), a narrow ridge of shelly material received in a socket in the opposite valve, serving to articulate the two valves of one shell and prevent them from rotating with respect to one another.
- hyperstrophic (G)**—coiled sinistrally (i.e., with the aperture on the left, in conventional spire-up orientation) but with dextral anatomy (or vice versa).
- hypoplax (B)**—in some Pholadidae, an elongate accessory plate covering the posterior part of the dorsal margin.
- imbricate**—a general term to describe overlapping sculptural elements in both gastropods and bivalves (e.g., the overlapping scale-like commarginal ridges of some *Acar* species); in gastropods of the Turritellidae, a whorl profile in which a strongly protruding basal cord is situated immediately above the suture, cutting in sharply (horizontally) to the suture, and each whorl tapers reasonably regularly from the protruding cord towards the upper suture.
- impressed (B, G)**—of bivalve muscle scars, excavated so the positions of former muscle attachments are clearly visible on empty shells (also of the pallial line and sinus); of gastropod sutures, clearly marked by a spiral groove, i.e., both adjoining whorl surfaces are turned inwards adaxially.
- inductura (G)**—a smooth shell layer, commonly extending from the inner (left) side of the aperture over the parietal region, columellar lip, and (in some taxa) the umbilicus and some or all of the exterior surface.
- inequivalve (B)**—having the two valves unequal in size, shape, and/or inflation (opposite: equivalve).
- inflated**—swollen, or strongly convex.
- inner lip (G)**—the adaxial (left) margin of the aperture, extending from the suture to the base of the columella; consists of the parietal region (lip) and columellar lip.
- insertion plate (P)**—a marginal extension of the articulamentum of the anterior (head) and posterior (tail) valves and of the sides of the intermediate valves, embedded in the girdle; absent or very narrow in primitive chitons (Lepidopleuridae and Hanleyidae, among Cenozoic-Recent taxa) but well developed in all higher chitons.
- integripalliate (B)**—without a pallial sinus (= entire).
- intermediate valve (P)**—valves 2-7; the series of six similar valves between the anterior and posterior valves of one chiton; in most chitons, each intermediate valve is markedly wider than it is long, with insertion plates and one or a few slits on each side, and with two sutural laminae on the front edge.
- interriviceal tube (G)**—in Muricidae Typhinae, a tubular spine on the whorl surface (commonly on the shoulder angle) between two varices.
- intritalcalx (G;B?)**—a calcareous, chalky-looking (although firm, not particularly soft) outer layer on the surface of some gastropod teleoconchs, apparently replacing or deposited on the periostracum and, in most, finely and intricately sculptured; present in some Muricidae, Bursidae, Cancellariidae, Turritellidae, and Epitoniidae (genera related to *Opalia*). A similar chalky outer layer (although not regularly sculptured) on some Pectinidae (notably *Adamussium colbecki* (Smith), Recent, Antarctica) appears to be analogous to the gastropod intritalcalx.

- involute (G,N)**—in gastropods, coiled so the last whorl envelopes all earlier ones, and the height of the aperture corresponds to that of the shell, but with parts of the earlier whorls visible in umbilici (see convolute); usually used of planispiral shells. In nautiloids, with whorls overlapping well, so that umbilici are narrow.
- jugal angle (P)**—the dorsal angle between the flat surfaces of the two sides (halves) of an intermediate valve.
- jugal area (P)**—the relatively narrow dorsal (median) area of intermediate (and some posterior) valves adjacent to the jugum, in some chitons sculptured differently from the rest of the tegmentum (= dorsal area; “jugum” is also used sometimes in this sense).
- jugal sinus (P)**—an anterior embayment between the two sutural laminae of one intermediate or posterior valve (= sutural sinus, anterior sinus).
- jugum (P)**—the longitudinal median dorsal ridge of intermediate (and some posterior) valves; when present, may be rounded or sharply angled, and may be differently sculptured from the rest of the tegmentum (also commonly used in the sense of jugal area).
- labial teeth (G)**—in Cyraeacea and Lamellariacea (“cowries”), the narrow, closely spaced, transverse ridges on the interior margin of the outer lip.
- labral teeth (G)**—in Cyraeacea and Lamellariacea (“cowries”), sometimes used of the narrow, closely spaced, transverse ridges on the columellar lip (“columellar teeth” is less likely to be confused with “labial teeth”).
- lachrymiform (G)**—tear-drop shaped, e.g., the aperture shape of bullomorph opisthobranch shells.
- lamella**—a thin plate (eg., a thin hinge tooth, in bivalves) or a thin, well raised sculptural ridge; commonly used of narrow commarginal sculpture in bivalves, and of narrow axial sculpture in gastropods, eg., *Trophon*.
- last whorl (G)**—in coiled shells, the last-formed (distal) whorl or volution (preferred here to the inaccurate term “body whorl”, previously used in this sense).
- lateral area (P)**—part of the dorsal surface (one on each side) of the tegmentum of intermediate and some posterior (tail) valves, triangular in shape, lying between the more anterior pleural (central) area and the posterior margin, subdivided into two by the jugum, radially sculptured in most chitons, marked off from the pleural area by a diagonal ridge and by a different direction of sculpture (which is longitudinal on pleural areas of most chitons).
- lateral lobe (N)**—an adapical (abapertural) inflection, curve or undulation of the suture line, showing on whorl sides (between any possible ventral and dorsal lobes).
- lateral saddle (N)**—an adapertural (abapical) inflection, curve or undulation of the suture line on whorl sides, ie., curved in the opposite direction to a lateral lobe (both a lateral lobe and a lateral saddle are present in the suture line of the most common Cenozoic nautiloid, *Aturia*).
- lateral tooth (B)**—a hinge tooth, commonly parallel or subparallel to the dorsal valve margin, located some distance from the beak; ie., not radiating from beneath the beak; anterior or posterior to the cardinal teeth.
- lateropleural area (P)**—of Acanthochitonidae, the undivided lateral and pleural areas (which see), sculptured similarly and so not readily distinguished as in most other chitons (although subdivided by a low diagonal ridge in some species).
- left (G)**—the side of the shell closest to the left side of the extruded head-foot of the moving animal; the left side of the shell in conventional orientation, with spire upward and aperture facing the observer.
- left valve (B)**—the valve lying on the left when the shell is oriented with the anterior facing away from the observer, the plane of the commissure vertical, and the hinge uppermost; of Pectinacea, the valve *without* the byssal notch; of oysters, the attached (lower) valve.
- length (B, S)**—of bivalves, the distance between the anterior and posterior extremities of the shell, parallel to the plane of the commissure; of scaphopods, the shortest distance between the apex and the aperture.
- ligament (B)**—an elastic horny structure or structures joining the two valves of one shell dorsally, acting as a spring to open the valves when the adductor muscles relax; in many taxa, subdivided into the internal ligament (= resilium) and external ligament.
- ligamental groove (B)**—a narrow, usually antero-posteriorly elongate groove in the cardinal area, in which the ligament is attached; shallowly chevron-shaped in many taxa (= chevron groove).
- ligamental nymph (B)**—a ridge below the attachment groove of the external ligament in some bivalves in which the ligament is posterior to the beak, especially in heterodonts; particularly thick, long, high, and square-ended in many Cardiidae.
- ligamental pit (B)**—a relatively broad depression in the hinge or cardinal area for the attachment of the ligament.
- linguliform (G)**—tongue-shaped.
- lira (G)**—a very low, narrow, raised ridge on the shell surface or within the outer lip.
- lithodesma (B)**—a small calcareous plate reinforcing the internal ligament in some genera, usually edentulous (ie., in Anomalodesmata).
- lobe (N)**—of the suture line, any inflection, curve or undulation with its apex directed adapically (abaperturally) (see saddle).
- longitudinal (S)**—parallel to the long axis of the shell. Many Dentaliidae have longitudinal sculpture of costae or costellae that extend the length of the shell, but in others the longitudinal sculpture extends only a short distance from the apex.
- lunule (B)**—a depression or distinctively sculptured area anterior to the beaks in many bivalves, commonly cordate (heart-shaped) in an articulated shell.
- mamillate (G)**—of protoconchs, nipple-shaped, ie., with a pointed apex, weakly inflated whorls, and a very weakly impressed suture.
- mantle**—the integument surrounding the visceral mass of all molluscs, and secreting the shell.

- mesoplax (B)**—a transversely elongated accessory plate lying across the umbonal region of some Pholadidae.
- metaplax (B)**—a long narrow accessory plate covering the postero-dorsal gape in some Pholadidae.
- mid-fasciolar band (G)**—see fasciolar bands.
- mucro (P)**—on some posterior (tail) valves, a projecting point at the posterior end of the jugum, at the junction of the diagonal ridges separating the pleural and posterior areas, varying greatly from taxon to taxon in position and prominence; on some intermediate valves, a posterior point projecting beyond the valve margin at the end of the jugum.
- mucronate (P)**—bearing a mucro.
- multispiral (G)**—of protoconchs, with relatively numerous whorls.
- multivincular (B)**—of hinges, having several to many ligamental pits or grooves.
- muscle scar (B)**—an impression (or raised area, less commonly) on the interior of the shell where a muscle was formerly attached.
- myophoric ridge (B)**—a ridge on the valve interior, formed as the growth track of an elevated adductor muscle scar (eg., common in Glycymerididae and Arcidae).
- myostracum (B)**—the areas of the shell secreted at the attachments of the adductor muscles.
- mytiliform (B)**—shaped as in *Mytilus*, with an anteriorly terminal umbo.
- nacreous**—“pearly”; shell structure consisting of thin leaves of aragonite parallel to the inner surface of the shell, exhibiting a characteristic pearly lustre.
- naticiform (G)**—shaped as in *Natica*; with a low spire, capacious last whorl, and no siphonal canal or notch.
- neck (G)**—the distal (lower, abapical, anterior) part of siphonostomatous shells, beginning where the outline of the left side changes from convex to concave.
- nepioconch (B)**—an early-formed part of the dissoconch, separated from the later part by a pronounced discontinuity.
- nucleus (G)**—the first whorl of the protoconch (not recommended); the earliest-formed part of the shell (outdated, = protoconch); the subcentral, marginal or terminal, earliest-formed point of the operculum.
- nymph (B)**—see ligamental nymph.
- oblique (B)**—most elongate (extended) in neither the antero-posterior nor the dorso-ventral directions, but intermediate to these.
- oblique sculpture (B)**—external sculpture crossing the expected directions of commarginal and radial sculpture, and terminating at an angle to the valve margin (oblique sculpture may also divaricate, as in *Divaricella* and *Solecurtus*).
- operculum (G)**—a calcareous or conchiolin structure on the dorsal surface of the foot, wholly or partly closing the aperture when the animal is retracted.
- opisthocline (G)**—of sculpture or of outer lip, inclined forwards from the upper suture. Less common than prosocline or orthocline (opposite: prosocline).
- opisthocyrt (G)**—of sculpture or of outer lip, arched (curved) with the apex of the arch directed backwards (abaperturally) (opposite: prosocyrt).
- opisthodontic (B)**—of the external ligament, posterior to the beak.
- opisthogyrus (B)**—of the beaks, curved or pointing towards the posterior (normal in Nuculacea, but uncommon in other bivalves) (opposite: prosogyrous).
- ornament**—sculpture; the relief pattern on the surface of many shells.
- orthocline (G)**—of sculpture or of outer lip, at right angles to the sutures (see opisthocline, prosocline).
- orthogyrous (B)**—of beaks, straight, ie., pointing directly at the opposite beak (see opisthogyrus, prosogyrous).
- orthostrophic (G)**—coiled in the normal manner; not heterostrophic.
- outer lip (G)**—the abaxial (right) margin of the aperture, from the suture to the base of the columella, or to the base of the siphonal canal in siphonostomatous taxa.
- pagodiform (G)**—shaped like a pagoda, i.e., with a tall, strongly stepped (or gradate) spire.
- pallet (B)**—in Teredinidae, a small calcareous siphonal structure (two in each living animal) closing the boring when the siphons are retracted.
- pallial line (B)**—a line or narrow band on the interior of the valve, usually near and parallel to the margin, marking the line of attachment of the mantle.
- pallial sinus (B)**—an embayment in the pallial line to accommodate the siphons.
- parietal callus (G)**—in Olividae Ancillinae, a callus (inductura) on the parietal lip, with a clearly defined abapertural (left) margin, confluent posteriorly with the spire callus.
- parietal callus pad (G)**—in some Turridae, a parietal tubercle swollen and extended to form the adaxial edge of the marked anal sinus.
- parietal region (G)**—the basal surface of the previous whorl (“paries” = wall), protruding into the aperture at the upper left (in conventional orientation, with spire up and aperture facing the observer), forming a marked swelling above the columellar lip.
- parietal ridge (G)**—a spiral ridge on the upper parietal region, in most neogastropods and higher mesogastropods margining a posterior (anal) sinus or shallow canal at the top (adapical end) of the aperture.
- parietal tubercle (G)**—a short, rounded, prominent parietal ridge; very prominent and of taxonomic significance where it is raised into the parietal callus pad of some Turridae.
- patelliform (G)**—limpet-shaped, ie., a very short, uncoiled, widely open cone.
- paucispiral (G)**—of protoconchs, with relatively few whorls.
- pedal**—relating to the foot.
- pedal gape (B)**—an opening between the margins of the two valves of a closed, articulated shell, for passage of the foot (common in deep-burrowing taxa).
- pedal retractor muscle (B)**—a muscle serving to withdraw

- the foot, commonly leaving a marked (although small) scar near (usually above) the anterior adductor muscle scar. (A pedal protractor muscle scar is present less commonly).
- peribasal (G)—of a cord, or angulation; a spiral sculptural element extending around the edge of the base; eg., in Turbinellidae Columbariinae, a marked cord or angulation appearing out of the suture of the previous whorl.
- periostracum—the conchiolin outer layer of molluscan shells, upon which the calcareous layers are deposited; commonly a thin brown, yellow or greenish sheet, peeling easily from dry, empty shells, but thick, prominent and pilose (“hairy”) or lamellose in some gastropods (particularly Ranellidae).
- periphery (G)—the outermost (widest) part of the gastropod shell; the angled or rounded zone around the last whorl, determining the diameter.
- peristome (G,N)—the lips of the aperture; in gastropods, commonly used in Muricidae for a continuous, raised (usually reflected) apertural rim.
- phragmocone (N)—the chambered (camerate) part of the shell.
- plait (G)—a fold or plica on the columella aiding attachment of the columellar muscle.
- planispiral (G)—coiled in a flat plane, i.e., with a slightly sunken spire, equal to the umbilicus.
- pleural area (P)—the lateral slopes of the tegmentum, not including the jugal area and lateral areas, on intermediate valves and some posterior valves; commonly longitudinally sculptured, and marked off from the lateral areas by a diagonal ridge, as well as by a sculptural difference (also known as the central area which, however, is too easily confused with the jugal area, and should not be used).
- plica (G)—(1) a fold or plait on the columella, aiding attachment of the columellar muscle; (2) a prominent axial costa, or fold, affecting the whole thickness of the shell wall.
- posterior—opposite to the direction in which the living animal moves.
- posterior area (B,P)—in bivalves, a posterior part of the shell marked off from the rest in some way, usually either by an umbonal-ventral ridge, or by having distinctive sculpture (eg., in Cardiidae); in chitons, the area around the posterior end of the tegmentum of the posterior (tail) valve, where present sculptured as on the lateral areas of intermediate valves and the anterior area of the anterior (head) valve.
- posterior lateral tooth (B)—a lateral tooth behind the beak.
- posterior ridge (B)—an umbonal-ventral ridge marking off a posterior area.
- posterior siphonal groove (G)—in Olividae Ancillinae, a shallow groove in the spire callus extending adapically from the adapical end of the aperture.
- posterior siphonal tube (B)—in Clavagellidae, the secondary shelly tube extending posteriorly from the sac, enclosing the siphons.
- posterior valve (P)—the tail valve; the posteriormost (eighth) valve or plate of a chiton shell; commonly approximately semicircular, but variously modified in some taxa.
- posterodorsal margin (B)—that part of the dorsal margin of the valve lying behind the beak.
- prismatic (B)—a shell structure consisting of small calcitic prisms, breaking into fibrous rods perpendicular to the valve surface; the normal shell structure in the outer layer of the Pterioidea, and this layer is therefore very fragile and commonly not preserved in Cenozoic fossils.
- prodissoconch (B)—the embryonic shell of bivalves.
- prosocline (G)—of sculpture or of outer lip, inclined backwards from the upper suture (opposite: opisthocline).
- prosocyrt (G)—of sculpture or of outer lip, arched (curved) with the apex of the arch directed forwards (adaperturally) (opposite: opisthocyrt).
- prosodetic (B)—of the external ligament, anterior to the beak.
- prosogyrous (B)—of the beaks, curved (or pointing) towards the anterior, the condition in most bivalves other than Nuculacea (opposite: opisthogyrous).
- protoconch (G)—the embryonic shell of gastropods (also of shelled cephalopods); in gastropods, the rest of the shell (the post-embryonic shell) is termed the teleoconch.
- protoplax (B)—a flat, spearhead-shaped accessory plate (divided longitudinally into two in some taxa) covering the anterodorsal margin in most Pholadidae; protects the anterior adductor muscle, which is external and attached to the strongly reflected anterodorsal valve margins in Pholadidae.
- provinculum (B)—in Pectinacea, a narrow, vertically striated area on either side of the ligamental pit; also used for the central area of the larval hinge in other bivalves.
- proximal—the first-formed part of the shell.
- pseudumbilicus (G)—a depression or cavity in the base of the last whorl only, commonly a shallow groove alongside the columellar lip or siphonal canal; as distinct from a true umbilicus, which affects all (or most) whorls. Commonly called a “false umbilicus”.
- punctate—sculpture of shallow pits, as in many shelled bullomorph opisthobranchs, and in some species of the bivalve genus *Melliteryx*.
- punctum—a shallow pit (plural: punctae).
- pupiform (G)—shaped as in *Pupa*, i.e., with tall spire, convex outlines, and a blunt, rounded apex.
- pyriform (G)—pear-shaped.
- Quenstedt muscle (B)—a small muscle of unknown function represented by a scar below the ligament in oysters.
- radial (B)—of sculpture, radiating from the umbonal area towards the ventral margin.
- radial aperture (G)—an aperture which is coplanar with the coiling axis, i.e., perpendicular to the direction of coiling. Uncommon in Cenozoic or extant molluscs,

- other than in Architectonicidae where it is ubiquitous (see tangential aperture).
- radula (G,N,P,S)—the tooth-like or (collectively) rasp-like, hardened, chitinous structures with which molluscs (other than bivalves) rasp, pierce, grasp, bite, gather, or “sting” (in *Conus*) their food; the radular teeth are attached to a flexible membrane on the floor of the buccal cavity. In gastropods, the number and shape of the radular teeth is of primary importance in classification.
- ramp (G)—see sutural ramp.
- recurved (G)—of the siphonal canal, with the distal end bent away from the observer, in conventional spire-up, aperture-facing orientation.
- resilial (B)—pertaining to the resilium.
- resilifer (B)—a pit or hollow in the hinge bearing the internal ligament (or resilium); if protruding below the hinge plate, it is known as a chondrophore.
- resilium (B)—the internal ligament.
- reticulate (G)—net-like sculpture produced by the intersection of spiral and prosocline or opisthocline elements, i.e., not at right angles to each other (cf. clathrate sculpture, in which the elements intersect at right angles).
- right (G)—opposite of left (which see).
- right valve (B)—the valve lying on the right when the shell is oriented with the anterior end facing away from the observer, the plane of the commissure vertical, and the hinge uppermost; of Pectinacea, the valve *with* the byssal notch and fasciole; of oysters, the free (upper) valve.
- rostrate (B)—with a pointed, beak-like extremity (usually the posterior end, reflecting elongate siphons).
- sac (B)—in Clavagellidae, the subspherical to irregular, inflated anterior region of the secondary shell enclosing the visceral mass and incorporating the shell valves (or, in some taxa, having one or both valves enclosed inside); the anterior tubules permit passage of water through the anterior end of the sac, and the posterior siphonal tube protects the siphons as they extend behind the sac.
- saddle (N)—of the suture line, any inflection, curve or undulation with its apex directed adaperturally (abapically).
- scales (P)—small, flattened, calcareous structures ornamenting the girdle of many living chitons.
- sculpture—ornament; the relief pattern on the surface of many shells.
- selenizone (G)—a spiral band of crescentic growth lines or threads, formed as the trace of a narrow notch or slit in the outer lip that allows passage of the anal current in Pleurotomariacea and related primitive gastropods.
- septum (B,G,N)—in nautiloids, a partition dividing the phragmocone into chambers (camerae) and attached to the inside of the wall of the shell, perforated by the siphuncle (plural, septa); when the shell is removed, the junction of septa with the shell wall forms the suture lines. In gastropods, unperforated septa are formed near the apex of some tall-spined taxa to close off the shell after (or to allow for future) damage to the apical area. In bivalves, unperforated septa are formed by some Teredinidae to close off portions of the secondary shell tube.
- shagreen microsculpture (B)—in Pectinacea, fine external sculpture of a screenlike or rasplike pattern of intersecting raised lamellae; the lamellae are neither radial nor strictly commarginal, but intersect diagonally at a low angle. Sometimes forms small, closely spaced, ventrally hollow scales.
- shelf (G)—a horizontal sutural ramp.
- shoulder (G)—an angulation near or above mid-height on the whorls, delimiting the sutural ramp (formerly used also for the ramp).
- sinistral (G)—the opposite of dextral.
- sinupalliate (B)—having a pallial sinus (see integripalliate).
- sinus (G)—any embayment in the outer lip, forming a corresponding undulation in growth lines; commonly used for the anal sinus of Turridae, but similar (if shallower) posterior sinuses occur in many other neogastropods, and a shallow, more anterior one (the stromboid notch) occurs also in some taxa (again, mainly Turridae).
- siphon (B,G)—in bivalves, a tubelike extension of the mantle to allow passage of the exhalent and/or inhalent currents (commonly two in each individual, but they are fused in some taxa); in gastropods, a tubular or semitubular fold in the mantle of neogastropods and higher mesogastropods, for passage of the inhalent water current; taxa with a siphon are recognisable by having an anterior siphonal canal in the shell (a short posterior or anal siphon is present in a few gastropods, notably Bursidae).
- siphonal canal (G)—a semitubular (less commonly tubular) or spout-like extension of the abapical (anterior) area of the aperture, to enclose the siphon; gastropods having one can be described as siphonostomatous.
- siphonal notch (G)—a notch in the abapical (anterior) apertural margin to accommodate the siphon; commonly at the abapical end of the siphonal canal (but some taxa have a notch, but no canal); generates the fasciole.
- siphonoplax (B)—a tubular secondary calcareous or conchiolin structure forming a posterior extension of the shell in most Pholadidae; protects the siphons.
- siphonostomatous (G)—having a siphonal canal.
- siphuncle (N)—a long, slender tube extending through all chambers (camerae) of the phragmocone to the protoconch, consisting of soft and shelly portions, perforating the septa, and allowing access to the chambers for gaseous exchange (so forming, with the chambers, a flotation mechanism).
- slit (G,P,S)—of gastropods, a narrow, parallel-sided slot in the outer lip of some archaegastropods (in the Pleurotomariidae and Scissurellidae, among Cenozoic-Recent taxa), in some taxa extending abaperturally for a quarter whorl or more; its track on the whorl surface

- is the selenizone (which see). In chitons, a marginal slit in the insertion plate, subdividing it into teeth; commonly several (five to eight or more) in the terminal valves and one in each side of each intermediate valve, but many more in some taxa. Of scaphopods, a narrow slit in the shell margin at the apical end, quite deep and prominent in some taxa (eg., *Fissidentalium*).
- socket (B)—a groove in the hinge, accepting a matching tooth in the hinge of the opposite valve.
- spicules (P)—long, narrow, spine-like, siliceous, calcareous or conchiolin structures ornamenting the girdle of some chitons; siliceous ones are almost ubiquitous in Acanthochitonidae.
- spiral (G)—of sculpture, passing continuously around the outer surface of the whorls, almost parallel to the suture (also used loosely for “a spiral cord”, but to be avoided).
- spiral cord (G)—a raised sculptural element following a spiral course, ie., almost parallel to the suture (finer elements are spiral thread, spiral lira, etc.).
- spire angle (G)—the angle between the outer edges (periphery) of the whorls, in the plane of the coiling axis.
- spire callus (G)—in Olividae Ancillinae, the (commonly thick) smooth or spirally grooved callus covering the spire and, in many taxa, hiding the sutures and protoconch; commonly confluent with the parietal callus.
- spout (G)—a rudimentary siphonal canal.
- stria—a very narrow, shallow groove.
- strombiform (G)—shaped as in *Strombus*, ie., roughly biconic-fusiform, but with an expanded outer lip.
- stromboid notch (G)—in Turridae, a shallow, commonly relatively wide inflection or undulation in the abapical area of the outer lip, adapical to its termination, producing a shallow notch similar to that allowing passage of the right optical tentacle in *Strombus*.
- subsutural (G)—immediately abapical to (below) the suture; commonly used of a spiral raised cord, the subsutural fold.
- subsutural fold (G)—a low to prominent spiral swelling immediately abapical to (below) the suture, ie., around the top of the sutural ramp (commonly present in Turridae).
- subulate (G)—awl-shaped; slender and tapering to a point, with convex outlines.
- suprasutural (G)—immediately adapical to (above) the suture; commonly used of spiral sculptural elements.
- sutural lamina (P)—a thin, plate-like anterior extension of the articulamentum (one present on each side of the anterior margin of valves 2-8) underlying the posterior margin of the immediately anterior valve, embedded in the girdle, and allowing enrolling of the animal (the two sutural laminae of one valve are separated by the jugal sinus).
- sutural ramp (G)—an outward-sloping, flattened or weakly concave to convex spiral surface area immediately abapical to (below) the suture of many gastropods, delimited by the shoulder angle.
- suture (G,N)—of gastropods, the continuous spiral line on the shell surface where the whorls join; of nautiloids, the line where a septum joins the outer shell wall. Although a coiled gastropod shell has only one suture, for purposes of description a distinction is made between the upper and lower sutures of one whorl.
- taeniod muscle (B)—in Parilimyidae (Anomalodesmata), a single long, narrow tape-like muscle in each valve, retracting the siphons, and forming a single small subcentral scar in each valve (important for distinguishing Parilimyidae from Pholadomyidae).
- tail valve (P)—the posterior valve.
- tangential aperture (G)—one which is oblique to the coiling axis and tangential to the surface of the last whorl; the normal condition in Cenozoic and living gastropods (contrast “radial aperture”).
- taxodont (B)—with numerous short, similar hinge teeth, some or all of them transverse to the hinge margin.
- teeth (B,P)—of bivalves, hinge structures (received in corresponding sockets in the opposite valve) along the dorsal margin of the valve (see also hinge teeth); of chitons, the segments of insertion plates between the slits; of all molluscs except bivalves (which lack a radula) used also for individual radular elements.
- tegmen (P)—the outer, porous, sculptured layer of chiton valves; the part of chiton valves exposed outside the girdle of the living animal.
- teleoconch (G)—the post-larval gastropod shell, ie., the shell excluding the protoconch.
- telescoped (G)—in Turritellidae, a whorl profile in which a wide, prominent, rounded zone below the upper suture is the most prominent sculptural feature, and whorls are flat-sided below that; ie., looking as though each whorl has been pushed inside the one below.
- terminal pipe (S)—a short, narrow tube protruding from the apex of some scaphopods.
- terminal ridge (G)—in Cypraea and Lamellariacea (“cowries”), a low, narrow, slightly oblique ridge at the base (anterior end) of the inner lip.
- tessellate (B, G)—sculpture or colour pattern of contiguous polygonal areas, resembling a tile mosaic.
- tesserae (B, G)—the tile-like, flattened, polygonal sculptural elements produced by tessellate sculpture.
- thread—a very fine, raised sculptural element.
- top fasciolar band (G)—see fasciolar bands.
- transposed hinge (B)—a condition occurring uncommonly in some “lower” heterodont families, in which the hinges are mirror images of that expected in the species, ie., the “right” hinge is found in the left valve, and vice versa.
- transverse (S)—perpendicular to the long axis of the scaphopod shell. Definite transverse sculpture is uncommon in scaphopods, but many taxa have transverse ridges, lines or constrictions formed by pauses in growth.
- trema (G)—an orifice in the outer shell wall of Haliotidae and some Scissurellidae, for passage of the exhalent water current (plural, tremata).

trigonal—three-cornered (roughly triangular), commonly used of bivalve shell outlines.

trochiform (G)—shaped as in *Trochus*, ie., with a moderately tall, flat-sided spire and a flat, or nearly flat, base.

truncate—with the curvature of the outline terminated by a straight line (eg., of the bivalve pallial sinus); or of the gastropod spire, shortened (ie., decollate).

tubercle—a moderately prominent rounded elevation on the shell surface.

turbiniiform (G)—shaped as in *Turbo*, ie., with a broadly conical spire, evenly rounded whorls, and a convex base.

turriculate (G)—with an acutely conical spire in which whorls are numerous and more-or-less flat-sided.

turrid sinus (G)—sometimes used loosely to refer to the anal sinus (or posterior (adapical) apertural sinus) characteristic of Turridae.

umbilicate (G,N)—having an umbilicus.

umbilicus (G,N)—a cavity or depression formed around the coiling axis by the adaxial faces of whorls that do not coalesce to form a solid columella; in the centre of the base in gastropods in which it is present, and one present on each side of many nautiloids.

umbo (B)—the region of the valve surrounding the point of maximum curvature, or beak; situated along the dorsal margin, and near its centre in many bivalves (umbo denotes a wider or more generalised area than the beak) (plural, umbones).

umbonal angle (B)—in Pectinacea, the angle between the anterodorsal and posterodorsal margins, below the auricles.

umbonal cavity (B)—a hollow beneath (inside) the umbo (behind the hinge plate) of many bivalves.

umbonal-ventral groove (B)—in some Pholadidae, a shallow, somewhat diagonal groove extending from the umbo to the ventral margin, separating distinctly sculptured anterior and posterior areas.

umbonal-ventral ridge (B)—any radial ridge or angulation extending from the umbo towards the ventral margin; commonly marking off a posterior area of the shell surface (also known simply as an umbonal ridge).

umboniiform (G)—shaped as in *Umbonium*, ie., with very low conic spire and weakly convex base, lenseoid in cross-section.

valve—one of the calcareous parts of a molluscan shell (one in all gastropods, cephalopods (if present at all) and scaphopods, two in bivalves, eight in chitons).

varicate (G)—bearing a varix or varices.

variceal spine (G)—a spine on a varix; common in Muricidae.

variceal tube (G)—in Muricidae Typhinae, a tubular spine on a varix (present on the shoulder angle of all varices of most taxa).

varix (G)—an elevated axial sculptural element more prominent than axial costae, and commonly more widely spaced than costae; formed as a thickened outer apertural lip, and so evidence of episodes of shell growth followed by pauses.

ventral—the direction opposite to dorsal, ie., towards the lower side (venter) of the living animal when it moves; equivalent to the apertural side in most conispiral gastropods, and to the aperture (or base) in limpets; the margin opposite the hinge in bivalves; the outer, narrow, strongly curved area of the shell wall in nautiloids.

ventral face (S)—normally the convex face of a scaphopod shell; in some species of *Cadulus* both faces are convex, but the ventral face is the more convex.

ventral lobe (N)—a lobe (see above) situated on the ventral area (the outermost, narrowly curved part of the shell) of a nautiloid.

vesicular deposits (B)—soft, chalky, cellular deposits in the otherwise more solid lamellar calcite shell, diagnostic of Gryphaeidae Pycnodonteinae.

whorl (G,N)—one complete coil of a spiral shell.

wing (B,G)—in bivalves, an area below the hinge-line demarcated from the rest of the shell surface by a ridge or hollow, or by sculptural differences, elongated anteriorly (if an anterior wing) or posteriorly, larger and commonly less clearly demarcated than an auricle (ear). In gastropods, a more-or-less flattened expansion of the outer lip (eg., in some Strombacea).

xenomorph (B,G)—pertaining to xenomorphism.

xenomorphism, xenomorphic sculpture (B,G)—sculpture on the shell surface that is not normally present in that taxon, but reflects the sculpture of other shells to which the mollusc is attached; not uncommon on the free (upper) valve of oysters and Anomiidae, in Bivalvia (notably in specimens of *Anomia* attached to Pectinidae); in gastropods, represented by sulci in the shell margin, and the prominent ribs generated by the sulci, in some Capulidae that live attached to coarsely sculptured substrates such as the shells of Pectinidae.

ILLUSTRATED GLOSSARY OF TERMS USED FOR PARTS OF MOLLUSCAN SHELLS

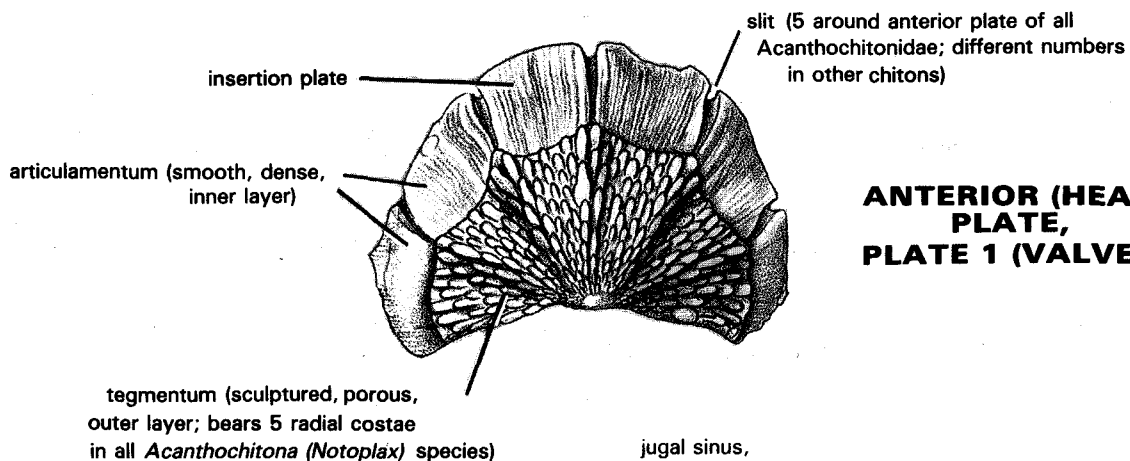
The labelled drawings on the following 13 pages (Figure 9) use specific New Zealand examples, from the plates in this book, to illustrate the specialised terms that have been developed to describe precisely and unambiguously the parts of molluscan shells.

Many of the included terms apply very widely (e.g., hinge, umbo, pallial line in Bivalvia; suture, spire, last whorl in Gastropoda) and we have identified these parts on several illustrations, to clarify their application. The description of shell shapes limited to particular families (e.g. cowry shells, Family Cypraeidae), the development of specialised notations for describing sculpture in a few families (notably the spiral cords of Turritellidae) and the description of highly specialised shells adapted to particular environments (e.g. the rock-boring Pholadidae, with the example of *Pholadidea suteri*) have necessitated the development of special terminologies, and we have included examples illustrating most of the more commonly used specialised terminologies that have been applied to New Zealand and Cenozoic Mollusca. All terms are defined more precisely in the accompanying descriptive glossary.

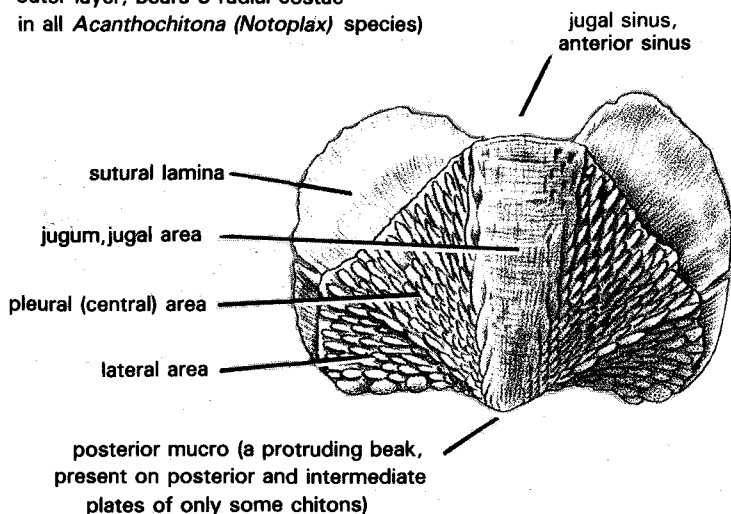
CLASS POLYPLACOPHORA

FAMILY ACANTHOCHITONIDAE : *Acanthochitona (Notoplax) mariae*, dorsal view of 3 of the 8 plates (or valves); only 1 of the 6 similar intermediate plates is shown.

ANTERIOR



ANTERIOR (HEAD) PLATE, PLATE 1 (VALVE 1)

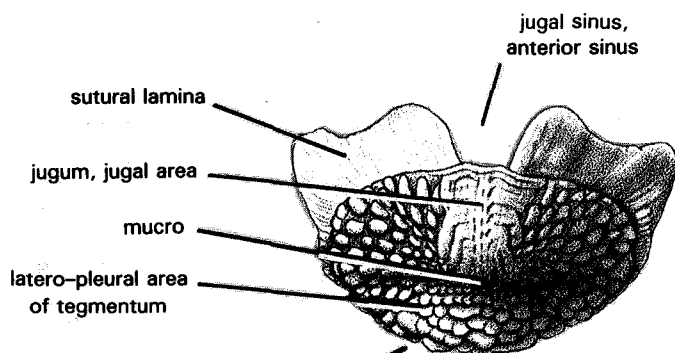


INTERMEDIATE PLATE, PLATES 2-7 (VALVES 2-7)

lateral slit (1 in each side of all intermediate plates of most chitons, but more in some groups, notably Callochitonidae)

LEFT

RIGHT



POSTERIOR (TAIL) PLATE, PLATE 8 (VALVE 8)

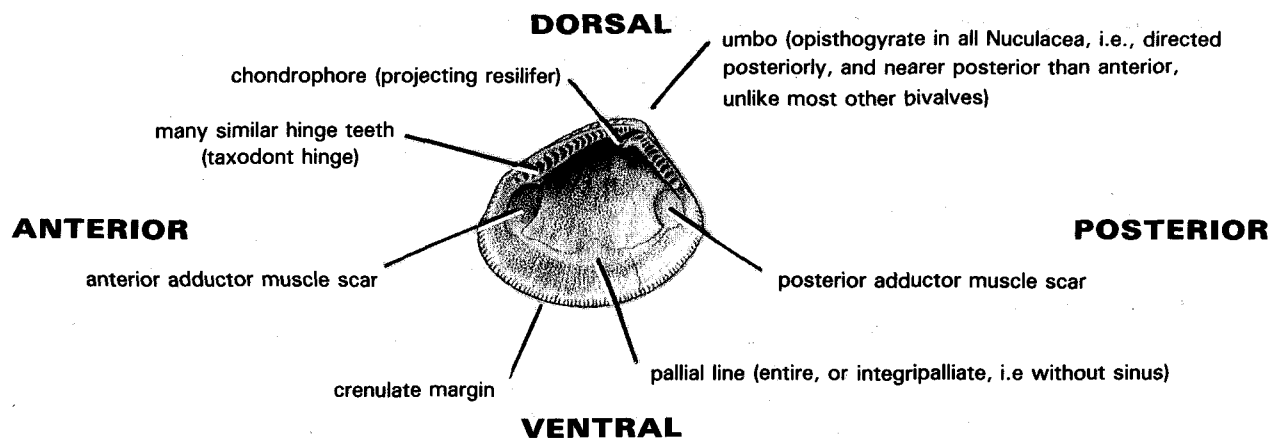
(inner margin of posterior end has several slits in most chitons, 5 in most Acanthochitonidae)

POSTERIOR

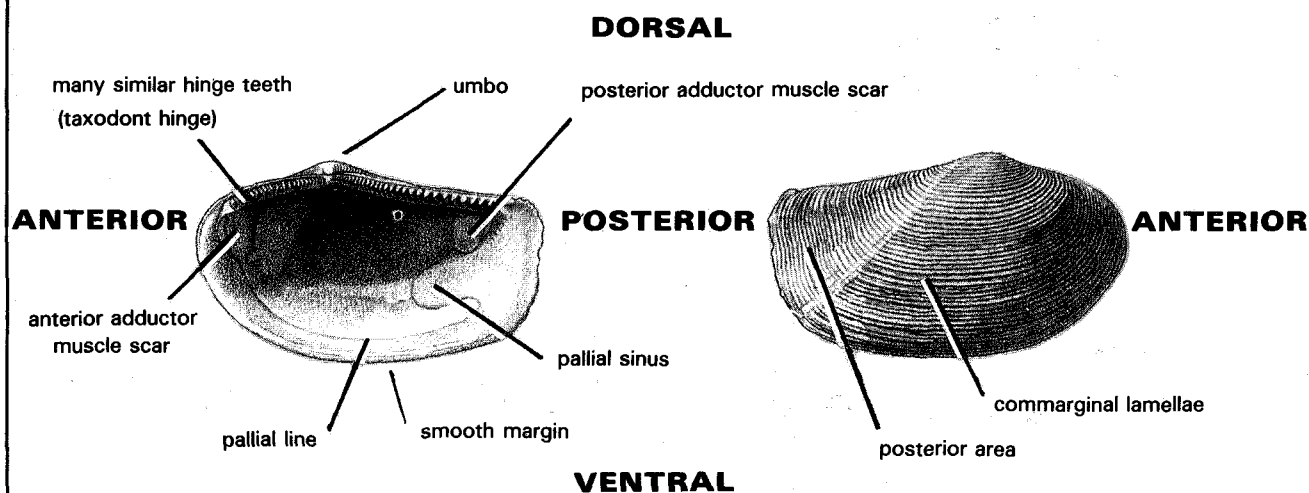
Figure 9(a-m) Illustrated glossary of the terms commonly applied to parts of molluscan shells.

CLASS BIVALVIA

FAMILY NUCULIDAE: *Varinucula sagittata*, interior of right valve



FAMILY MALLETIIDAE: *Neilo awamoana*, right valve



FAMILY GLYCYMERIDIDAE: *Glycymeris shrimptoni*, left valve

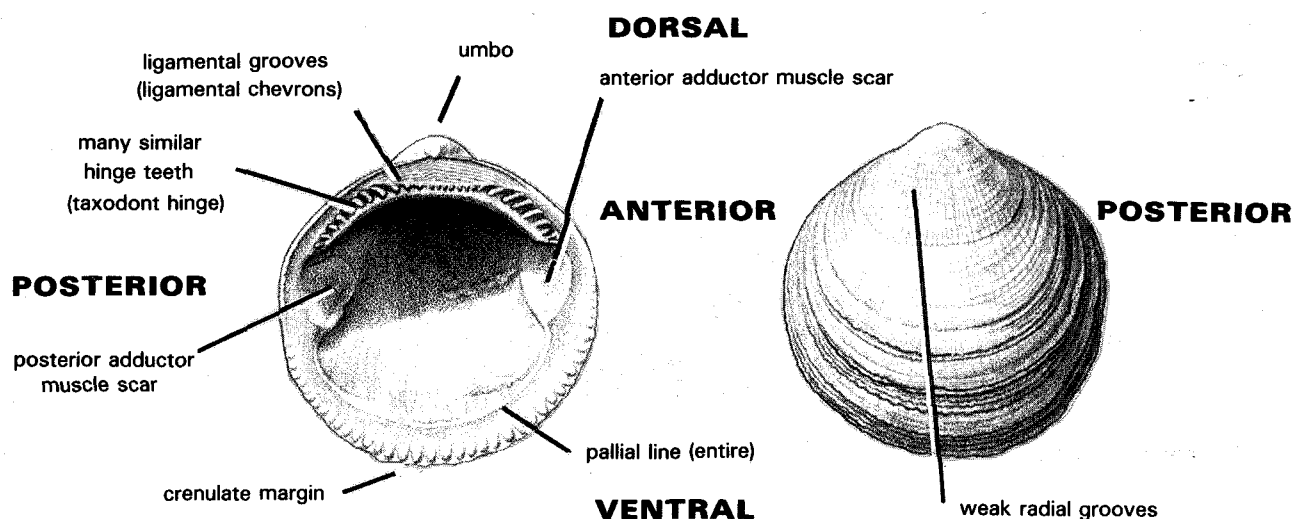
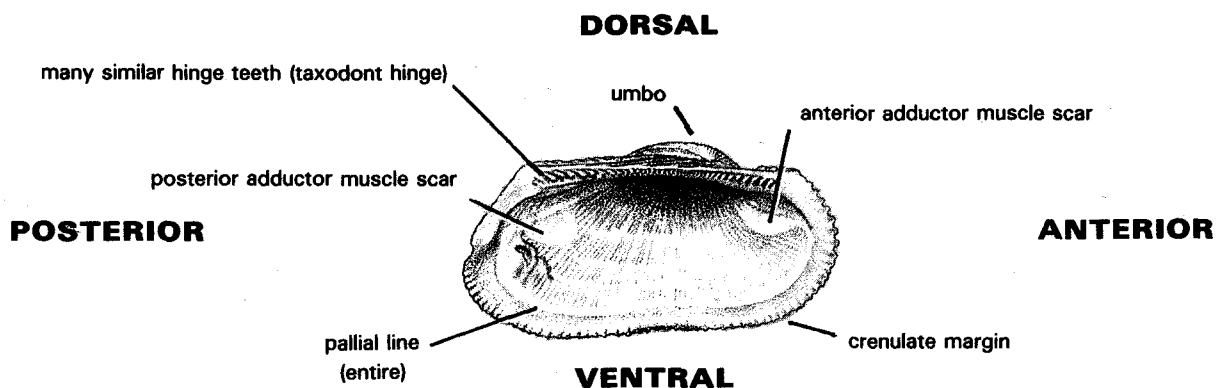
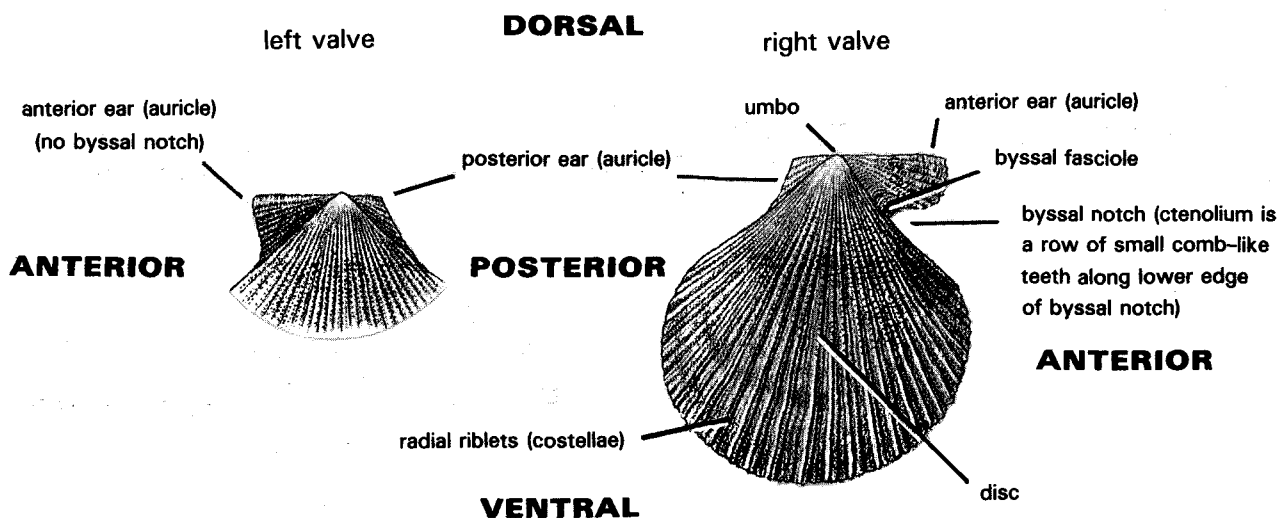


Fig. 9b

FAMILY ARCIDAE : *Barbatia novaezelandiae*, interior of left valve



FAMILY PECTINIDAE : *Chlamys gemmulata*, exterior of both valves



FAMILY ISOGNOMONIDAE (BAKEVELLIIDAE ?) : "*Isognomon*" *zealandicum*, interior of right valve

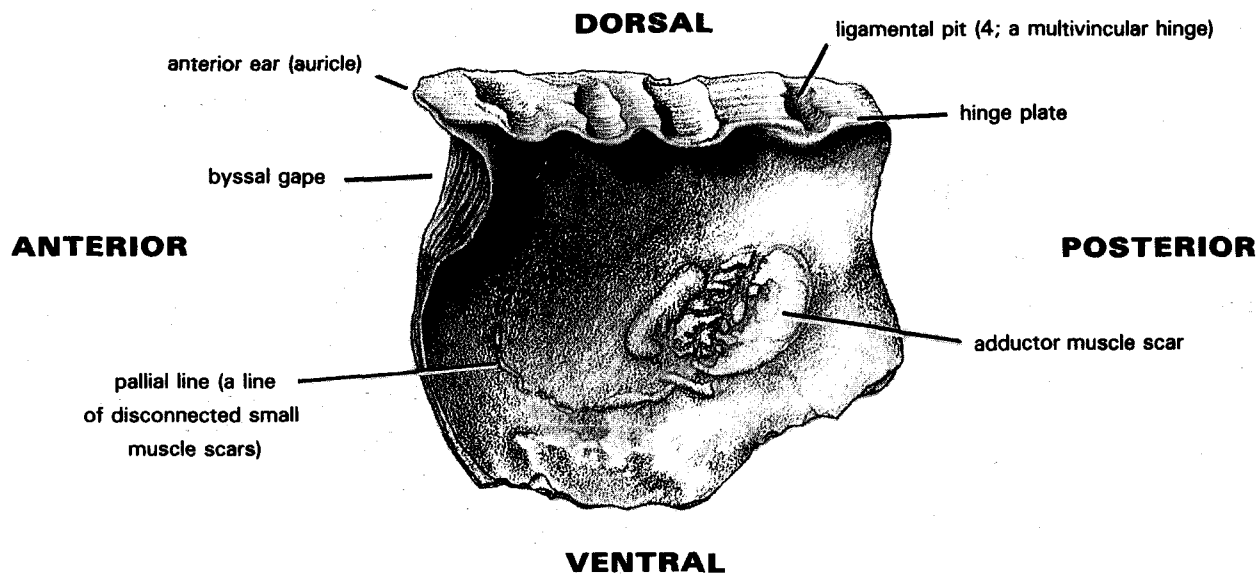


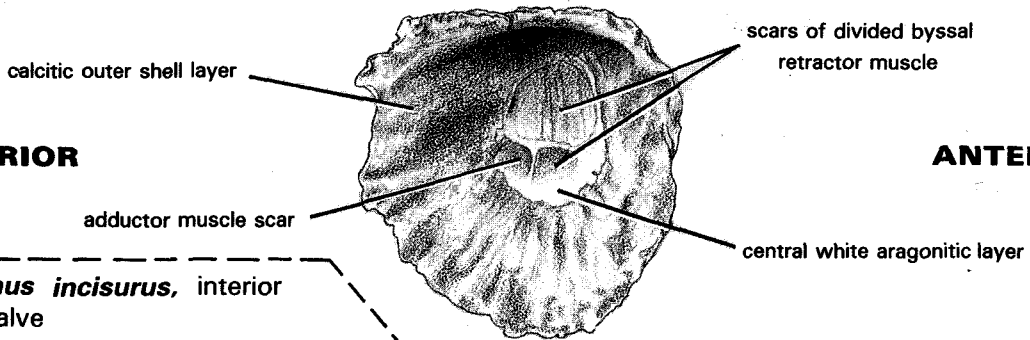
Fig. 9c

FAMILY ANOMIIDAE : *Anomia trigonopsis*, interior of left valve

DORSAL

POSTERIOR

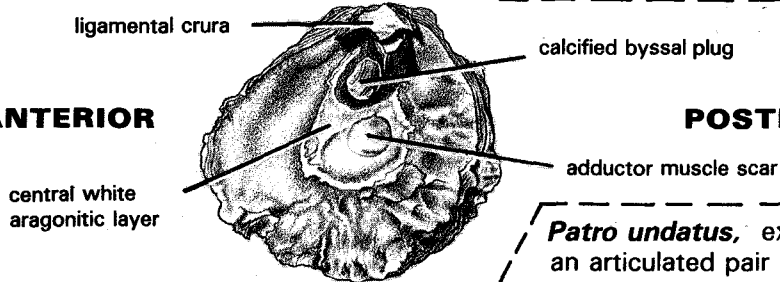
ANTERIOR



Pododesmus incisurus, interior of right valve

ANTERIOR

POSTERIOR



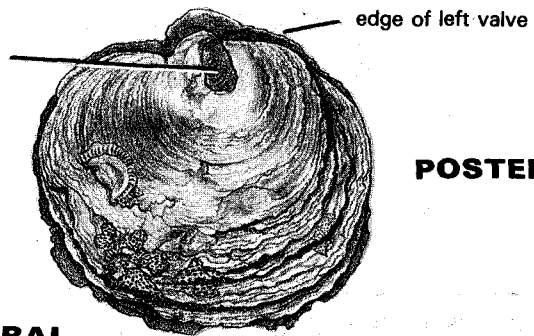
Patro undatus, exterior of right (attached) valve of an articulated pair

calcified byssal plug protruding through deep byssal notch in right valve

ANTERIOR

POSTERIOR

VENTRAL

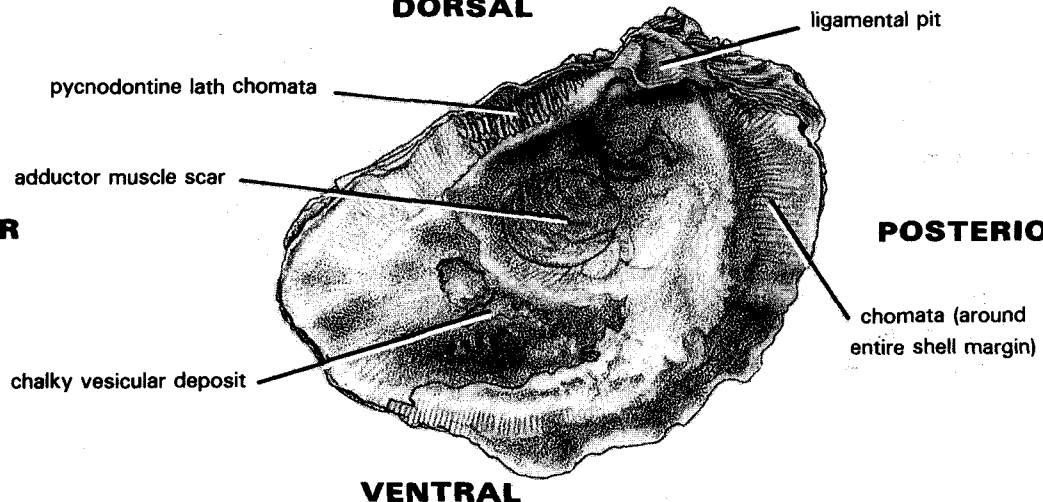


FAMILY GRYPHAEIDAE : *Crenostrea wuellerstorffi* (an "oyster"), interior of right (upper) valve

DORSAL

ANTERIOR

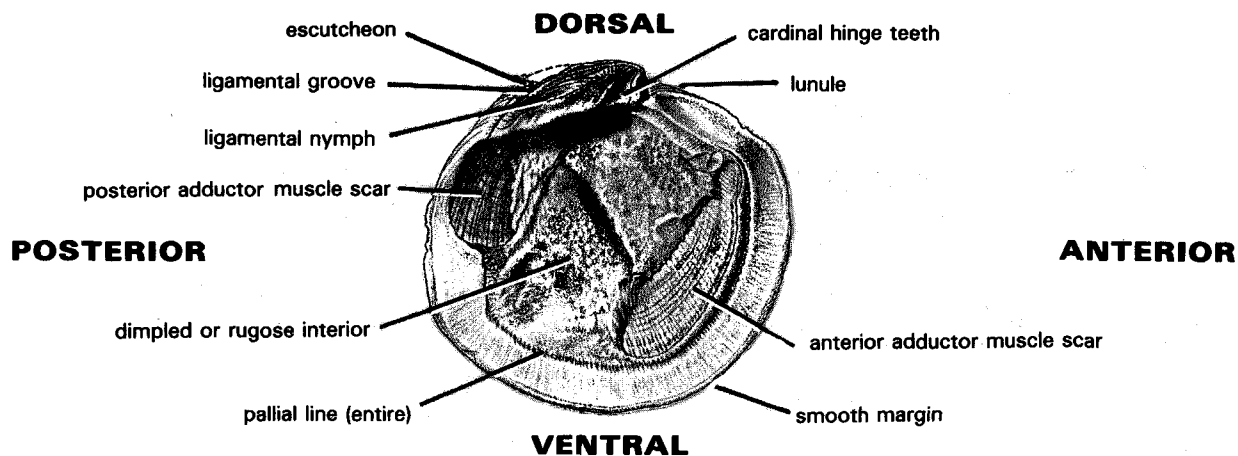
POSTERIOR



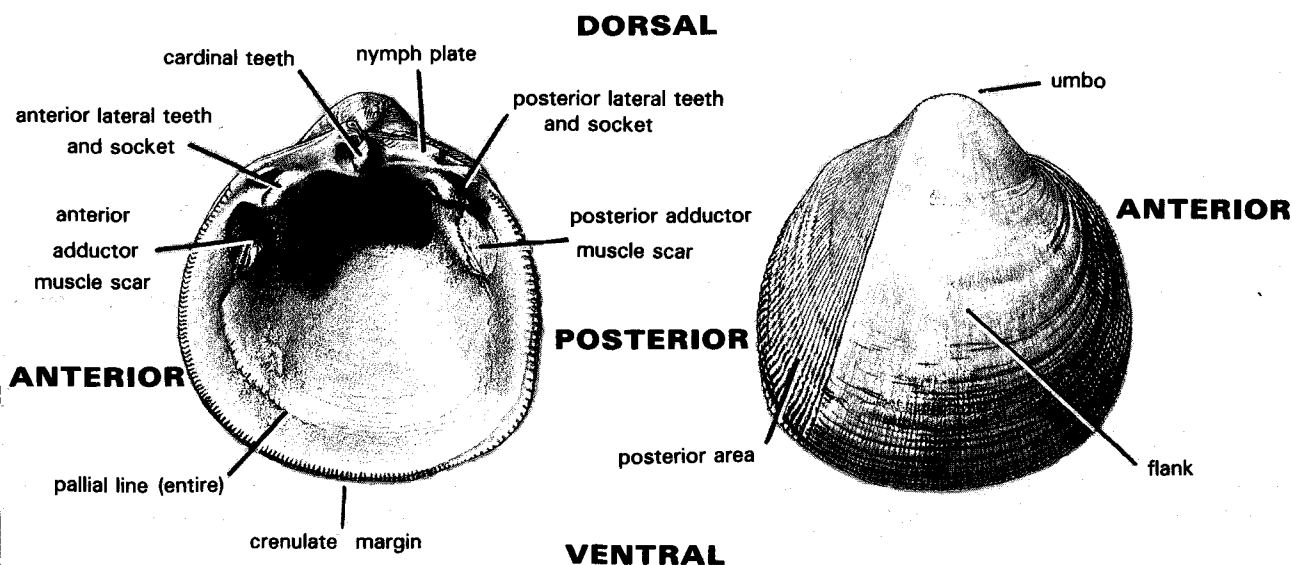
VENTRAL

Fig. 9d

FAMILY LUCINIDAE : *Miltha neozelanica*, interior of left valve



FAMILY CARDIIDAE : *Nemocardium (Varicardium) patulum*, interior and exterior of right valve



FAMILY MACTRIDAE : *Mactra (Mactrona) mula*, interior of left valve

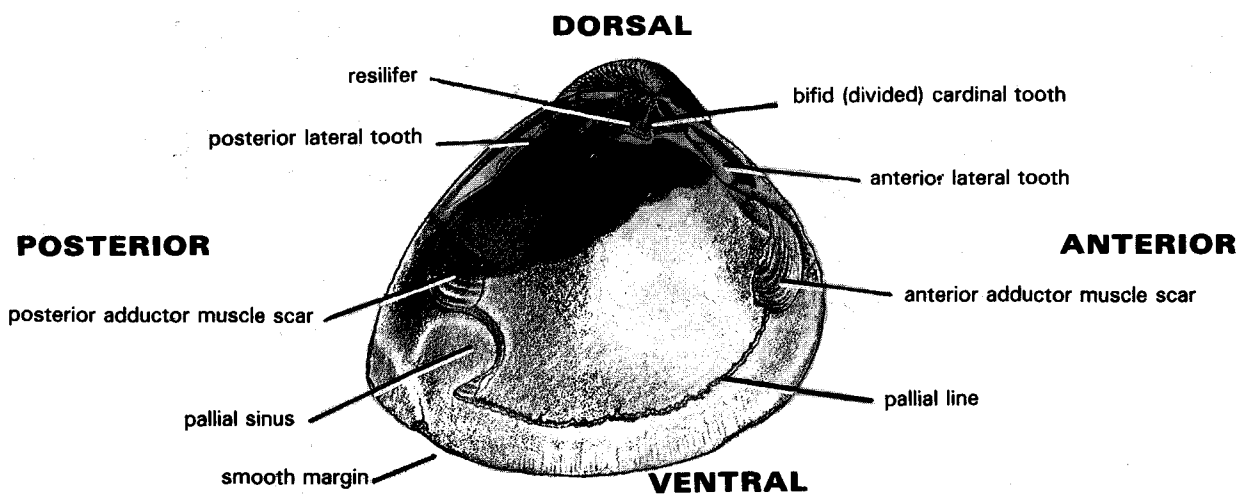
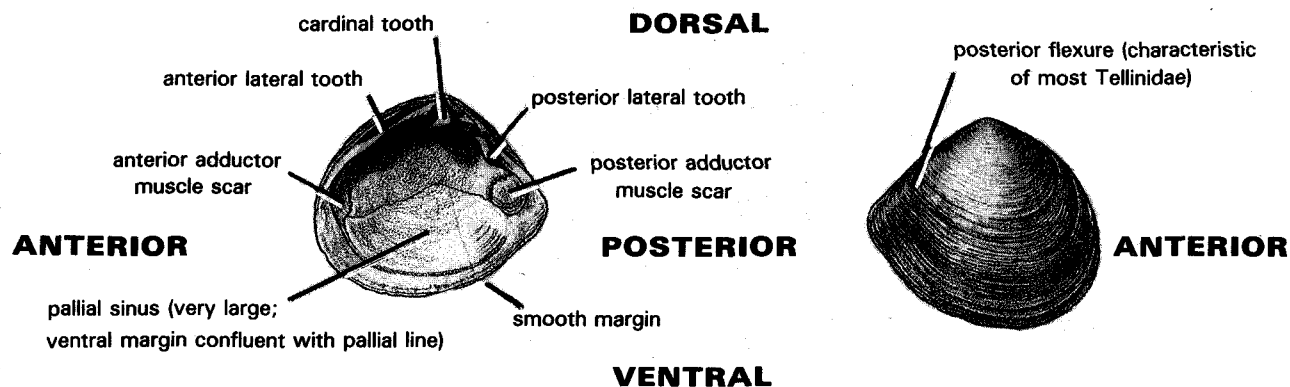
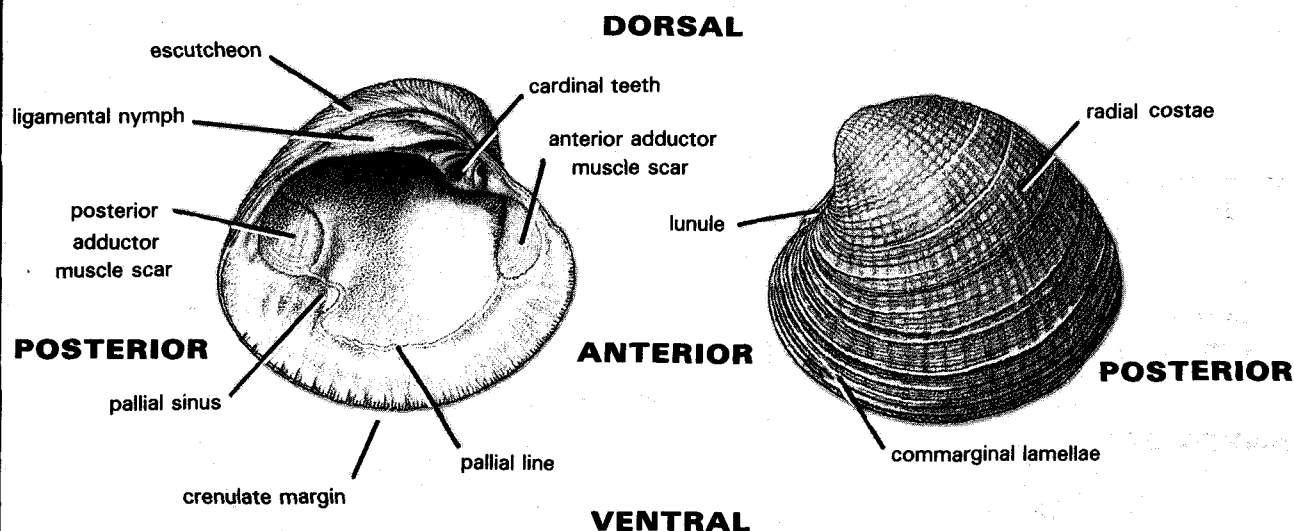


Fig. 9e

FAMILY TELLINIDAE : *Barytellina crassidens*, interior and exterior of right valve



FAMILY VENERIDAE : *Austrovenus crassitesta*, interior and exterior of left valve



FAMILY PHOLADIDAE : *Pholadidea suteri*, exterior of right valve and dorsal view of exterior of articulated shell

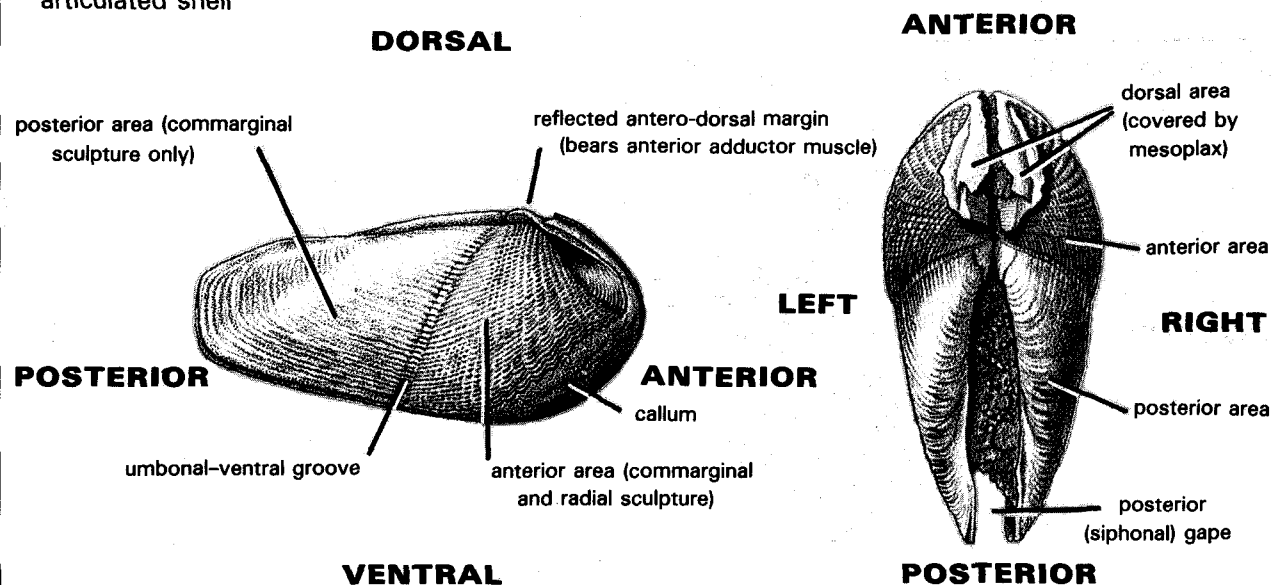
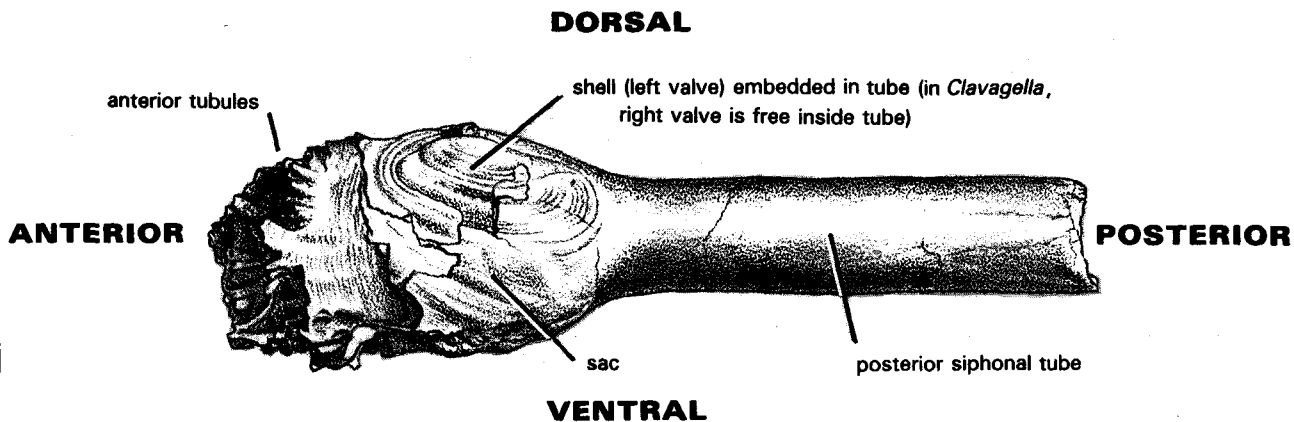


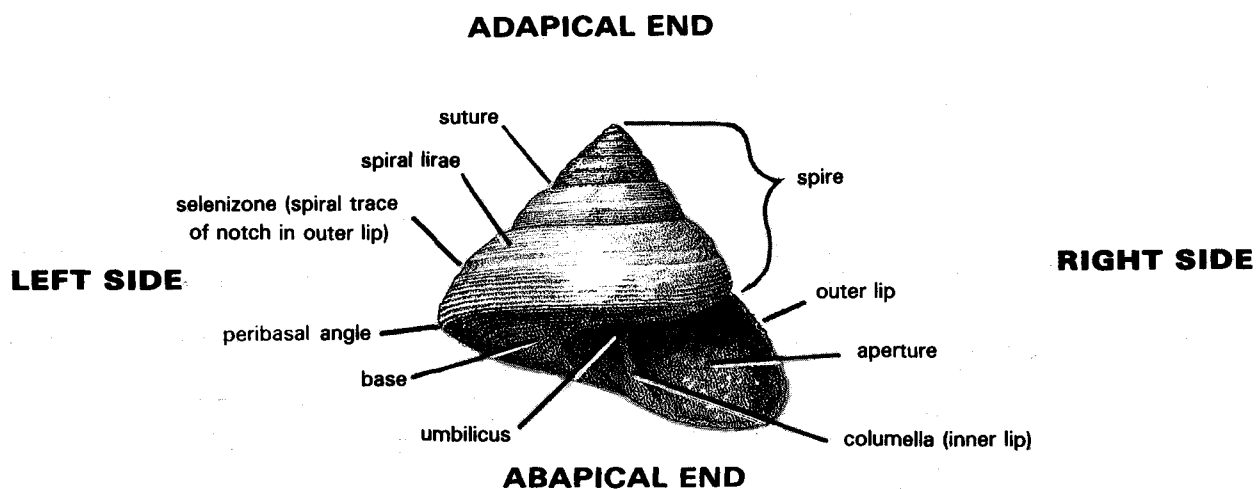
Fig. 9f

FAMILY CLAVAGELLIDAE : *Clavagella oamarutica*, exterior of left side



CLASS GASTROPODA

FAMILY PLEUROTOMARIIDAE : *Perotrochus allani*, apertural view



FAMILY HALIOTIDAE : *Haliotis* n.sp., Cookson Volcanics (Oligocene) , dorsal and left lateral views

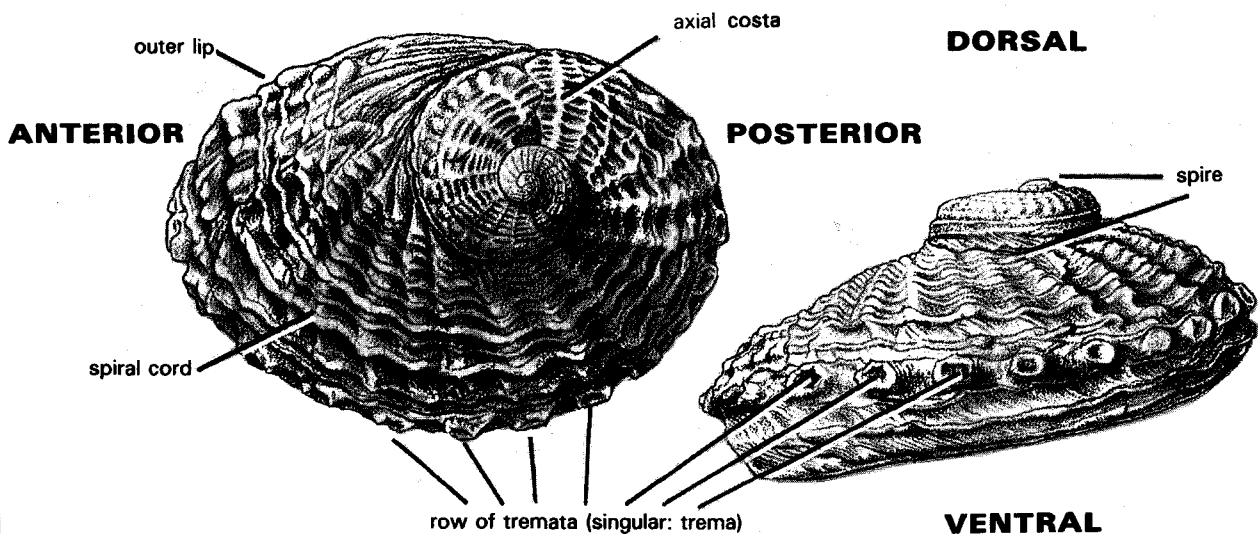
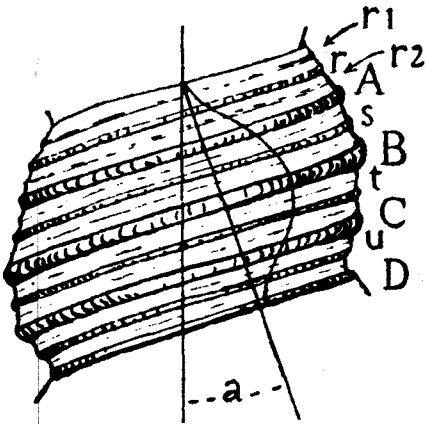
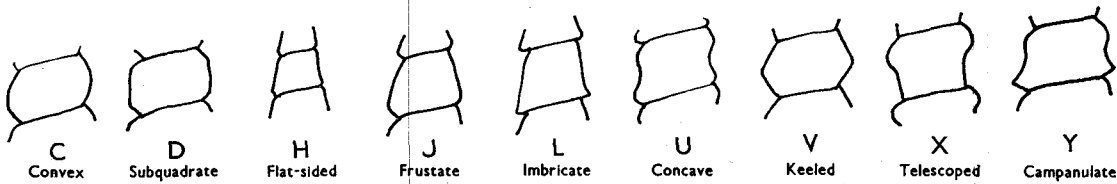


Fig. 9g

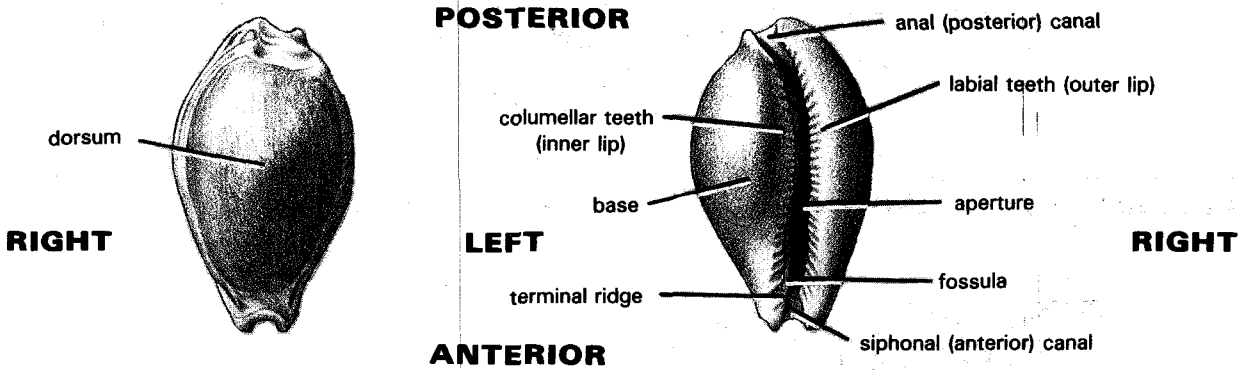
FAMILY TURRITELLIDAE : (1) diagram of notation of spiral cords, from Marwick (1957,fig. 1). Primary cords are denoted A,B,C,D, secondary cords are denoted r,s,t,etc., and tertiary threads r1,r2,etc. The diagram also shows a growth line, and the growth line angle, a



(2) terms used for whorl profiles (from Marwick 1971,fig.1)



FAMILY CYPRAEIDAE : *Cypraea (Notocypraea) clifdenensis*, dorsal and ventral views



FAMILY ARCHITECTONICIDAE : *Wangaloa ngaparaensis*, dorsal and ventral views

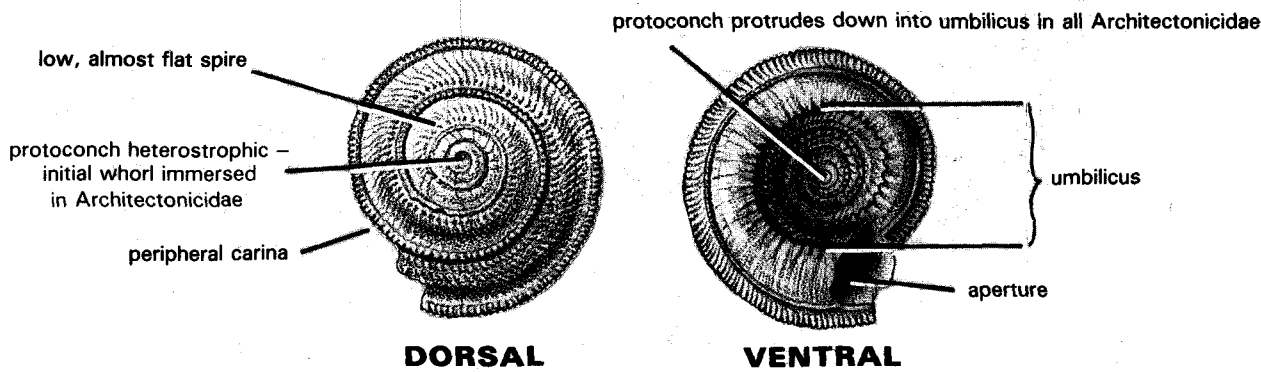
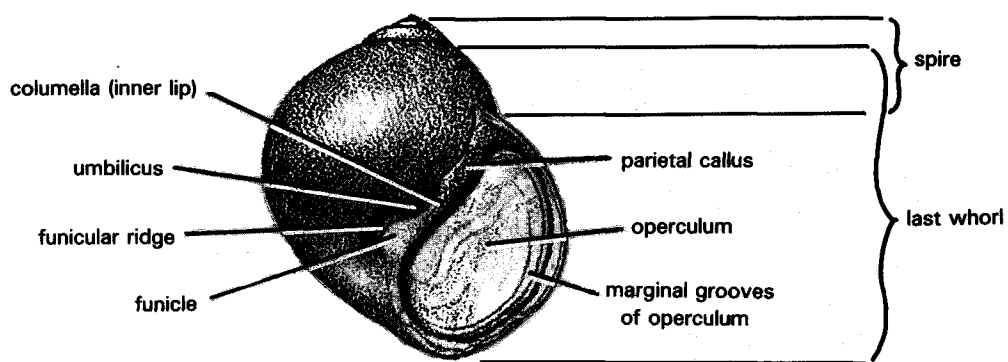
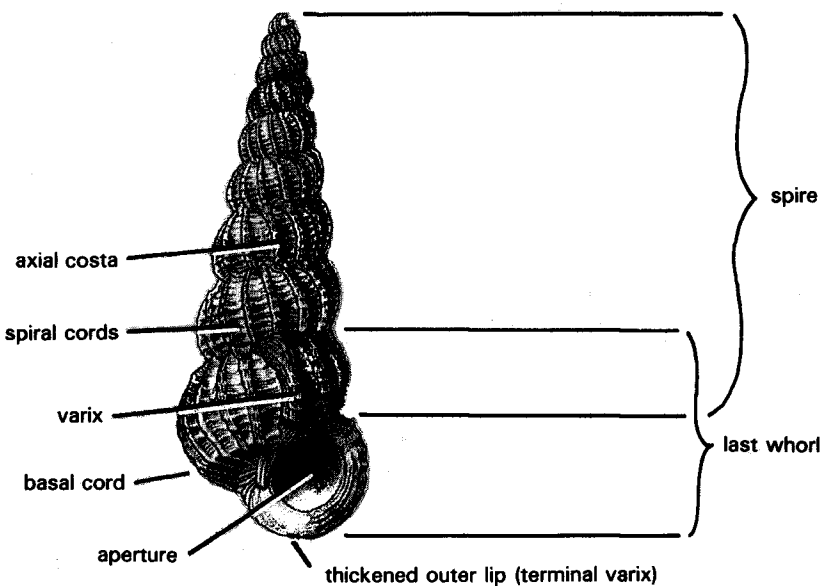


Fig. 9h

FAMILY NATICIDAE : *Tanea zelandica*, ventral (apertural) view



FAMILY EPITONIIDAE : *Cirsotrema lyrata*, ventral (apertural) view



FAMILY RANELLIDAE : *Sassia (Sassia) parkinsonia*, ventral (apertural) view

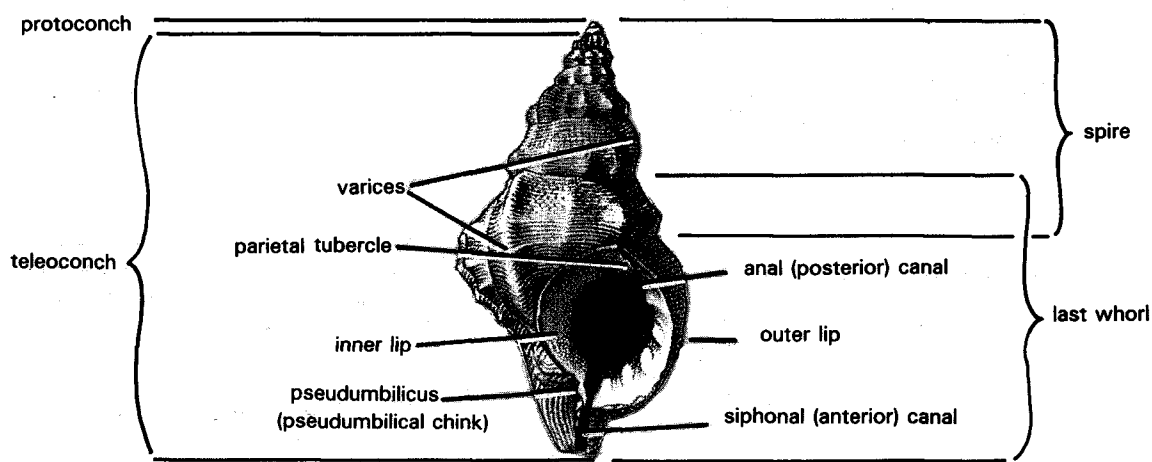
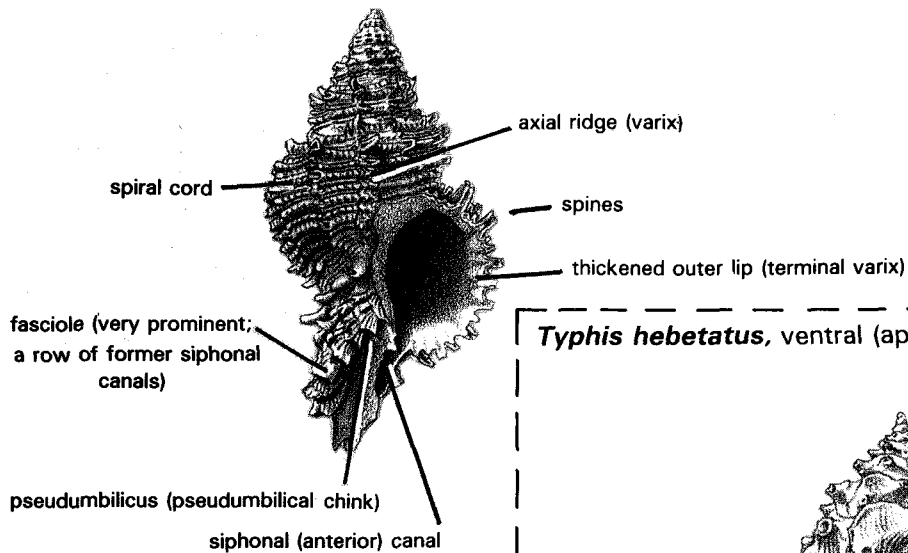
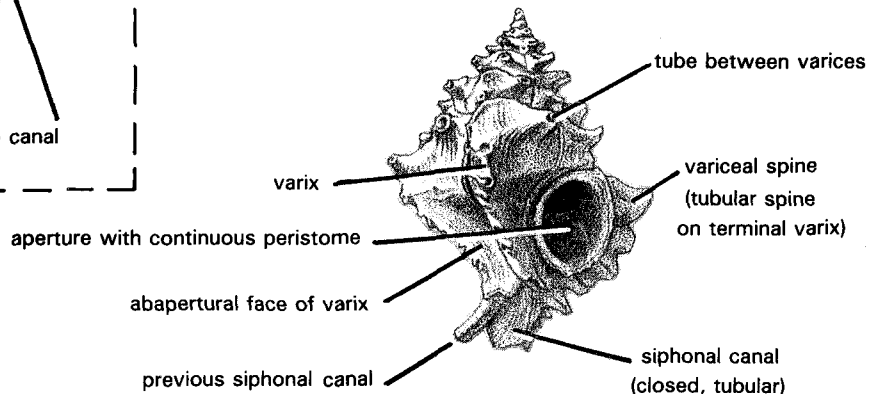


Fig. 9i

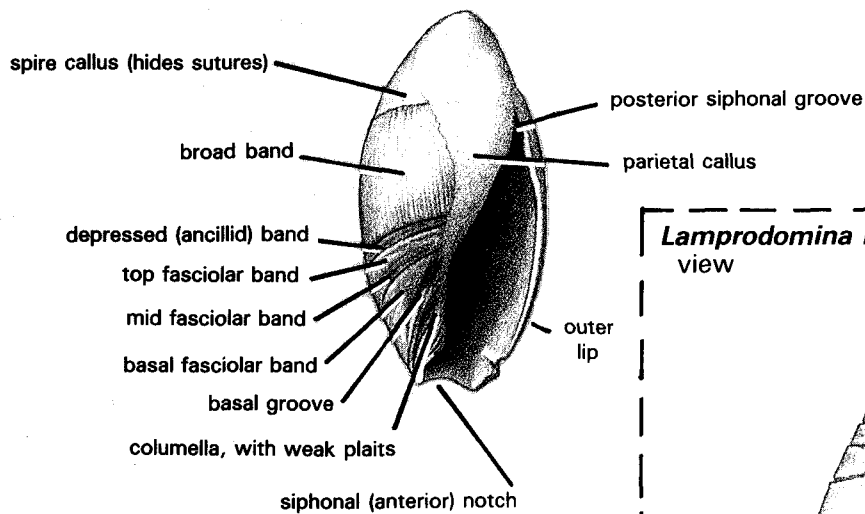
FAMILY MURICIDAE : *Murexsul octogonus*, ventral (apertural) view



Typhis hebetatus, ventral (apertural) view



FAMILY OLIVIDAE : *Amalda (Baryspira) mucronata*, ventral (apertural) view



Lamprodomina neozelanica, ventral (apertural) view

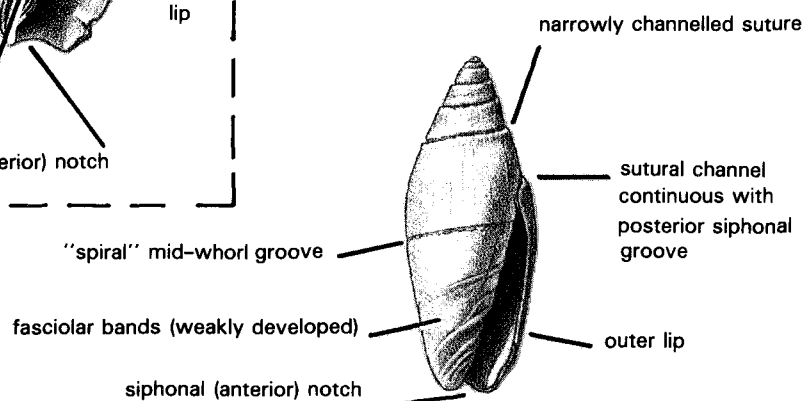
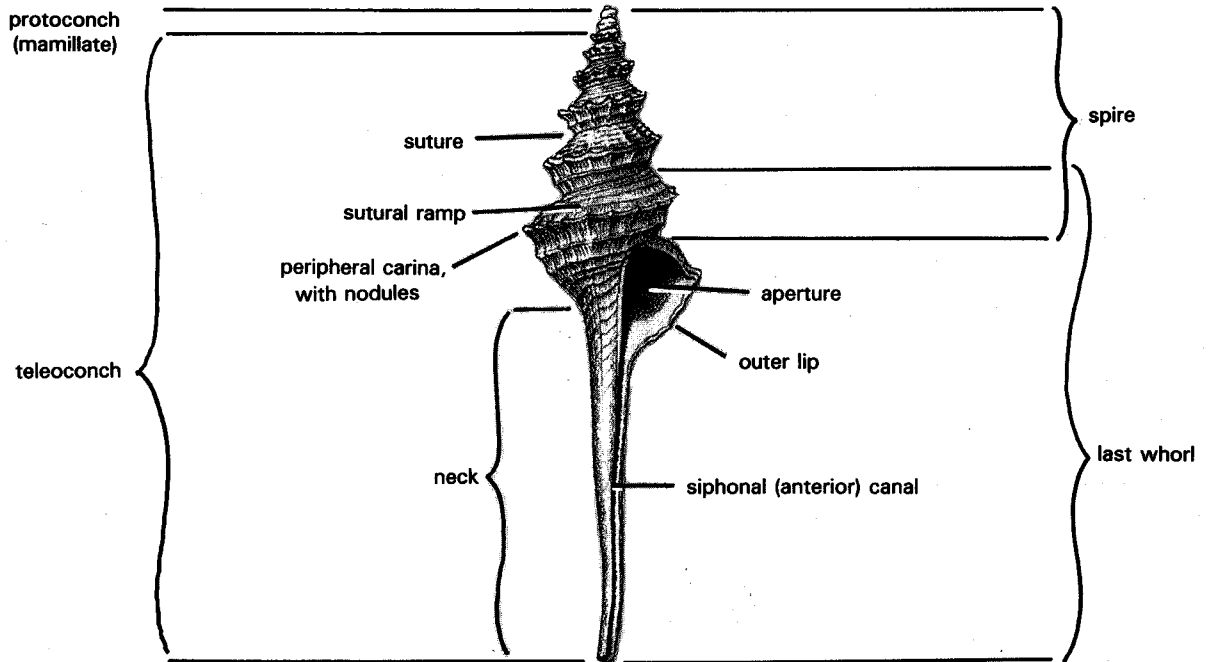
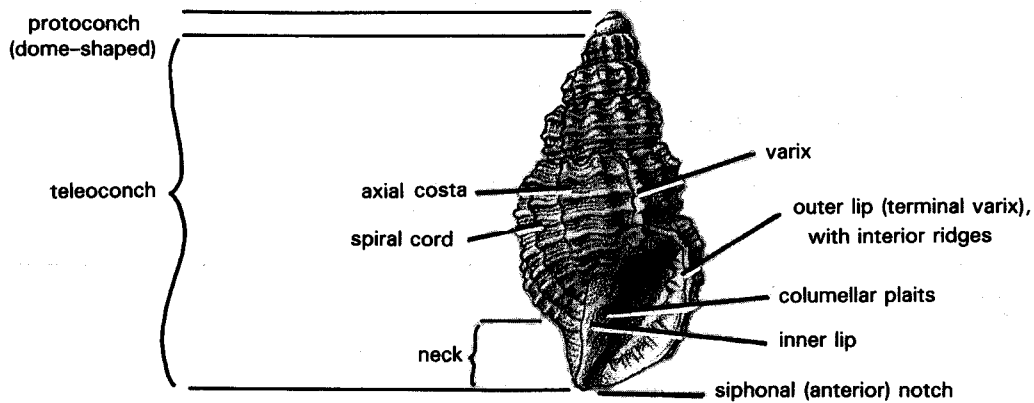


Fig. 9j

FAMILY TURBINELLIDAE : *Coluzea spiralis*, ventral (apertural) view



FAMILY CANCELLARIIDAE : *Fusiaphera marshalli*, ventral (apertural) view



FAMILY VOLUTIDAE : *Mauira biconica*, ventral (apertural) view

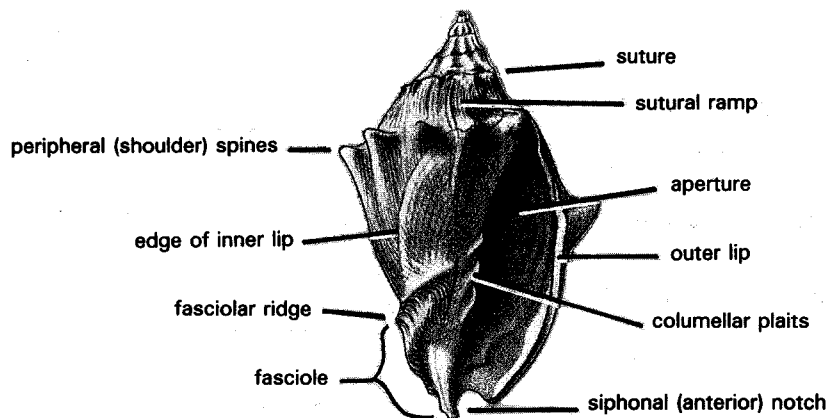
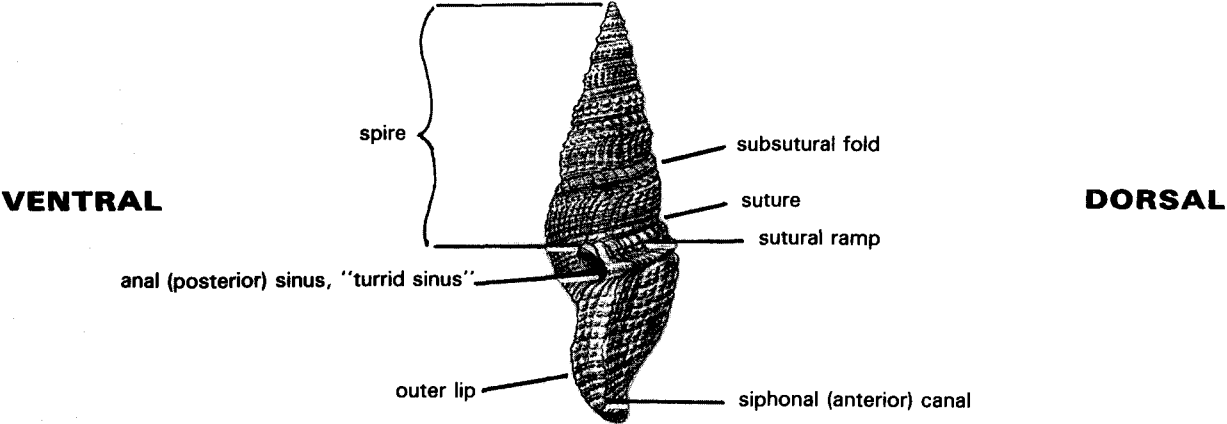
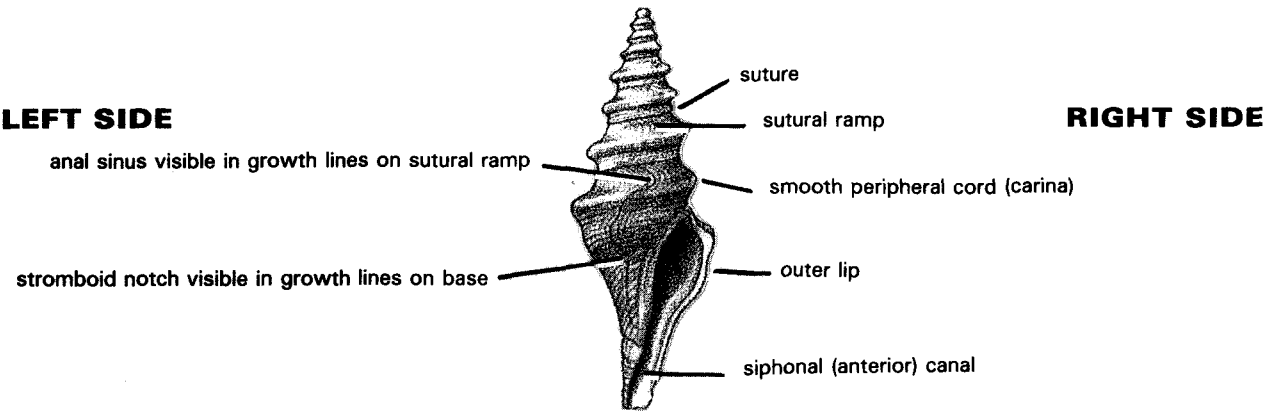


Fig. 9k

FAMILY TURRIDAE : *Phenatoma rosea*, right lateral view



Paracomitas protransenna, ventral (apertural) view



Austroclavus tenuispiralis, ventral (apertural) view

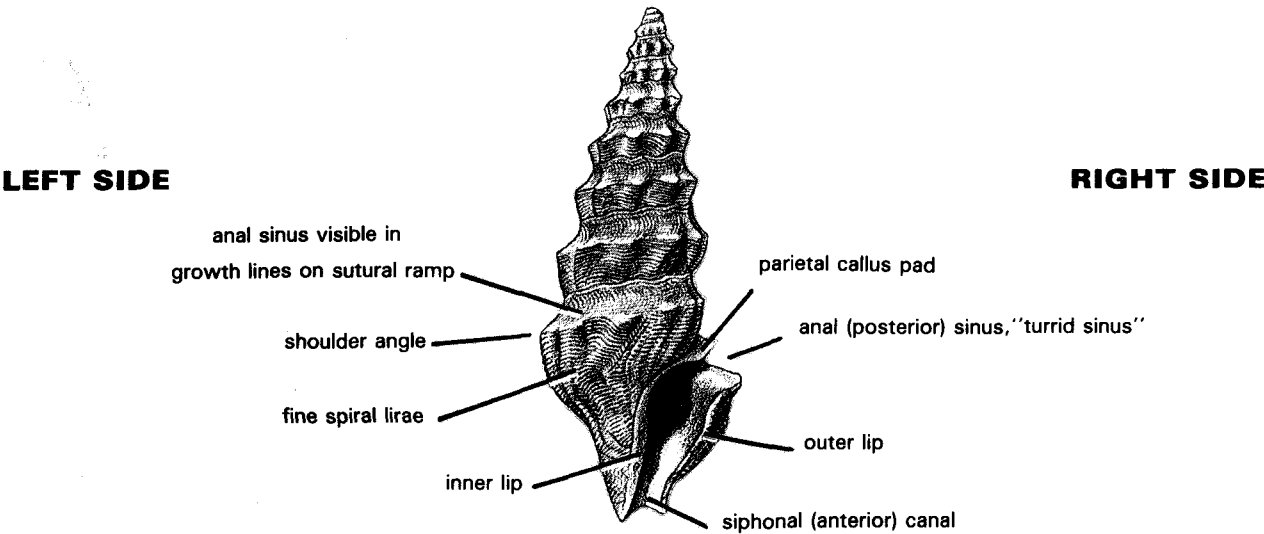
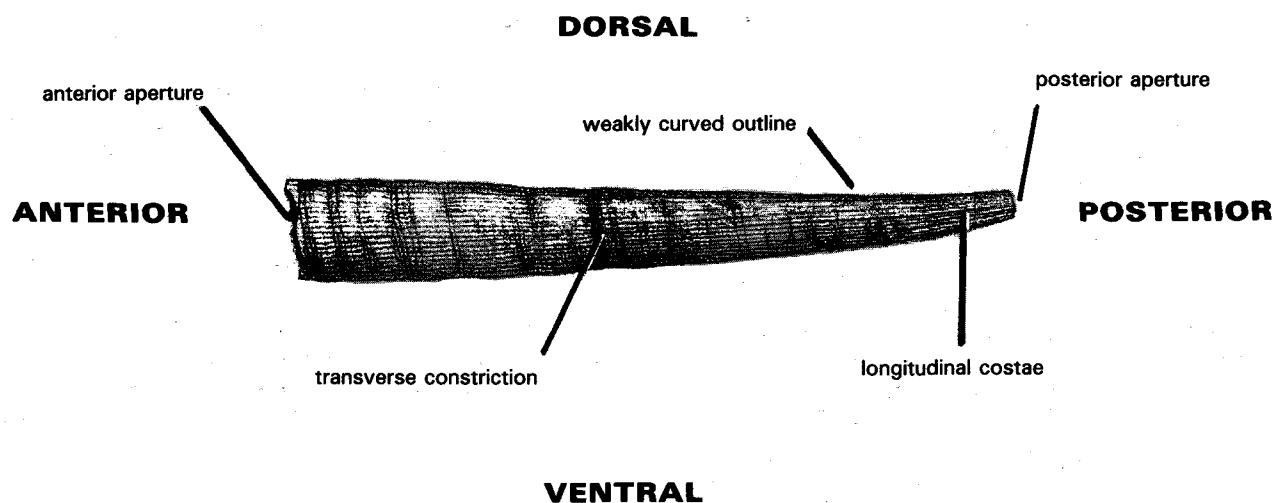


Fig. 91

CLASS SCAPHOPODA

FAMILY DENTALIIDAE : *Fissidentalium* cf. *solidum*, lateral view



CLASS CEPHALOPODA

FAMILY ATURIIDAE : *Aturia cubaensis*, left lateral view of incomplete phragmocone. (The outer shell is missing, revealing the sutures between the internal septa [singular, septum; the septa separate the chambers] and the outer shell; the non-septate body chamber also is missing. Strictly speaking, the shell is upside down)

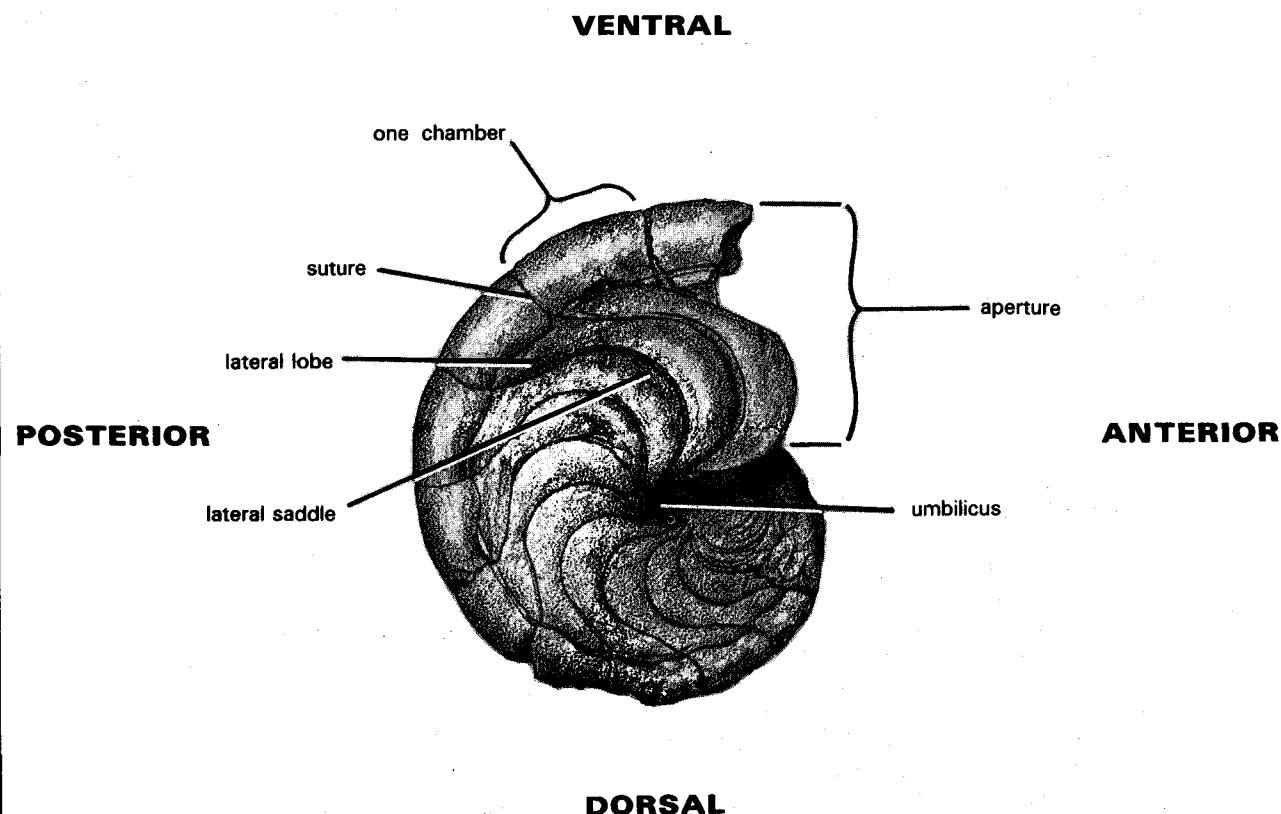


Fig. 9m

THE NEW ZEALAND CENOZOIC MOLLUSCAN FAUNA

CHAPTER 5. PALEOCENE FAUNAS ("WANGALOAN", EARLY TEURIAN STAGE): PLATES 1, 2

INTRODUCTION

Although marine rocks of Paleocene age (Teurian Stage) are quite widespread in New Zealand, and are at least locally well exposed, they are relatively thin and are for the most part devoid of identifiable macrofossils of any kind. The absence or rarity of molluscs in particular may result partly from leaching during diagenesis, but it is more likely to reflect the sedimentary regime that seems to have existed during much of the Paleocene in New Zealand. Sedimentological evidence suggests that New Zealand at this time was low-lying and bordered by shallow, mostly poorly oxygenated seas (Hornibrook in Fleming 1959b, p. 397). In Northland and along much of the east coast from near Gisborne south to North Canterbury, in northeast Otago, and in the Great South Basin, Paleocene rocks typically consist of glauconitic or siliceous sandstone, siltstone or mudstone ("shales") often of dark brown colour and with a distinctive "sulphur" (actually jarosite) efflorescence on weathered surfaces. Except for a moderately diverse faunule from Kaiwhata Stream, eastern Wairarapa (see below), very few Paleocene molluscs have been recorded from these areas. One noteworthy occurrence is of an unusually large thyasirid bivalve (*Conchocele* sp.) from Wimbledon, southern Hawke's Bay—it is probably significant that at least some extant thyasirids harbour symbiotic sulphide-oxidising bacteria enabling them to live in anoxic environments (Reid and Brand 1986). A deeper-water lithofacies is represented in the lower part of the Amuri Limestone (and associated flint beds) in eastern Wairarapa and Marlborough, but to our knowledge, no Paleocene molluscs have yet been recorded from this unit.

From mid-Canterbury to south-east Otago, most Paleocene sediments are of shallow-water facies and comprise sandstone and conglomerate with locally developed shell-beds, in places closely associated with coal measures. Early Paleocene (Danian) molluscan faunules occur at Wangaloa (near Kaitangata) and at Boulder Hill (near Dunedin); smaller assemblages of similar or possibly somewhat younger age are recorded from the Kauru Formation in North Otago and lower Waihao Valley, South Canterbury, and from the Broken River Formation, Castle Hill Basin.

The third important area where Paleocene and Early Eocene rocks are exposed is in the Chatham Islands, where the Takatika Grit, Tutuiri Greenland, Red Bluff Tuff and Matanginui Limestone are partly or wholly of Teurian or Waipawan age (Campbell et al. 1988). Several Paleocene molluscs were described by Marwick (1928) from Tioriori and "Waikaripi", both on Chatham Island; subsequent collections, particularly from Pitt Island, have shown that many more species are present. The Chathams faunules are strikingly different from those on mainland New Zealand and seem to have lived in deeper-water, more oceanic conditions. They are also for the most part significantly younger than the well known Wangaloa and Boulder Hill faunules, and are discussed in the next chapter.

In some sections Paleocene sediments constitute the basal part of a transgressive sequence and rest directly and with marked angular discordance on Torlesse Supergroup "greywacke" or on Haast Schist; in others they disconformably overlie Late Cretaceous beds, the contact being marked by a sharp change in lithology, by phosphorite nodules or by intense bioturbation ("burrowing"). Although precise microfossil control is usually lacking, it seems likely that in most shallow-water sequences there is an important hiatus between Paleocene and Late Cretaceous rocks. No sections are known where Late Cretaceous (Haumurian) and Early Paleocene molluscan faunules occur in sequence.

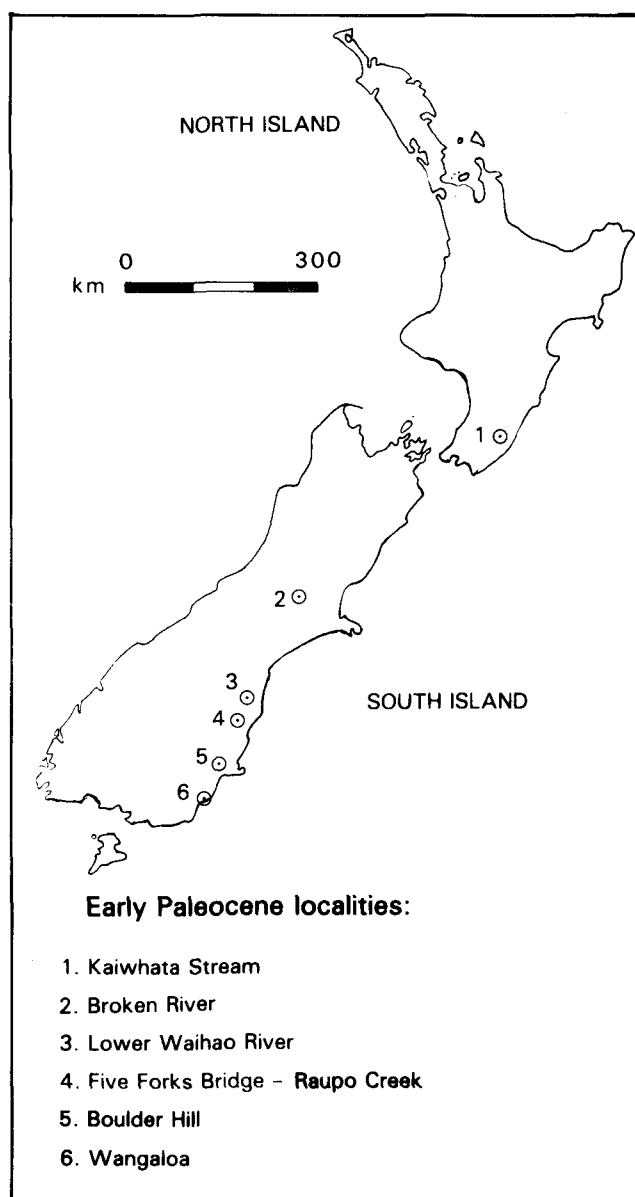


Figure 10 The main molluscan fossil localities of "Wangaloan" (Early Paleocene) age.

Early Paleocene faunas

Our knowledge of the Early Paleocene molluscan fauna is based almost entirely on two faunules from east Otago (Fig. 10). One of these is from quartz sandstone and conglomerate with cemented fossiliferous lenses (Wangaloa Formation) exposed in the coastal section between Mitchell Rocks (or Point) and Measly Beach near Wangaloa, north of the mouth of the Clutha River. Although it was first collected in 1869, its importance was not recognised until the early part of the 20th century when Patrick Marshall described the faunule and concluded that it must be considerably older than any other New Zealand Tertiary assemblage known at that time (Marshall 1916a, b; 1917). In the following year Morgan (*in* Chapman 1918, p. 40) introduced the Wangaloan as a stage of the Kaitangatan "Group" and correlated it with the Eocene.

In 1920 H.E. Fyfe discovered a richly fossiliferous lens overlying quartz sandstone and conglomerate on the north flank of Boulder Hill, near Dunedin. The molluscan faunule from this locality has many species in common with that from Wangaloa, but is considerably more diverse and much better preserved. In a classic monograph, Finlay and Marwick (1937) concluded that the Wangaloa and Boulder Hill faunules are of similar age, and described the combined fauna in considerable detail. From a comparison of the fauna with overseas faunas, and on the basis of its mixed Cretaceous-Tertiary aspect, they correlated the Wangaloan with the Danian, at that time considered to be latest Cretaceous. Finlay and Marwick (1940, p. 81, 105; 1947, p. 220) continued to regard the Wangaloan as the topmost Cretaceous stage in their landmark papers on the subdivision of the New Zealand Late Cretaceous and Tertiary, and in the second of these papers placed it between the newly proposed Teurian (then thought to be Senonian) and Waipawan (Paleocene) Stages.

Hornibrook and Harrington (1957) were unable to obtain microfossils from the Wangaloan stratotype or from the fossiliferous beds at Boulder Hill, but on stratigraphic grounds showed that the Wangaloan must be equivalent to part of the Teurian Stage (which was based on foraminifera). They therefore advocated removal of the Wangaloan from the local stage scheme, a view later supported by Webb (1973a, b) on the basis of detailed sampling of relevant sections in east Otago. Webb's work indicates that the Wangaloan is equivalent, at least in part, to the lower part of the Teurian. By the time this work was done the Danian was generally regarded as basal Tertiary rather than latest Cretaceous, mainly because of the absence of typical Cretaceous taxa (e.g. ammonites, belemnites, *Inoceramus* and trigoniids), and the Cretaceous-Tertiary boundary in New Zealand was placed between the Haumurian and Teurian Stages (Hornibrook 1962). Although the name Wangaloan has hardly been used in the last 30 years (but see Fleming 1966b, p. 9) we retain it here for the distinctive shallow-water molluscan faunules of Wangaloa and Boulder Hill (and their possible correlatives), mainly because of its convenience, but also because its precise relationship to the very long Teurian Stage (c. eight million years) has yet to be demonstrated. We do not, however, advocate its reintroduction into the standard system of local stages.

The combined Wangaloa and Boulder Hill molluscan faunules comprise 77 genus-group taxa, several of which include two or more nominal species, although a thorough revision would probably reduce the number of species recognised (see comments under *Pseudofax ordinarius*, below). The differences between the two faunules are relatively minor and are probably attributable to differences in depositional environments. The Wangaloan stratotype (the "Mitchell Point facies" of the Wangaloa Formation) includes locally abundant *Ophiomorpha* burrows, teredinid-bored wood and sedimentary structures indicating an in-shore environment with frequent storm deposition (Lindqvist 1986). The fossiliferous unit at Boulder Hill, by contrast, seems to have accumulated in quieter conditions, although the presence of large glycymeridids, *Cucullaea* and venerids indicates an inner or mid-shelf rather than a significantly deeper-water environment.

Composition of the Wangaloan fauna

The Wangaloan molluscan fauna is highly distinctive, mainly because of the presence of a considerable number of genus-group taxa not otherwise recorded from New Zealand. This distinctiveness, however, may be more apparent than real, and may merely reflect our poor knowledge of Middle Paleocene to Early Eocene shallow-water molluscan faunas (see next chapter). The following taxa are known only from the Wangaloan (at least in New Zealand) but it seems likely that some range higher — *Ledina*, *Spineilo*, *Cucullona*, *Dosinobia*, *Marwickia*, *Leptocolpus*, *Spirogalerus*, *Amauropsona*, *Tudiciana*, *Taioma*, *Microfulgur*, *Fyfea*, *Heteroterma*, *Campylacrum*, *Ongleya* and *Priscaphander*, as well as several rarer forms. A few taxa, including *Cucullastis*, *Lahillia*, *Conchothyra* and *Struthioptera* — all of which are known from the New Zealand Late Cretaceous — are last recorded from the Wangaloan. Taxa which appear at this time include *Limopsis* (sensu lato), *Electroma*, *Miltha*, *Pratulium*, *Conominolia*, *Colposigma*, *Polinices*, *Polinella*, *Globisium*, *Perissodonta*, *Galeodea* (sensu lato), *Exilia*, *Priscoficus*, *Penion*, *Nassicola*, *Pseudofax*, *Marshallaria*, *Tholitoma*, *Zemacies*, *Wangaloa*, *Acteon* and *Cylichnania*.

From a global perspective the Wangaloan molluscan fauna is of considerable importance for it is one of the few of Paleocene age recorded from the circum-Pacific. The very rich assemblages from the Simi Hills, California (Zinsmeister 1983 a,b) were thought to be Late Paleocene but are now considered to be Early Paleocene (Saul 1983) (i.e. of similar age to the Wangaloan fauna). For the most part the Californian fauna bears little similarity to the Wangaloan fauna, but it does include probable species of *Glycymerita* (otherwise recorded only from Late Cretaceous to Pliocene in New Zealand), *Heteroterma*, and the widely distributed genus *Priscoficus*.

The small faunule from Pebble Point, Victoria is Middle Paleocene (Darragh 1985, p. 99) and the even smaller faunule from Rivernook Beach, Victoria is Late Paleocene (Darragh 1985, p. 99-100). The former faunule includes the biogeographically important genus *Lahillia*, but otherwise has little similarity to the Wangaloan faunules. Paleocene faunas from other parts of the world also have little in common with those from New Zealand

except for the presence of some widely distributed, probably cosmopolitan taxa (e.g. *Limopsis*, *Miltha*, *Panopea*, *Polinices*, *Priscoficus*, *Exilia* and *Tornatellaea*).

More important from a biogeographic viewpoint is the presence in the Wangaloan fauna of many taxa that are either endemic to the New Zealand region or are shared with other former parts of Gondwana. At least some of the latter group were already present around the shores of Gondwana during the Late Cretaceous and constitute what Fleming (1963) termed the "paleoaustral" element in the Wangaloan fauna. Zinsmeister (1979) introduced the Weddellian Province for the shallow-water, cool-temperate region that included south-east Australia, New Zealand, West Antarctica and southern South America from latest Cretaceous time into the Eocene. He identified Lahilliidae, *Struthioptera*, Struthiolariidae and Taiomidae—all of which are represented in the Wangaloan—as being particularly important (Zinsmeister 1979; 1982, text fig. 6), but the biogeographic significance of the Taiomidae is uncertain in view of the presence of possible *Taioma* in the Middle Paleocene of Greenland (see below). The other taxa, however, are known only from former components of the Weddellian Province. Zinsmeister (1982, table 1) classed 47 of the genus-group taxa in the Wangaloan fauna as "paleoaustral", but many of them have not as yet been recorded from outside the New Zealand region and would therefore be more appropriately regarded as endemic—these include *Cucullona*, *Cucullastis*, *Pteromyrtea*, *Dosinobia*, *Marwickia*, *Spelaenacca*, *Conchothyra*, *Microfulgur*, *Fyfea*, *Nassicola*, *Pseudofax*, *Campylacrum* and *Wangaloa*.

Climate

New Zealand occupied a high latitudinal position during the Early Paleocene (Stevens 1985, p.76) but apart from *Perissodonta* there is nothing in the Wangaloan fauna that indicates particularly cool conditions. Beu (1966) suggested that subtropical conditions prevailed on the basis of the presence of such taxa as *Cucullaea*, Pteriidae, *Miltha*, *Polinices* and Ficidae, but the evidence for warm waters is not as strong as it is in the Late Paleocene (see next chapter).

Other possible occurrences of Wangaloan Mollusca

Several molluscan faunules of possible Wangaloan age have been discovered since Finlay and Marwick's monograph was published. The most important of these are from the Kauru Formation, which was proposed by Gage (1957, p. 25-28) for sandstone and siltstone with associated conglomerate at the base of the Tertiary sequence in inland North Otago, and was extended into South Canterbury by Field and Browne (1986, p. 13-14). Some faunules, particularly those from the Kakanui River near Five Forks Bridge, and from the lower Waihao River, include such characteristic taxa as *Spineilo*, *Lahillia*, *Leptocolpus*, *Amauropsona*, *Tudiclanella*, *Fyfea*, *Microfulgur* and *Heteroterma*, and are probably Wangaloan. Others, however, (e.g. Raupo Creek) lack such taxa but include several (e.g. *Serripecten*, *Hedecardium*, *Spirocolpus*, *Zeacolpus* (sensu stricto), *Sigapatella* (sensu stricto) and *Eoturris*) not recorded from the Wangaloan (Fleming in Gage 1957, p. 28)—these

faunules are probably significantly younger than Early Paleocene.

Further north, in the Castle Hill Basin, shellbeds with abundant oysters in the Broken River Formation (Gage 1970, p. 513-514; Field and Browne 1986, p. 11-13) have long been thought to be Late Cretaceous on the supposed presence of *Inoceramus* and *Conchothyra parasitica* (Hutton). Recent palynological studies have shown that the oyster beds are Teurian, and it is now known that the alleged *Inoceramus* is a new species of *Isognomon* (Crampton 1988). The *Conchothyra* is much less strongly callused than typical *C. parasitica*, and more closely resembles the Wangaloan species *C. australis* (see below). A small collection from a tributary in the upper reaches of Broken River includes *Zeacolpus* (*Leptocolpus*) *semiconcavus* and possible *Dosinobia* (Scott in Gage 1970, p. 538) and is probably Wangaloan.

A float boulder from Kaiwhata Stream, east Wairarapa, is apparently derived from low in the Tertiary sequence, and contains abundant but poorly preserved molluscs dominated by a small nuculanid (probably a species of *Jupiteria*). The presence of *Ongleya* (otherwise known only by the type species, *O. tholispira*, from Wangaloa) and of possible *Tudiclanella* is weak evidence for a Wangaloan age, but the *Galeodea* and the *Priscoficus* in the faunule differ from their Wangaloan congeners and possibly indicate a significantly younger age.

REPRESENTATIVE EARLY PALEOCENE MOLLUSCA

Pl. 1b. *Spineilo elongata* (Marshall, 1917) [*Malletia elongata* Marshall 1917, p. 458; *Neilo elongata*; *N. (Spineilo) elongata*]. Type species of *Spineilo* Finlay and Marwick, 1937 (Malletiidae).

Size moderate for family (length 25-30 mm), elongate-ovate; anterior end rounded, posterior end produced, pointed; escutcheon lanceolate, slightly concave. Commarginal sculpture of fine, bevelled ridges; no radial sculpture. Hinge long, taxodont with numerous chevron-sectioned teeth, anterior and posterior series narrowing and meeting under beaks; no resilifer but dorsal margin of posterior series shallowly excavated over part of its length to accommodate external ligament. Adductor muscle scars small, subequal; pallial sinus moderately deep, rounded. Margins smooth.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill; lower Waihao River, South Canterbury (moderately common at all localities).

Spineilo elongata differs from species of *Neilo* (e.g. *N. awamoana*, Pl. 16a, c) in its much more elongate shape and in its pointed rather than truncate posterior end. Puri (in Moore 1969, p. N235) synonymised *Spineilo* with *Nuculanella* Link, 1807, but the absence of a resilifer and the presence of an external ligamental groove indicate that *S. elongata* is related to *Neilo* rather than to the Nuculanidae. *Spineilo* may be represented in the Late Cretaceous of Quiriquina, Chile by the species recorded as "*Malletia pencana* Phil. sp." by Wilckens (1904, p. 230, pl. 19, fig. 6) (Marshall 1917, p. 459; Finlay and Marwick 1937, p. 17), although this does not seem to be conspecific with *Neilo pencana* (Philippi, 1887) which looks like a typical *Neilo* (Stinnesbeck 1986, p. 166, pl. 1, fig. 12-14). Figured specimen (Pl. 1b): holotype, Wangaloa, Wangaloan (Otago University Geology Department) x 2.

Pl. 1 l, m. *Cucullaea (Cucullona) inarata* Finlay and Marwick, 1937 [p. 18]. Type species of *Cucullona* Finlay and Marwick, 1937 (Cucullaeidae).

Moderately large for family (length 65-90 mm), robust, rounded-oblong, strongly inflated, subequilateral; umbones large, rounded. A well developed radial sulcus running from umbones to upper part of posterior margin. Exterior smooth except for growth ridges and almost totally submerged radial elements that become accentuated by weathering. Hinge heavy, with 4 prominent, long, subhorizontal, transversely grooved teeth at each end, median part with numerous irregular denticles. Adductor muscle scars large, posterior scar with prominent myophoric ridge. Internal margin strongly crenulate.

Wangaloan, Boulder Hill (type); Wangaloa (rather uncommon at both localities). Readily distinguished from other New Zealand species of *Cucullaea* by its almost completely submerged radial elements.

Figured specimen (Pl. 1l, m): paratype, GS10195, I44/f8486, Boulder Hill, Wangaloan (TM4123, NZGS) x 1.

Pl. 1 a, c. *Cucullaea (Cucullastis) barbara* Finlay and Marwick, 1937 [p. 20-21]. Type species of *Cucullastis* Finlay and Marwick, 1937 (Cucullaeidae).

Moderately large for family (length 60-73 mm), subquadrate, strongly inflated, with a broad, shallow depression running radially across middle of disc, forming a shallow sinus in middle of ventral margin. Umbones very high. Left valve with about 35 narrow, rounded radial costae on anterior and middle parts of shell, well preserved specimens with numerous very fine radial threads as well. Posterior area almost smooth except for radial threads and growth ridges. Right valve with about 50 relatively broad, flat-topped radial costae, each with a narrow median groove and rendered finely scaly by growth lines. Hinge relatively narrow, with rather few (3 or 4), long, subhorizontal, striated teeth at each end. Adductor muscle scars large, posterior scar with prominent myophoric ridge. Inner margin crenulate.

Wangaloan, Boulder Hill (type); Wangaloa (rather uncommon at both localities).

Cucullaea barbara differs markedly from *C. inarata* (see above) in its more elongate shape, its medially concave ventral margin and its narrower hinge and, most importantly, in having definite radial sculpture. Younger New Zealand species of *Cucullaea* (which were assigned to the subgenus *Latiarca* by Boreham (1965, p. 8, 13)) have less prominent umbones and have radial sculpture of broad, flattened costae in both valves, though these are more subdued in the left valve than in the right.

Figured specimen (Pl. 1a, c): paratype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.

Pl. 1 e, h. *Glycymerita (Glycymerita) concava* (Marshall, 1917) [*Glycymeris concava* Marshall 1917, p. 459; *Glycymeris (Glycymerita) concava*]. Type species of *Glycymerita* Finlay and Marwick, 1937 (Glycymerididae: Glycymeridinae).

Moderately large for family (length 50-60 mm), subquadrate, strongly inflated, robust. Umbones prominent, posterodorsal margin longer than anterodorsal margin; anterior margin gently convex, ventral margin strongly convex, posterior margin distinctly truncate. Radial sculpture of about 45 costae, those near anterior and posterior ends narrow and rounded, others flattened with sharply defined margins. Well preserved shells with numerous fine, submerged threads as well. Hinge highly variable, some specimens with long, almost horizontal teeth, others with short, steeply inclined teeth. Ventral margin strongly crenulate.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (common at both localities); ? Kakanui River.

Glycymerita concava is readily distinguished from younger species of *Glycymerita* by its very well-defined, square-cut radial costae. *Glycymerita* is usually classed as a subgenus of *Glycymeris*, but it includes a group that has been distinct from *Glycymeris* since Late Cretaceous time, and its morphology differs sufficiently from that of *Glycymeris* (in having a subquadrate rather than a subcircular shell, and in its relatively prominent radial sculpture) to warrant generic rank in this conservative family.

Glycymerita ranges from Late Cretaceous (*G. selwynensis* (Woods, 1917)) to Waipipian in New Zealand, and is also recorded from Europe and California (Newell in Moore 1969, p. 267). The Neogene New Zealand species are typically of large size (e.g. *G. rangatira*, Pl. 28g, h). All records of the genus are from shallow-water (inner or middle shelf) assemblages.

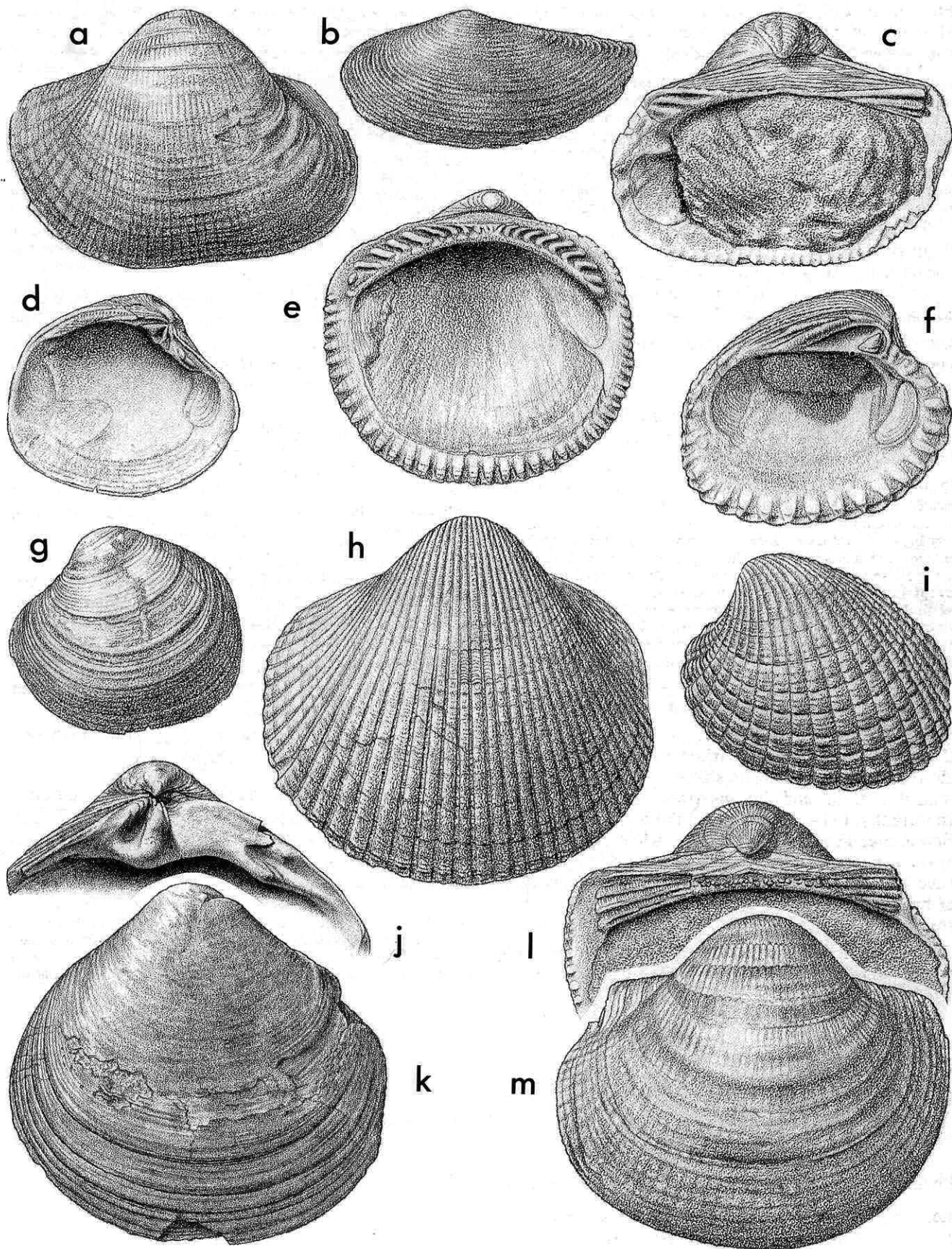
Figured specimens (Pl. 1e, h): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 1.5.

Pl. 1 f, i. *Purpurocardia (?) fyfei* (Finlay and Marwick, 1937). [*Venericardia fyfei* Finlay and Marwick 1937, p. 26; *V. (Purpurocardia) fyfei*] (Carditidae: Venericardiinae).

Size moderate for family (length 40-50 mm), robust, suboval, strongly inequilateral. Lunule small, bounded in front by a deep groove; escutcheon narrow, bounded below by a narrow rib. Posterior area slightly concave. Radial sculpture of about 26 very prominent costae, narrow and tuberculate when young, tubercles decreasing in strength during growth. Anterior and posterior costae remaining relatively narrow

Plate 1 Early Paleocene ("Wangaloan") Mollusca (1).

- a, c. *Cucullaea (Cucullastis) barbara* Finlay and Marwick, x 1.
- b. *Spineillo elongata* (Marshall), x 2.
- d, g. *Marwickia parthiana* (Marwick), x 1.
- e, h. *Glycymerita (Glycymerita) concava* (Marshall), x 1.5.
- f, i. *Purpurocardia (?) fyfei* (Finlay and Marwick), x 1.
- j, k. *Lahillia neozelanica* Marshall and Murdoch, x 1.
- l, m. *Cucullaea (Cucullona) inarata* Finlay and Marwick, x 1.



throughout growth, others becoming broader with very narrow interspaces. Commarginal sculpture other than costal tubercles consisting of prominent growth lines and ridges. Left hinge with prominent triangular anterior cardinal and narrow, high, arched posterior cardinal tooth. Right hinge with very weak anterior cardinal and a large triangular median cardinal. Adductor muscle scars large, ovate, impressed; pallial line distant from ventral margin. Ventral margin strongly crenulate.

Wangaloan, Boulder Hill (type) (common); Wangaloa (moderately common).

The affinities of this carditid are uncertain, although in shape and sculpture it is similar to some species of *Purpurocardia*, a taxon otherwise known no earlier than Waitakian. Shape in itself, however, is not a reliable indication of relationship in the Venericardiinae, as there is evidence to suggest that elongate species have arisen repeatedly from more equilateral forms in the subfamily.

Figured specimen (Pl. 1f, i): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 1.

Pl. 1 j, k. *Lahillia neozelanica* Marshall and Murdoch, 1923b [p. 130; "*Mactra crassa* Hutton?" (not of Hutton, 1885)]. Type species of *Lahilleona* Finlay and Marwick, 1937 (as a subgenus of *Lahillia*), now regarded as inseparable from *Lahillia* Cossman, 1889 (Zinsmeister 1984, p. 1515) (Lahilliidae).

Moderately large for superfamily (height 50-80 mm), rather thick-shelled dorsally, particularly in hinge region, but otherwise relatively thin-shelled; subequilateral with high, broad umbones. Posterior area not differentiated; lunule long, rather narrow; no escutcheon. Sculpture of growth lines and ridges only, but weak subsurface radial elements visible on some weathered shells. Hinge heavy, left valve with a prominent, high, triangular anterior cardinal and a feeble posterior cardinal tooth; right valve with a stout median cardinal and a subobsolete anterior cardinal. Both valves with a prominent posterior lateral tooth, but no anterior laterals. Nymph-plate very prominent, projecting above posterodorsal margin and separated from it by a deep ligamental groove. Adductor muscle scars moderately large, impressed dorsally. Pallial sinus shallow, rounded. Inner margins smooth.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (rather uncommon but conspicuous at both localities).

Specimens of *Lahillia* from certain Late Cretaceous localities (i.e. Middle Waipara; Haumuri Bluff; Shag Point) were identified by Finlay and Marwick (1937, p. 32-33) as *L. aff. neozelanica*. If these should prove to be conspecific with the Paleocene species, *L. neozelanica* would be the only bivalve known to have survived from Late Cretaceous into the early Cenozoic in New Zealand.

Lahillia is of considerable biogeographic interest, as it is known only from southern South America (Late Cretaceous-Late Miocene), Seymour Island (Late Cretaceous-Early Oligocene), New Zealand (Late Cretaceous-Early Paleocene) and Australia (Middle Paleocene) (Zinsmeister 1982, text fig. 6). It is one of the most characteristic faunal elements in the Weddellian Province, proposed by Zinsmeister (1979) for Late Cretaceous-early Paleogene shallow-water marine assemblages in eastern Gondwana.

Figured specimens (Pl. 1j): GS10195, I44/f8486, Boulder Hill; (Pl. 1k): GS1494, M46/f9500, Wangaloa, Wangaloan (NZGS) x 1.

Pl. 1 d, g. *Marwickia parthiana* (Marwick, 1927) [*Finlaya parthiana* Marwick 1927, p. 596]. Type species of *Finlaya* Marwick, 1927 (not of Theobald, 1903) = *Marwickia* Finlay, 1930 (Veneridae: Pitarinae).

Size moderate for family (length 35-45 mm), well inflated. Lunule large, concave, not bounded by groove; escutcheon narrow, not sunken. Exterior smooth except for commarginal grooves which are absent from middle of shell. Left hinge with a lamellar anterior cardinal, a very broad triangular median cardinal, a narrow posterior cardinal which is joined to nymph, and a strong anterior lateral tooth separated from dorsal margin by a groove. Right hinge with a small anterior cardinal, a narrowly triangular median cardinal and a curved, grooved posterior cardinal tooth; anterior lateral pit well separated from cardinals, posterior lateral tooth prominent, separated from margin by deep groove. Nymphs somewhat rugose. Pallial sinus moderately deep, truncate, slightly ascending. Internal margin smooth.

Wangaloan, Boulder Hill (type) (uncommon); Wangaloa (common).

Marwickia parthiana is readily distinguished from other New Zealand venerids by the presence of a posterior lateral tooth in the right valve. *Marwickia* is monotypic, but may be closely related to the Northern Hemisphere genus *Dosiniopsis* Conrad, 1864 (Paleocene-Eocene) which also has a right posterior lateral tooth and a rugose nymph.

Figured specimen (Pl. 1d, g): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.

Pl. 2 a. *Conominolia conica* (Marshall, 1917) [*Heliacus conicus* Marshall 1917, p. 453]. Type species of *Conominolia* Finlay, 1926 (Trochidae: Solariellinae).

Rather small for family (height 7-10 mm), turbiniform, widely umbilicate. Protoconch small, apparently smooth, of a little more than 1 whorl. Teleoconch of 5-5.5 whorls, spire whorls biangulate, upper (adapical) angulation descending during growth. Last whorl with additional angulation on periphery (exposed on penultimate whorl of some shells). Sutural shelf moderately wide, horizontal on early whorls, sloping on later ones. Spiral sculpture on spire of 2 narrow cords marking angulations, with considerably finer threads between and on sutural shelf. Base with additional cord marking peribasal angulation, and 8-10 fine, closely spaced cords between it and umbilicus. On well preserved shells spirals are finely beaded by the numerous, closely spaced growth lines. No other axial sculpture. Umbilicus with 7-10 fine cords within. Aperture subcircular.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (common at both localities).

The Whaingaroan species *C. sulcatina* (Pl. 9l) has more evenly convex whorls, a narrower sutural shelf, crisper spiral cords, stronger basal spirals and much weaker axial sculpture than *C. conica*. Several other trochids ranging in age from Duntroonian to Mangapanian or Nukumaruan have been assigned to *Conominolia*, but these are much smaller and have less strongly convex whorls and fewer umbilical spirals than either *C. conica* or *C. sulcatina*. Most records of the genus are from shallow-water (inner shelf) sandstone or shellbeds.

Figured specimen (Pl. 2a): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 3.

Pl. 2 b. *Zeacolpus (Leptocolpus) semiconcavus* (Suter, 1911) [*Turritella semiconcava* Suter 1911, p. 595]. Type species of *Leptocolpus* Finlay and Marwick, 1937 (Turritellidae).

Moderately large for family (height 70-90 mm), attenuate. Protoconch not known. Early teleoconch whorls sharply angled medially by spiral B, A and C remaining very weak until about 5th whorl when A increases in strength, B shifts to a more abapical position, secondary spirals appear and whorls become biangulate. During growth B decreases in dominance, C and secondaries increase in strength and whorls become flat-sided or gently concave. Adult whorls with about 9 subequal cords and a few weaker ones, particularly adapically. Base with about 10 additional spirals, those at and just below periphery stronger than those

below. Outer lip with broadly arcuate, rather shallow sinus, both limbs almost straight, the adapical limb extending further forward than the abapical one.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill; Kakanui valley; lower Waihao River; Castle Hill Basin.

Zeacolpus semiconcavus is one of the most common molluscs at Wangaloa, Boulder Hill and Waihao River. It is distinguished from superficially similar, younger species of *Zeacolpus* (e.g. *Z. pukeuriensis*, Pl. 20a) by its much shallower sinus with a markedly less strongly opisthocline abapical limb. *Z. semiconcavus* is the oldest known member of the genus, and its relationship to the deeper-sinused species (which are first recorded from beds of probable Early Eocene age in the upper Waihao River) is uncertain.

Figured specimen (Pl. 2b): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 1.

Pl. 2 c, d. *Sigapatella (Spirogalerus) lamellaria* (Finlay and Marwick, 1937) [*Spirogalerus lamellaria* Finlay and Marwick 1937, p. 46]. Type species of *Spirogalerus* Finlay and Marwick, 1937 (Calyptraeidae).

Size moderate for family (height 20-30 mm), crepiduloid. Protoconch eroded in all known specimens; teleoconch of 3-4 whorls; spire low, strongly exsert. Suture strongly impressed, descending rapidly on last whorl. No sculpture apart from rather sinuous growth lines. Aperture very large, elongate-ovate with a prominent concave septum well within, forming a shallow depression ("false umbilicus") at junction with upper wall.

Wangaloan, Boulder Hill (type) (common).

Sigapatella (Spirogalerus) lamellaria differs from typical species of *Sigapatella* in having a very strongly exsert spire and an elongate-ovate rather than a subcircular aperture. Although Finlay and Marwick gave *Spirogalerus* generic rank, the differences between it and *Sigapatella* (sensu stricto) are rather minor and do not warrant more than subgeneric differentiation. Finlay and Marwick (1937, p. 46) and Boshier (1960, p. 390, fig. 3) considered *S. lamellaria* to be the probable ancestor of *Sigapatella* (sensu stricto), which is first recorded from beds of probable Early Eocene age in the upper Waihao River.

Figured specimen (Pl. 2c, d): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.5.

Pl. 2 e. *Drepanocheilus (Tulochilus) bensoni* Finlay and Marwick, 1937 [p. 63]. Type species of *Tulochilus* Finlay and Marwick, 1937 (Aporrhaidae).

Small for family (height c. 11 mm). Protoconch unknown; teleoconch whorls angled below middle on spire, last whorl with prominent peribasal keel emerging from suture and stopping abruptly at base of wing. Axial sculpture on early whorls of narrow, low costae reaching from lower suture almost to upper suture and slightly thickened on angulation, but restricted to peripheral tubercles on later whorls; about 16 per whorl. Spiral sculpture on spire of fine threads; last whorl with cord marking peribasal keel, and about 4 cords with interstitial threads on base. Columella slightly concave, inner lip callused; outer lip with a broad, thin wing spreading adapically as far as upper suture. A narrow groove running from upper angulation to extremity of wing.

Wangaloan, Boulder Hill (type)(rare).

Drepanochilus bensoni is one of the very few Cenozoic aporrhoids recorded from New Zealand. Most members of the family are of Mesozoic age, but extant species occur in the Northern Hemisphere. All are characterised by having lateral extensions to the outer lip, and are

among the most bizarre gastropods known. *Tulochilus* differs from *Drepanocheilus* (sensu stricto) in having angled rather than convex spire whorls, in having the outer lip extending further up the spire and in having a less strongly produced columella.

Figured specimen (Pl. 2e): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 5.

Pl. 2 g, h. *Conchothyra australis* (Marshall, 1916) [*Pugnellus australis* Marshall 1916b, p. 120] (Struthiolariidae).

Size moderate for family (height 40-50 mm). Protoconch not known; teleoconch of about 5 whorls, strongly shouldered near middle on spire, last whorl with 2 additional, less pronounced angulations or keels. Axial sculpture of prominent nodules on shoulder angulation, only slightly extended abapically on last whorl where they probably number about 20 (uncertain because of obscuring callus). Lower keels with more numerous but much weaker nodules or swellings. Spiral sculpture, other than cinguli marking the lower keels, consisting of fine threads over surface not covered by callus. Aperture rather narrow because of callus, broader adapically and constricted abapically. Columella short, apparently straight, but obscured by callus in adult shells. Apertural callus very prominent, smooth, thickest just below lowest keel where it forms a large swelling, extending well up spire (to apex in some shells), forming a broad, flat varix on the strongly sinuous outer lip.

Wangaloan, Wangaloa Formation, Wangaloa (type) (common); Boulder Hill; Broken River (?).

Finlay and Marwick (1937, p. 65) described *C. expedita* from Boulder Hill (type locality) and Wangaloa, differentiating it from *C. australis* on what seem to be minor differences in callus and sculptural characters; it is unlikely to be distinct. *C. parasitica* Hutton, 1877 (Haumurian (Late Cretaceous), Waipara River; Selwyn Rapids) has callus extending over the back of the shell and completely covering it in adult shells.

Conchothyra is the oldest known member of the Struthiolariidae, a family which is well represented in New Zealand (particularly in the Neogene and modern faunas) and is also present in Australia, the subantarctic islands, Seymour Island and Patagonia. The precise relationship of *Conchothyra* to the younger members of the family is uncertain, but it is probably significant that *Struthiolaria calcar* (Pl. 20g, h) and other early species of *Struthiolaria* have a very similar sculptural plan to *C. australis*. They differ, however, in having a less extensive callus, a straighter outer lip, and a right-deflected, concave columella.

Figured specimen (Pl. 2g, h): GS1494, M46/f9500, Wangaloa, Wangaloan (NZGS) x 1.

Pl. 2 j, k. *Polinices (Polinella) finlayi* (Marwick, 1924) [*Uber finlayi* Marwick 1924d, p. 565; *Polinella finlayi*] (Naticidae: Poliniceinae).

Size moderate for genus (height 25-45 mm), ovate or globose, spire low, pointed. Protoconch not distinguishable from teleoconch in available material, about 6 whorls in all, last strongly convex, capacious. No sculpture apart from growth lines. Aperture semicircular, inner lip almost straight except for shallow excavation near adapical end in most specimens. Inner-lip callus relatively narrow for genus, typically parallel-sided over most of its length, lacking definite transverse grooves, filling umbilicus completely in some shells, but leaving a shallow depression or groove in others. Outer lip slightly sinuous, strongly prosocline, inclined at about 35° from shell axis.

Wangaloan, Boulder Hill (type); Wangaloa (common at both localities).

Polinices (Polinella) finlayi differs from younger species of *Polinices (Polinella)* in having a much more strongly inclined outer lip and in lacking transverse grooves on the inner-lip callus. Except for a possible occurrence in the Late Cretaceous Quiriquina fauna of Chile, *Polinella* appears to be endemic to New Zealand, where it ranges from Wangaloan to Waipipian. *Polinella* is generally regarded as a subgenus of *Polinices*, differing from typical species of that taxon in having a much more restricted callus and, in most species, transverse grooves on the callus. *Polinella* seems to have been bathymetrically more tolerant than *Polinices* (sensu stricto); the two taxa occur together in some shallow-water (inner or middle shelf) assemblages, but species of *Polinella* are more characteristic of outer shelf or upper bathyal sediments. Figured specimen (Pl. 2j, k): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 1.5.

Pl. 2 i. *Lunatia fyfei* (Marwick, 1924) [*Uber (Euspira) fyfei* Marwick 1924d, p. 569] (Naticidae: Poliniceinae).

Moderately large for family (height 38-55 mm), globose or ovate. Protoconch not known; teleoconch whorls convex, last whorl very large; sutures strongly impressed. No sculpture apart from growth lines. Aperture large, ovate; outer lip almost straight, strongly prosocline. Parietal callus thin; umbilicus open, moderately large, without funicle or callus.

Wangaloan, Boulder Hill (type); Wangaloa (rare at both localities).

Lunatia fyfei is distinguished from other New Zealand naticids by its combination of large size, its strongly prosocline outer lip, its strongly impressed suture and its absence of an umbilical callus or funicle. *L. lateaperta*, also from Boulder Hill (type) and Wangaloa, supposedly differs from *L. fyfei* in its smaller size, higher spire and wider umbilicus, but it is unlikely to be distinct. The only other New Zealand record of the genus is a doubtful one from Hampden Beach (Bortonian). *Lunatia* is long-ranging (Cenomanian-Recent) and is recorded from most parts of the world.

Figured specimen (Pl. 2i): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.

Pl. 2f. *Globisinum spirale* (Marshall, 1917) [*Ampullina spiralis* Marshall 1917, p. 452] (Naticidae: Globisininae).

Size moderate for family (height 22-45 mm), ovate, spire relatively high for genus. Protoconch not distinguishable from teleoconch in available material; last whorl capacious, with a very narrow umbilicus. Sculpture of spiral grooves and low, narrow, flat-topped cords. Inner lip slightly sinuous, parietal callus very thin; outer lip only moderately prosocline (c. 20° to vertical).

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (uncommon at both localities).

Globisinum spirale is distinguished from younger members of the genus by its relatively elevated spire, by its relatively prominent spiral sculpture and by its very narrow umbilicus. *G. miocaenicum* (Waitakian-Altonian) is lower-spined and more finely sculptured and has a better-defined umbilicus, *G. crassilatum* (Pl. 15h) is much smaller, has distinctly impressed sutures and is more widely umbilicate, and *G. drewi* (Pl. 47t) is larger, lower-spined, more weakly sculptured and is non-umbilicate. *G. elegans* (Bortonian-Kaaitan) differs markedly from all the above in having very weak spiral sculpture (obsolete in some shells) and a wide umbilicus. With the exception

of *G. elegans*, species of *Globisinum* are readily distinguished from other New Zealand naticids by having a globose or ovate shell and relatively distinct spiral sculpture, and in being narrowly umbilicate or non-umbilicate. Spiral sculpture is also present in species of *Sinum*, *Eunaticina* and *Propesinum*, as well as *Polinices propeovatus* (Pl. 29l) and a few other New Zealand naticids, but these differ markedly from species of *Globisinum* in shell form and in umbilical and sutural characters. The unusual radula of *G. drewi* (Powell 1933a, fig. 19) is additional evidence for the distinctiveness of the genus and is the basis of Powell's proposal that it be placed in a separate subfamily. Dell (1956a, p. 46) suggested that *Globisinum* is closely related to *Bulbus* Brown, 1839 (= *Acrybia* H. and A. Adams, 1853) from the Arctic and North Atlantic.

Globisinum drewi ranges from mid-shelf to upper slope, and most of the fossil species seem to have occurred at similar depths, but *G. spirale* may have penetrated into shallower waters, to judge by its occurrence at Wangaloa.

Figured specimen (Pl. 2f): holotype, Wangaloa, Wangaloan (Otago University Geology Department) x 1.5.

Pl. 2 l, s. *Galeodea (Taieria) allani* (Finlay and Marwick, 1937) [*Taieria allani* Finlay and Marwick 1937, p. 68]. Type species of *Taieria* Finlay and Marwick, 1937 (Cassidae: Cassinae).

Rather small for genus (height 30-40 mm), broadly fusiform. Protoconch not known; teleoconch whorls angled somewhat below middle on spire, last whorl inflated, with a moderately long, twisted neck. Axial sculpture of rounded tubercles on shoulder angle, 14-16 per whorl. Spiral sculpture of rather sharp threads (c.40 on last whorl), one noticeably stronger than the others forming a narrow cingulum on periphery of last whorl, and another, slightly weaker one a short distance below. Aperture pyriform, siphonal canal moderately long, unnotched. Inner-lip callus smooth, moderately thick over columella, but not projecting. Outer lip thin, edge finely crenulate.

Wangaloan, Boulder Hill (type) (rare). A small cassid (height about 30 mm) from the Red Bluff Tuff, Tarawhenua Peninsula, Pitt Island (Teurian) is very similar to *G. (Taieria) allani*, but has fewer and stronger shoulder tubercles (10 on last whorl); it may be conspecific in view of the considerable variation in sculpture noted in other cassids.

Taieria is a monotypic taxon so far recorded only from the early Cenozoic of New Zealand. Although it was proposed as a genus, the type species is very similar in most respects to typical species of *Galeodea* (sensu stricto), differing chiefly in having a relatively restricted columellar callus and an unthickened outer lip. These differences are relatively minor and we accordingly relegate *Taieria* to subgeneric rank under *Galeodea*.

Figured specimen (Pl. 2l, s): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.5.

Pl. 2 w. *Priscoficus obtusa* (Marshall, 1917) [*Perissolax obtusa* Marshall 1917, p. 454; *Proficus obtusus*]. Type species of *Proficus* Finlay and Marwick, 1937, here synonymised with *Priscoficus* Conrad, 1866 (Ficidae).

Moderately large for family (available specimens 41-47 mm high, complete specimens probably at least 65 mm). Protoconch not known. Spire low, dome-shaped; teleoconch whorls strongly clasping, so that the sutural ramp extends up to shoulder angle of previous whorl. Last whorl very large, with 3 prominent keels, middle one on the periphery

and slightly closer to abapical than to adapical one, interspaces concave; base gently excavated below lowest keel. Sutural ramp becoming wider and steeper on later part of last whorl, so causing keels to descend near outer lip. Axial sculpture, apart from growth lines and ill-defined folds, of prominent rounded nodules on keels, 20-25 on adapical row, those on lower keels not consistently corresponding to those on adapical row in position or number. Spiral sculpture of numerous low, narrow threads with moderately wide interspaces, over whole surface. Aperture large, polygonal, contracted anteriorly to gradually narrowed siphonal canal of unknown length; columella gently twisted to left near middle, otherwise almost straight. Inner lip with thin callus wash over columella and parietal nodules. Outer lip thin, polygonal, smooth within, "sagging" because of widening sutural ramp.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (uncommon at both localities).

Finlay and Marwick (1937, p. 75) proposed the genus *Proficus* for this species, distinguishing it from *Priscoficus* on the basis of its "sagging" aperture and supposedly broad and short siphonal canal. The former character (more marked on the figured specimen than on other shells) is regarded as a specific character of little taxonomic significance. The siphonal canal appears very short on the figured shell but is severely broken; another, larger shell from Boulder Hill has a notably longer and narrower canal, like that in typical species of *Priscoficus*. *P. obtusa* is the oldest known member of the genus; the only older fid is *Protopirula capensis* Rennie, 1931 from the Late Cretaceous of South Africa (Wenz 1941, p. 1079).

Figured specimen (Pl. 2w): GS10195, I44/f8486, Boulder Hill, Wangaloan (hypotype of Finlay and Marwick, 1937, pl. 10, fig. 1, 2) (NZGS) x 1.

Pl. 2 t. *Pseudofax ordinarius* (Marshall, 1917) [*Phos ordinarius* Marshall 1917, p. 456; *P. conicus* Marshall 1917, p. 456; *Pseudofax ordinarius ordinarius*; *P. ordinarius conicus*]. Type species of *Pseudofax* Finlay and Marwick, 1937 (Buccinidae).

Small for family (height 10-20 mm), elongate-ovate. Protoconch broadly conical, of about 3 convex whorls, too worn in available material to tell if sculpture originally present. Teleoconch whorls 5-6 in adult, evenly convex or obtusely angled near middle on spire; base of last whorl excavated, with short neck. Axial sculpture of low, rounded, orthocline, slightly opisthocyrte costae, c. 14-20 on penultimate whorl, not extending onto base of last whorl. Spiral sculpture of narrow, low cords of variable number and spacing, over-riding axial costae with little or no change. Aperture ovate, inner lip moderately callused, with a weak ridge marginating a short, open, notched siphonal canal. Fasciole well developed, margined above by a narrow ridge. Outer lip thin, lirate within.

Wangaloan, Wangaloa Formation, Wangaloa (type locality of both nominal species); Boulder Hill (common at both localities).

Pseudofax ordinarius is a highly variable species, some specimens resembling the figured one in having a slender shell, distinctly angled teleoconch whorls and relatively prominent axial sculpture; others ("conicus" type) having a stumper habit with convex whorls and subdued axial sculpture and looking rather like a nassariid. Finlay and Marwick (1937, p. 80) recognised the variation in this species but retained Marshall's names (as subspecies) for the extreme morphotypes. They are synonymised here in keeping with contemporary taxonomic ideas.

Pseudofax is a rather generalised buccinid of the *Cominella-Fax* type. It is similar in general appearance to *Fax* Iredale, 1925 (Recent, Australia) but differs in

having a broadly conical rather than a cylindrical protoconch. The genus is also recorded from faunules of probable late Dannevirke Series age (Heretaungan or Porangan?) i.e. Castle Hill Shaft, Kaitangata; "Island Sandstone", Waihao River (Finlay and Marwick 1937, p. 107, 120) and Otaio Gorge (Marwick 1960, p. 22) but has not been reported from Bortonian assemblages.

Figured specimen (Pl. 2t): GS10195, I44/f8486, Boulder Hill, Wangaloan (hypotype of Finlay and Marwick 1937, pl. 9, fig. 16) (NZGS) x 3.

Pl. 2 u, v. *Fyfea lirata* Finlay and Marwick, 1937 [p. 74]. Type species of *Fyfea* Finlay and Marwick, 1937 (Turbinellidae: Vasinidae?).

Very small for family (height 9-12 mm), broadly ovate. Protoconch described as "conoid-papillate". Teleoconch of 4-5 whorls, those on spire flat to slightly convex; last whorl with rounded periphery, base strongly excavated with a short, curved neck. Axial sculpture (apart from growth lines) normally absent, but some shells with weak nodules or costae on early whorls, persisting onto last whorl of a few specimens. Spiral sculpture of narrow cords with interspaces similar in width to cords or somewhat wider, about 30 on last whorl. Aperture pyriform with short siphonal canal; inner lip thickly but narrowly callused in adults, smooth except for a low fold at top of siphonal canal. Outer lip thin, gently sinuous.

Wangaloan, Boulder Hill (type) (common); Wangaloa (rare).

Fyfea is known only from the Paleocene of New Zealand. A second species, *F. tuberculata*, was described from Wangaloa—it differs from *F. lirata* in having fewer but stronger spiral cords, particularly on the base of the last whorl, and prominent peripheral nodules. The available material suggests that it is a distinct taxon rather than a variant of *F. lirata*.

Figured specimen (Pl. 2u, v): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 4.

Pl. 2 q, r. *Microfulgur longirostris* (Marshall, 1917) [*Latirus (Mazzalina) longirostris* Marshall 1917, p. 455; *Tudicula sulcata* Marshall 1917, p. 455]. Type species of *Microfulgur* Finlay and Marwick, 1937 (Turbinellidae: Vasinidae?).

Small for family (height 15-25 mm), pyriform, spire low, conical. Protoconch of 2 whorls, described as "conoid-papillate". Teleoconch whorls strongly clasping, reaching up to periphery of previous whorl; sutural ramp steep, slightly concave. Last whorl with rounded periphery, strongly excavated below to form long, curved neck. Axial sculpture of growth lines only; spiral sculpture of narrow, sharp cords which are much stronger on periphery than above or below. Aperture pyriform, columella gently convex with weak fold at top of the long, open siphonal canal. Inner lip moderately thickly callused over columella, thinly in parietal region. Outer lip thin, with weak sinus on ramp, gently convex and subvertical below.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (uncommon at both localities).

Microfulgur longirostris is superficially similar to *Fyfea lirata* but is somewhat larger and more elongate, and has a much longer siphonal canal. *Microfulgur* is known definitely only by the type species but Ponder (1970) described a Recent species, *Microfulgur(?) carinatus*, from 730 m off the Otago coast. Its generic assignment is very doubtful.

Figured specimen (Pl. 2q, r): GS10195, I44/f8486, Boulder Hill, Wangaloan (hypotype of Finlay and Marwick, 1937, pl. 9, fig. 7) (NZGS) x 3.

Pl. 2 m. *Tudiclana simulator* Finlay and Marwick, 1937 [p. 70]. Type species of *Tudiclana* Finlay and Marwick, 1937 (Turbinellidae: Vasinæ?).

Rather small for family (height 20-35 mm), pyriform, spire low. Protoconch apparently small, mamillate. Teleoconch whorls shouldered at or below middle on spire, sutural ramp almost flat. Last whorl with 3 or 4 prominent subequal keels, periphery broadly angled, strongly excavated below to form long, straight neck. Axial sculpture of small, rather sharp tubercles on keels and subdued collabral costae or ridges between keels. Tubercles much more prominent on 2 adapical keels than below; 20-25 on penultimate whorl. Spiral sculpture of narrow cords on keels and numerous much finer threads, some with even finer interstitial threads, over whole teleoconch surface. Aperture pyriform with a moderately long, open siphonal canal; columella almost straight with a low fold not visible from in front, above inception of canal. Inner lip thinly and narrowly callused; outer lip with a shallowly arcuate sinus on ramp, slightly convex and opisthocline below.

Wangaloan, Boulder Hill (type) (common); Wangaloa (very rare).

Tudiclana simulator is readily distinguished from *Microfulgur longirostris* by its lower spire, its tuberculate sculpture and its almost straight columella. *Tudiclana* is apparently closely related to *Tudicla* Röding, 1798, a genus that is first recorded from the Late Cretaceous and is represented in the modern fauna by a single species from the Bay of Bengal (Abbott 1959). It differs from *Tudicla* in its smaller size, having tuberculate sculpture, an unarmoured outer lip and a much weaker columellar fold, and in lacking a parietal plait. Rosenberg and Petit (1987, p. 58-60) discussed the confusion over *Tudicla* Röding, 1798, *Tudicula* H. and A. Adams, 1864, and the senior homonym *Tudicula* Ryckholt, 1862, provided the new name *Tudivasum* for *Tudicula* H. and A. Adams (preoccupied), and placed both *Tudicla* and *Tudivasum* in the Turbinellidae Vasinæ (following Abbott 1959). Rosenberg and Petit (1987, p. 60) listed *Tudicula sulcata*

Marshall, 1917 (= *Microfulgur longirostris*) among species incorrectly assigned to *Tudicula*. *Perissitys* Stewart, 1927, which is based on a Late Cretaceous species from California, is close to *Tudiclana* in sculpture but has two prominent folds or pseudofolds on the columella; it has recently been placed in its own family, *Perissityidae* (Popenoe and Saul 1987), but by the criteria of Rosenberg and Petit (1987) belongs in Turbinellidae Vasinæ. The family position of *Fyfea*, *Microfulgur*, *Tudiclana*, *Taioma* and *Heteroterma* is unclear, and we have tentatively left *Taioma* in *Taiomidae*, and refer the others tentatively to Turbinellidae Vasinæ.

Figured specimen (Pl. 2m): GS1494, M46/f9500, Wangaloa, Wangaloan (NZGS) x 1.5.

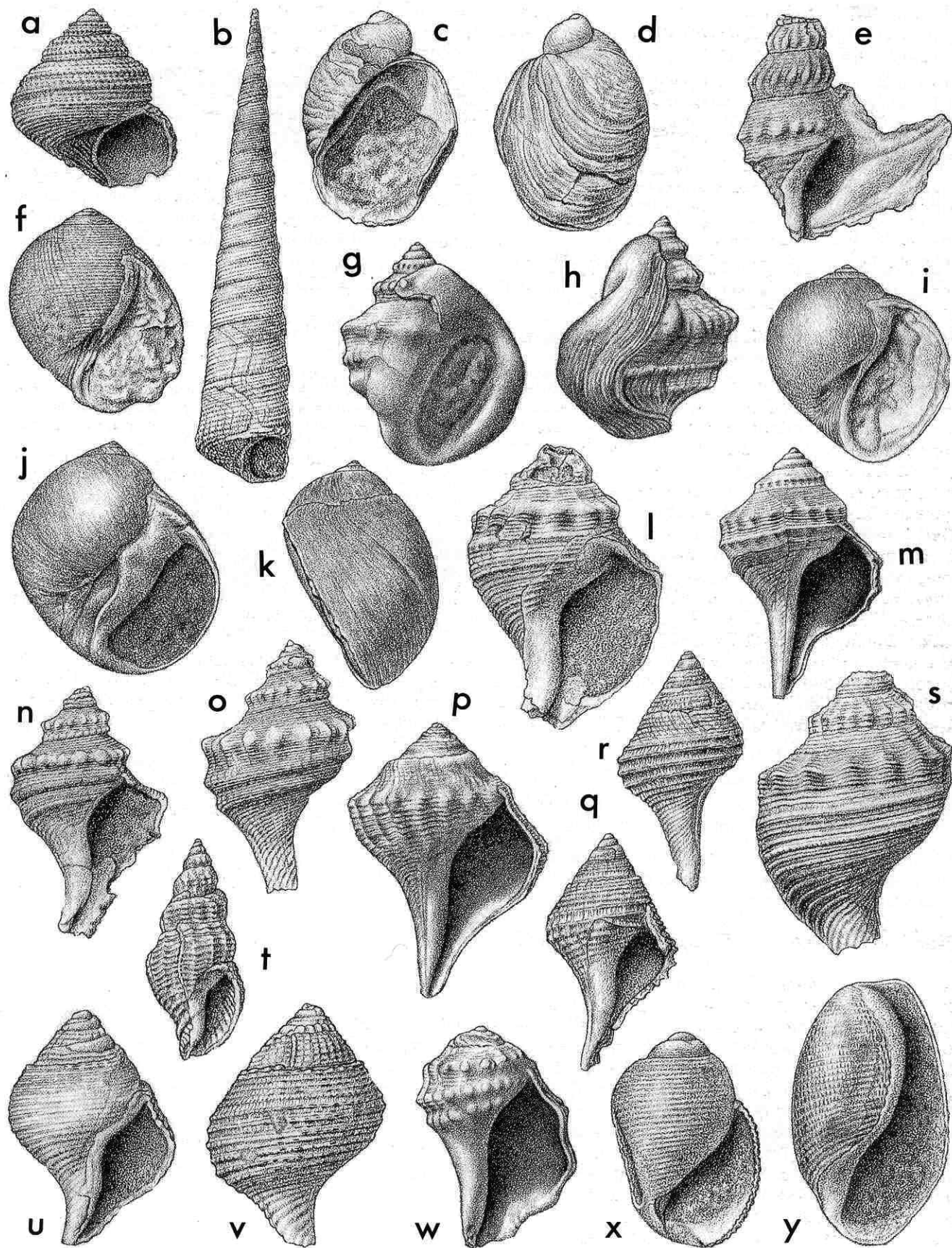
Pl. 2 p. *Heteroterma zelandica* Marshall, 1917 [p. 453] (Turbinellidae: Vasinæ?).

Size moderate for family (height 30-65 mm), pyriform; spire low, conical. Protoconch not known. Teleoconch whorls probably 6-8 in largest shells, strongly clasping, reaching up to periphery of previous whorl; sutural ramp concave. Last whorl with prominent peripheral angulation and weaker basal angulation, below which it is strongly excavated and contracted to a long, straight neck. Axial sculpture of short, slightly prosocline, rounded costae (15-18 on last whorl) extending from periphery to somewhat below basal angulation; sutural ramp with a subsutural row of low, rounded nodules, otherwise devoid of axial sculpture apart from growth lines. Spiral sculpture of narrow cords and threads which are noticeably stronger on whorl sides than on ramp or neck. Aperture pyriform, columella long, almost straight except for weak twist at inception of short, unnotched siphonal canal. Inner lip moderately and narrowly callused over columella, thinly callused in parietal region. Outer lip thin, with a broad shallowly arcuate sinus on ramp, slightly convex and almost vertical below.

Wangaloan, Wangaloa Formation Wangaloa (type) (not uncommon); Boulder Hill (common). Also doubtfully recorded from Red Bluff Tuff, Pukekio, Chatham Island (Teurian).

Plate 2 Early Paleocene ("Wangaloan") Mollusca (2).

- a. *Conominolia conica* (Marshall), x 3.
- b. *Zeacolpus (Leptocolpus) semiconcavus* (Suter), x 1.
- c,d. *Sigapatella (Spirogalerus) lamellaria* (Finlay and Marwick), x 1.5.
- e. *Drepanocheilus (Tulochilus) bensoni* Finlay and Marwick, x 5.
- f. *Globisium spirale* (Marshall), x 1.5.
- g,h. *Conchothyra australis* (Marshall), x 1.
- i. *Lunatia fyfei* (Marwick), x 1.
- j,k. *Polinices (Polinella) finlayi* (Marwick), x 1.5.
- l,s. *Galeodea (Taieria) allani* (Finlay and Marwick), x 1.5.
- m. *Tudiclana simulator* Finlay and Marwick, x 1.5.
- n,o. *Taioma tricarinata* Finlay and Marwick, x 1.5.
- p. *Heteroterma zelandica* Marshall, x 1.
- q,r. *Microfulgur longirostris* (Marshall), x 3.
- t. *Pseudofax ordinarius* (Marshall), x 3.
- u,v. *Fyfea lyrata* Finlay and Marwick, x 4.
- w. *Priscoficus obtusa* (Marshall), x 1.
- x. *Ongleya tholispira* Finlay and Marwick, x 3.
- y. *Priscaphander cingulatus* (Marshall), x 3.



Heteroterma is of uncertain affinity and has been included in the Turridae by some workers, but it has recently been assigned to the Tudicidae by Zinsmeister (1983, p. 1298), and tentatively to the Perissityidae by Popenoe and Saul (1987, p. 12). The type species, *H. trochoidea* Gabb, 1869, is from the Paleocene of California; other species are recorded from the Californian Paleocene, and possibly from the Late Cretaceous of Patagonia.

Figured specimen (Pl. 2p): GS10195, I44/f8486, Boulder Hill, Wangaloan (hypotype of Finlay and Marwick 1937, pl. 10, fig. 10) (NZGS) x 1.

Pl. 2 n, o. *Taioma tricarinata* Finlay and Marwick, 1937 [p. 72]. Type species of *Taioma* Finlay and Marwick, 1937 (Taiomidae?).

Moderately large for superfamily (height 25-50 mm), broadly fusiform, spire strongly gradate. Protoconch not known. Teleoconch of 6-7 whorls, strongly shouldered near or below middle on spire, last whorl with 2 additional, less prominent keels, upper one emerging from suture, sutural ramp flat or slightly concave. Last whorl strongly excavated with short, curved neck. Axial sculpture of prominent nodules on shoulder angulation (16-18 per whorl) and much less well defined ones on lower keels. Spiral sculpture of subequal threads over whole surface. Aperture pyriform, columella twisted to left medially to form moderately long, unnotched siphonal canal. Inner lip smooth, thinly callused; outer lip thin, with broadly arcuate sinus on ramp, its apex much closer to suture than to periphery.

Wangaloan, Boulder Hill (type) (rather uncommon); Wangaloa (rare).

Taioma is of uncertain affinity and was placed by Finlay and Marwick in its own family as it seems to combine characters of several muricean families. *T. tricarinata* is the only known New Zealand species, but the genus is recorded from the Late Eocene of Seymour Island (Zinsmeister 1982, table 3) and possibly also from the Paleocene of Greenland (specimen figured by Kollmann and Peel (1983, fig. 220) as "*Clinura* sp. 1"; also cast in NZGS, presented by A. Rosenkrantz).

Figured specimen (Pl. 2n, o): holotype, Boulder Hill, Wangaloan (Auckland Institute and Museum) x 1.5.

Pl. 2 x. *Ongleya tholispira* Finlay and Marwick, 1937 [p. 91]. Type species of *Ongleya* Finlay and Marwick, 1937 (Acteonidae).

Moderately large for family (height c. 14 mm), broadly ovate.

Protoconch heterostrophic, initial whorl small. Teleoconch of about 4 strongly convex whorls, last whorl very large, oval, with small pseudumbilicus. Sculpture of numerous strong spiral cords (c. 40 on last whorl) separated by deep, wide grooves that form regular pits where intersected by axial costellae. Aperture large, columella rather short with 2 distant, high plaits. Outer lip thin, not denticulate, strongly prosocline except near suture.

Wangaloan, Wangaloa Formation, Wangaloa (type) (rare).

Ongleya is monotypic, but is closely related to *Tornatellaea* Conrad, 1860—which also occurs at Wangaloa and Boulder Hill—differing from it in having a domed rather than a conic spire, and a strongly prosocline rather than an opisthocline outer lip.

Figured specimen (Pl. 2x): paratype, GS1494, M46/f9500, Wangaloa, Wangaloan (TM5748, NZGS) x 3.

Pl. 2 y. *Priscaphander cingulatus* (Marshall, 1917) [*Haminea cingulata* Marshall 1917, p. 458]. Type species of *Priscaphander* Finlay and Marwick, 1937 (Cylichnidae).

Moderately large for family (height 15-25 mm), oval, involute; apex non-umbilicate, covered by extension of parietal callus. Spiral sculpture of narrow, low, flat-topped or slightly convex cords separated by grooves of variable width. Axial sculpture of numerous, closely spaced costellae which are more obvious on cords than in grooves, and apparently become obsolete on the later part of the last whorl. Aperture large, constricted adapically; outer lip convex, thin, adapical end protruding above apex. Inner lip callus thin and laterally restricted except adapically where it spreads over apex and abapically where it covers the slightly convex columella.

Wangaloan, Wangaloa Formation, Wangaloa (type); Boulder Hill (common at both localities).

Priscaphander cingulatus is distinguished from species of *Scaphander*—a genus with several representatives in the New Zealand Cenozoic—by its oval shape, non-umbilicate apex and less concave columella. The genus is known definitely only by the type species, but Finlay and Marwick (1937, p. 92) noted the similarity of *P. cingulatus* to certain Eocene species from the Paris Basin and Louisiana.

Figured specimen (Pl. 2y): GS10195, I44/f8486, Boulder Hill, Wangaloan (NZGS) x 3.

CHAPTER 6. LATE PALEOCENE-EARLY EOCENE FAUNAS (TEURIAN-MANGAORAPAN STAGES): PLATES 3, 4

INTRODUCTION

Relatively little is known of the molluscan faunas that must have existed in the New Zealand region during the long period (at least 18 million years) between the Early Paleocene (Wangaloan) and the late Middle Eocene (Bortonian). It seems likely that some shallow-water

assemblages from North Otago and South Canterbury—particularly from the Kauru Formation (see previous chapter)—are of this age, but the lack of associated diagnostic microfossils has so far prevented reliable assignment of these faunules to any of the local stages. On the other hand, well dated rocks of Middle Paleocene

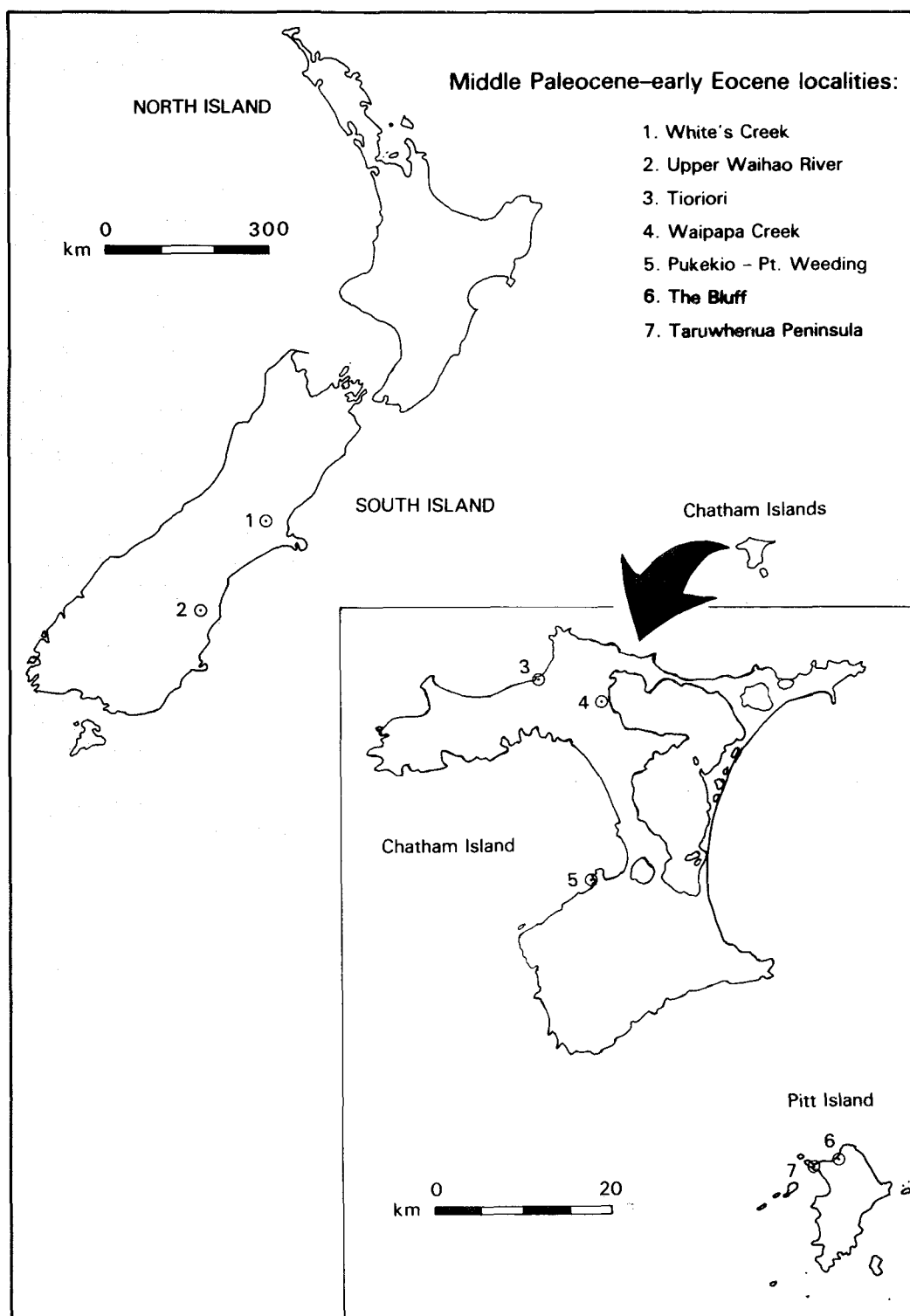


Figure 11 The main molluscan fossil localities of Teurian to Mangaorapan (Late Paleocene to Early Eocene) age.

to Early Eocene age typically lack molluscs entirely, or have only low-diversity faunules. The only reliably dated, moderately diverse faunules known at the present time are those from the Chatham Islands (mid-Teurian to Waipawan), and one from White's Creek, North Canterbury (Mangaorapan) (Fig. 11).

Chatham Islands

Rocks of Paleocene to Early Eocene age make up the bulk of the marine Tertiary sequence on the Chathams Islands, although this was not realised until quite recently. In particular, the thickest unit—the Red Bluff Tuff—was long thought to be much younger, of Middle to Late Eocene, or even Oligocene age. Four formations, the Takatika Grit, Red Bluff Tuff, Tutuiri Greensand and Matanginui Limestone are partly or wholly Paleocene, and molluscs have been collected from all except the first of these. The most diverse faunules are from the Red Bluff Tuff.

Red Bluff Tuff is particularly thick and well exposed in the coastal section between Pukekio and Point Weeding near Waitangi, Chatham Island. The type locality of the distinctive oyster *Pycnodonte* (*Notostrea*) *tarda* is probably from somewhere in this section, not—as thought by Marwick (1928, p. 462)—from the Tutuiri Greensand at Tioriori. Molluscs from the base of the section at Pukekio are poorly preserved but include pectens (particularly *Chlamys mercuria*), *Acesta* spp., *P. tarda*, two species of pleurotomariids (*Perotrochus* cf. *allani* and *Chelotia* (?) n.sp.), *Heteroterma* (?) sp., and two species of nautiloids (*Aturia* sp. and *Eutrephoceras* cf. *allani*). The presence of possible *Heteroterma* indicates weak correlation with the Early Paleocene Wangaloan faunules of mainland New Zealand. Better-preserved molluscs are present higher in the section, near the radio station—this is the type locality for nine species of bivalves and gastropods described by Marwick (1928) and for the nautiloid *Eutrephoceras allani*. The faunule includes abundant pectens (especially *Chlamys mercuria* and *Eburneopecten* n.sp.), *Hormomya* (?) *willeysi*, *Glyptoactis nuntia*, *Caryocorbula tophina* and *Perotrochus allani* (all illustrated here).

The most diverse faunules from the Red Bluff Tuff, however, are from two localities on Pitt Island, one from the west side of the neck of Tarawhenua Peninsula ("Rocky Side") (mid-late Teurian), the other from east of Flowerpot Harbour near "The Bluff" homestead (probably early Waipawan). These faunules (which differ considerably in composition, probably because of disparate depositional environments) include species of *Quadrilatera*, *Spondylus*, *Ctenoides*, *Acesta*, *Haliris*, *Emarginula*, *Anatoma*, *Bathybembix* (?), *Pareora*, Cypraeidae, Ranellidae, Personidae, *Teremelon*, Turridae and Epitoniidae. For many taxa this is their earliest New Zealand occurrence. The cypraeids include *Cypraea* (*Zoila*) n.sp. (see below) and *Bernaya chathamensis*—the latter species was described from "Flowerpot Harbour" and was thought to be from the Whenuataru Tuff (Pliocene) (Cernohorsky 1971a, p. 117–118) but the holotype is filled with typical Red Bluff Tuff matrix (Maxwell in Campbell et al. in prep.). The record of *Teremelon* is of considerable interest as it is the earliest undoubted volute so far known from the New Zealand

region, and furthermore is assigned to a still extant genus—*Paleopsephaea neozelanica* (Wangaloan, Boulder Hill) is almost certainly a turbinellid.

Except for the possible *Heteroterma* from Pukekio, and a specimen of a *Galeodea* similar to *G. (Taieria) allani* (Wangaloan, Boulder Hill) from Rocky Side, there is very little in common at the generic level between the Red Bluff Tuff faunules and those from Wangaloa or Boulder Hill. The Chathams faunules are for the most part significantly younger than the Wangaloan assemblages, but most of the disparity probably arises from environmental differences. The Red Bluff Tuff faunules inhabited a hard-ground substrate on the summits or flanks of volcanic sea-mounts in an oceanic environment, probably in moderately deep waters (i.e. at outer shelf or bathyal depths). The Wangaloan faunules, by contrast, have an inner shelf, soft-bottom aspect reflected in the considerable number of infaunal taxa (e.g. most of the bivalves). The considerable number of warm-water taxa in the Red Bluff Tuff (e.g. *Arca*, *Quadrilatera*, *Spondylus*, *Ctenoides*, *Perotrochus* and Cypraeacea (five species)) suggests subtropical conditions, despite the inferred high latitudinal position of the Chathams during the Paleocene and Early Eocene.

Molluscan faunules from the Tutuiri Greensand and Matanginui Limestone are less diverse than those from the Red Bluff Tuff. The Tutuiri Greensand, which is confined to the northern part of Chatham Island, is noteworthy as the source of the first Tertiary molluscs to be recorded from New Zealand (Dieffenbach 1841; Gray in Dieffenbach 1843, p. 296). One of these is *Pycnodonte tarda*, which occurs here in great profusion. Marwick (1928) described four other species from a locality usually known as "Tioriori" although it is actually 800 m to the north-east of Tioriori—these are *Serripecten tiorioriensis* (the oldest known species of this important genus), *Eburneopecten* (?) *imperfectus*, *Crenostrea cannoni* and *Cirsotrema* (*Tioria*) *youngi*.

Molluscs have been collected from the lower part of the Matanginui Limestone (early Waipawan) at a few localities. A pleurotomariid (apparently distinct from *Perotrochus allani*) is present at the base of the unit at Flowerpot Harbour, associated with *Spondylus* sp. and teredinid tubes. *Spondylus* also occurs in the lower part of the limestone at the mouth of Waipapa Creek, Chatham Island, with *Serripecten* cf. *tiorioriensis*, *Acesta* (*Plicacesta*) sp. (the oldest record of the subgenus), *Pycnodonte tarda* and *Crenostrea* cf. *cannoni*.

White's Creek, North Canterbury

The only well dated Early Eocene molluscan faunule so far recorded from New Zealand is from the View Hill Volcanics in White's Creek, a tributary of the Eyre River, near Oxford, North Canterbury. The local development of these volcanics (tuff and agglomerate associated with basalt) in shallow waters evidently allowed the establishment of a rich macrofauna; elsewhere, Early Eocene sediments consist largely of bathyal siltstone and mudstone (locally bentonitic) or micritic limestone (Amuri Limestone), which would have provided far less suitable substrates for molluscs. The only previously recorded mollusc from White's Creek is a species of the harpid *Eocithara* (Rehder 1973, p. 231), but recent

collections, particularly from a bed with abundant specimens of the orbitoid foraminifer *Asterocyclina speighti* (Chapman), have brought to light a diverse though rather poorly preserved assemblage. Taxa represented in the faunule include *Arca*, *Quadrilatera*, *Mytilidae* (including *Septifer*), *Spondylus*, *Haliotis* (sensu lato), *Rissoina*, *Pareora*, *Cerithiopsidae* (very diverse), *Triphoridae*, *Cypraea* (sensu lato), *Eratoinae*, *Sassia*, *Architectonicidae* and *Pyramidellidae*. Besides these benthic molluscs, the faunule includes a few thecosome pteropods, one of which closely resembles *Spiratella* (*Altaspiratella*) *bearnensis* (Curry, 1981), originally described from the Ypresian of southern France, and now known from other Early Eocene localities in France and England (A.W. Janssen, Rijksmuseum van Geologie en Mineralogie, pers. comm.). The presence of such taxa as *Quadrilatera*, *Septifer*, *Spondylus*, *Cypraea* and *Eocithara* indicate that conditions were at least as warm as during the Late Paleocene.

Upper Waihao River, South Canterbury

Rich well preserved molluscan faunules have been collected from shellbeds (here assigned to the Kauru Formation) in the upper reaches of the South Branch, Waihao River near "Pentland Hills". Some of these are probably Bortonian (Middle Eocene), but others, from the lower part of the marine Tertiary sequence, are significantly older and may be Early Eocene or even Paleocene. One well preserved faunule, from near the base of the sequence, includes *Propeleda*, *Acar*, *Spondylus*, *Plicatula* (only New Zealand record of the genus), *Lithophaga* (drilling into large colonial coral), *Eucrassatella australis*, *Gastrochaena*, *Rissoina*, *Spirocolpus*, *Strebloceras*, *Triphoridae*, *Ringiculina*, *Dischides* and chitons. A more diverse assemblage, from higher in the section, has *Austrotindaria*, *Quadrilatera*, *Limopsis*, *Notolimopsis*, *Dimya*, *Chama*, *Divaricella* (sensu lato), *Caryocorbula*, *Costacallista* aff. *hectori*, *Liotina turua* (type locality), *Teinostoma*, *Circulus*, *Triforis*, *Sigapatella*, *Gemmula*, *Cochlespira* (sensu lato), *Acteon* and *Pyramidellidae*. No age-diagnostic microfossils have been obtained from these beds, but pteropods from the younger assemblage include *Spiratella* (*Altaspiratella*) n.sp. aff. *bearnensis* and other species indicating a probable Early Eocene age. These faunules are here rather arbitrarily correlated with the Mangaorapan Stage.

Too little is yet known about Late Paleocene or Early Eocene molluscan faunas in New Zealand to say much about biogeographic affinities, but the considerable number of apparently warm-water taxa suggest a northern (Indo-Pacific or Tethyan) influence. On the other hand, there seem to be relatively few genus-group taxa that can be confidently identified as being endemic to New Zealand or to New Zealand and south-east Australia.

REPRESENTATIVE MIDDLE AND LATE PALEOCENE AND EARLY EOCENE MOLLUSCA

Pl. 4 a, d. *Acar* n. sp. (Arcidae: Arcinae).

Very small for family (length 6-7.5 mm), subtrapezoidal, strongly inequilateral, umbones broad and low, beaks prosogyrous, at about anterior quarter of length. Anterior margin convex, ventral margin

almost straight or somewhat sinuous, posterior margin truncate, dorsal margin long and straight. Posterior area very well defined, concave; umbonal ridge strong. Commarginal sculpture of prominent, low, imbricate, frill-like ridges of variable strength and spacing; and fine growth ridges. Radial sculpture on flanks of 15-23 narrow, low costae of variable spacing, crenulating the commarginal ridges or forming semitubular spines at their intersections. Posterior area with costae similar to those on flanks but more closely spaced, some apparently truly radial (i.e. arising from beak) but others diverging from umbonal ridge, all densely spinose. Hinge long and narrow, thinnest and edentulous for a short distance immediately behind beaks, teeth narrow, finely transversely grooved, radiating from a point well below hinge. Cardinal area very narrow, ligament opisthodontic. Adductor muscle scars prominent, anterior scar circular, posterior scar ovate, both slightly but distinctly raised above interior of shell. Anterior and posterior margins internally crenulate.

Mangaorapan?, Kauru Formation, South Branch, Waihao River near "Pentland Hills", South Canterbury (not uncommon).

The new species is similar to *Acar sociella* (Brookes, 1926) (Recent, northern New Zealand) in size and shape but has more prominent commarginal sculpture and better-developed spines. This is the oldest known New Zealand member of *Acar*, a genus that occurs sporadically in shallow-water assemblages up to the present day, and lives now under intertidal boulders on rocky shores, as well as byssally attached to boulders in deep water. *Acar* is characterised by its relatively small size, coarse commarginal and radial sculpture, very slender opisthodontic ligament, and raised adductor muscle scars. Most modern records are from tropical or subtropical regions.

Figured specimen (Pl. 4a, d): GS9957, J40/f6608, South Branch, Waihao River near "Pentland Hills", Mangaorapan? (NZGS) x 8.

Pl. 3 e. *Hormomya* (?) *willetsi* (Marwick, 1928) [*Mytilus* (*Aulacomya*) *willetsi* Marwick 1928, p. 444-445; *Aulacomya willetsi*; *Septifer willetsi*] (Mytilidae: Mytilinae).

Small for family (height 9-17 mm), mytiliform. Dorsal margin long, straight, weakly alate. Shell strongly inflated medially, with moderately well defined dorsal and ventral areas. Radial sculpture of low, rounded costae medially; dorsal and ventral areas with similar but somewhat divergent costae, some of which are radial, others branching off the main ribs. Commarginal sculpture of fine costellae in intercostal spaces, and growth ridges. Internal features not known, but umbonal septum apparently absent.

Waipawan (?), Red Bluff Tuff, sea-cliffs near radio station, Waitangi, Chatham Island (type) (common).

The affinities of this little mytilid are uncertain, but its overall size, shape and sculpture, and its association with warm-water molluscs, makes assignment to the cool-water genus *Aulacomya* unlikely. It is superficially similar to some species of *Septifer* (see below) but no trace of an umbonal septum—the diagnostic character of that genus—could be observed in any of the available material, possibly because of the rather poor preservation of most specimens. It is here tentatively included in *Hormomya*, species of which resemble *Septifer*, but lack a septum.

Figured specimen (Pl. 3e): holotype, GS10191, CH/f104, sea-cliffs near Waitangi radio station, Chatham Island, Waipawan (?) (TM4180, NZGS) x 3.

Pl. 4 h. *Eburneopecten* (?) n. sp. (Pectinidae).

Small for family (height 12-22 mm), higher than long, left valve

apparently somewhat more inflated than right. Anterior ears considerably larger than posterior ears, dorsal margins colinear; byssal notch moderately deep, fasciole depressed, ctenolium apparently absent. Disc with relatively prominent "Camptonectes" sculpture of divergent, discontinuous and rather irregular grooves, typically absent from proximal and central areas on larger shells. Radial sculpture of very low, flattened costellae, typically appearing at 3-4 mm from umbo, but not obvious on figured specimen until about 18 mm, seemingly divaricating distally because of intersecting "Camptonectes" grooves. Radial costellae on ears considerably more prominent than those on disc. Commarginal sculpture of very fine threads.

Waipawan (?), Red Bluff Tuff, sea-cliffs near radio station, Waitangi, Chatham Islands, not uncommon.

The new species is readily differentiated from most other New Zealand pecten by its small size, by its relatively prominent "Camptonectes" sculpture, and by having weak radial sculpture on the disc but more prominent radials on the ears. *Eburneopecten*(?) *imperfectus* (Marwick, 1928) (Waipawan, Tioriori, Chatham Island) is larger than the undescribed species (height of holotype, the only known specimen, 27 mm), is more circular in shape, has relatively strong radial sculpture on the left valve but only feeble striae on the right, and has smooth ears. Neither species seems to be closely related to any other known New Zealand pecten, and they are tentatively referred to *Eburneopecten* Conrad, 1865, which has been recorded previously from the Eocene and Oligocene of North America and Europe.

Figured specimen (Pl. 4h): GS12139, CH/f104A, sea-cliffs near Waitangi radio station, Chatham Island, Waipawan (?) (NZGS) x 2.

Pl. 4 e, f. *Chlamys* (sensu lato) *mercuria* Marwick, 1928 [p. 457] (Pectinidae).

Small for genus (height 12-20 mm), higher than long, apical angle acute, right valve more inflated than left. Anterior ears considerably larger than posterior ones, dorsal margins colinear; byssal notch well defined. Radial sculpture on disc of 22-24 prominent convex or subtriangular-sectioned costae. Surface apparently originally covered with rasp-like ("shagreen") microsculpture of diagonally intersecting lamellae producing a cellular pattern, but preserved only in intercostal spaces in most specimens. Anterior ears with a few weak radial costae.

Teurian-Waipawan, sea-cliffs near radio station, Waitangi (type) (common); Pukekio, Chatham Island (common); Tarawhenua Peninsula, Pitt Island (rare). All localities in the Red Bluff Tuff, Chatham Islands. This distinctive little pecten is readily distinguished from other New Zealand species of *Chlamys* by its small size, acute apical angle, very unequal ears, simple radial sculpture (i.e. without secondary costae) and rasp-like microsculpture.

Figured specimen (Pl. 4e, f): GS12169, CH/f477, Pukekio, near Waitangi, Chatham Island, Teurian (NZGS) x 3 and x 16.5.

Pl. 4 b. *Serripecten tiorioriensis* Marwick, 1928 [p. 458] (Pectinidae).

Small for genus (height 30-40 mm), known definitely only by the right valve, but left valve possibly represented by specimen from Pitt Island that is less inflated than right valve. Dorsal margins of right valve weakly divergent, finely serrate, those of putative left valve colinear. Radial sculpture on right valve of 37-38 narrow, rather low costae with somewhat broader interspaces, almost smooth over most of their length but becoming weakly scaly and developing a narrow, scaly costella in interspaces distally. Anterior ear with 4 or 5, posterior ear with 6 narrow, scaly radial costae. Presumed left valve with about 38 costae, more subdued than on right valve and becoming obsolete towards dorsal margins. Commarginal sculpture of growth lines and ridges.

Late Teurian-Waipawan(?); Tutuiri Greensand, Tioriori, Chatham Island (type); Matanginui Limestone, mouth of Waipapa Stream, Chatham Island; ? Tarawhenua Peninsula, Pitt Island (uncommon at all localities).

Serripecten tiorioriensis is the oldest known member of the genus and is differentiated from younger species by its small size and its relatively simple radial sculpture, particularly the nearly smooth nature of the costae and the late appearance of secondary costellae. *Serripecten* (which is also present in the Cenozoic of southern Australia) ranges up to Tongaporutuan in New Zealand and is one of the most characteristic pecten genera in shallow-water sediments, particularly in greensand and limestone. Only five species have been described to date, but several additional species are known, mostly from the Late Eocene and Early Oligocene (see below).

Figured specimen (Pl. 4b): topotype, GS12140, CH/f254A, Tioriori, Chatham Island, late Teurian(?) (NZGS) x 1.5.

Pl. 4 c, g. *Spondylus* n. sp. (Spondylidae).

Rather small for genus (height 35 mm), known only by the little-inflated, unattached left valve. Ears subequal, small. Radial sculpture of about 30 narrow, finely spinose costae, some with smooth or weakly spinose or scaly costellae in between, in places as strong as primary costae. Commarginal sculpture of very fine growth lines. Cardinal area very narrow; resilifer narrowly triangular, separated from prominent sockets on either side by narrow ridges. Crura large, upturned, adjacent to sockets. Adductor muscle scar large, subcircular. Internal margin finely crenulate.

Mangaorapan (?), Kauru Formation, South Branch, Waihao River near "Pentland Hills" in shell-rich greensand with abundant corals (not common).

The new species is very similar to *Spondylus aucklandicus* (Otaian-Clifdenian, Northland, Westland and Southland) but has relatively stronger secondary radial costae. *Spondylus* is generally regarded as an indicator of warm-water (subtropical or tropical) conditions, although *S. tenellus* Reeve, 1856 lives today in Tasmania and other parts of southern Australia, and *S. sparsispinosus* Dall, Bartsch and Rehder, 1938 (= *S. erectospinus* Habe, 1973) lives in deep water off northern New Zealand. The genus is recorded from the Late Cretaceous in New Zealand, but for a long time it was thought that the only Cenozoic occurrences were of Early Miocene age. More recent work has steadily increased its stratigraphic range, and it is now known to have been present from at least Late Paleocene (late Teurian or Waipawan, Chatham Islands) to Late Miocene (Waiauau, Waikuku Beach, North Cape). The record is very sporadic but the fact that the species illustrated here is very similar to the Early Miocene *S. aucklandicus* suggests that *Spondylus* has been present continuously in the New Zealand region from at least Early Eocene to Middle Miocene. The alternative possibility, that the scattered occurrences of *Spondylus* all represent independent, short-lived dispersals, seems less likely.

Figured specimen (Pl. 4c, g): GS11650, J40/f6612, Waihao River, near "Pentland Hills", Mangaorapan ? (NZGS) x 1.5.

Pl. 3 d, g. *Plicatula* n. sp. (Plicatulidae).

Size moderate for genus (height 25-35 mm), subtrigonal, known only by the thick, lamellar-shelled right valve. Sculpture of irregular, spinose

radial costae, mostly abraded from available specimens. Hinge prominent, cardinal area very small, noted only on young, less-abraded shells. Resilifer narrowly tubular, bounded by and largely covered by low, divergent ridges. Crura prominent, rather narrow but high, transversely grooved, separated from resilifer by prominent sockets. Adductor muscle scar large, sub-circular, in posterior position. Internal margin irregularly crenulate.

Same locality as *Spondylus* n. sp. (above) (moderately common, but rather poorly preserved). This is the only species of *Plicatula* so far recorded from New Zealand. The genus is confined to the tropics at the present day but it seems to have had a more cosmopolitan distribution in the past.

Figured specimen (Pl. 3d, g): GS11650, J40/f6612, Waihao River, near "Pentland Hills", Mangaorapan ? (NZGS) x 1.5.

Pl. 3 i. *Acesta* n. sp. (Limidae).

Small for genus (height 70 mm), ovate-trigonal, strongly inequilateral and oblique, little inflated. Anterior area narrow, lanceolate, strongly depressed. Posterior ear moderately large, triangular; anterior ear very small, not visible in external lateral view. Posterior and anterior margins long, straight, steeply sloping, merging smoothly with strongly convex ventral margin. Commarginal sculpture of fine growth lines and stronger growth ridges. Radial sculpture of narrow, low, rounded, wavy costae of uneven spacing over most of exterior, including ears and anterior area. Cardinal area narrow, triangular, resilifer narrowly triangular, strongly oblique, directed posteriorly.

Late Teurian, Red Bluff Tuff, Tarawhenua Peninsula, Pitt Island, Chatham Islands (rare).

The new species is apparently most closely related to *A. imitata* (Waitakian, Waipara River) but is much smaller and less strongly inflated, and has stronger radial sculpture at a similar stage of growth. Only three nominal species of *Acesta* have been described from New Zealand—*A. imitata*, which has narrow but definite radial costae over most if not all of the exterior; *A. regia* (Whaingaroan?, Seal Rock, Woodpecker Bay, Southwest Nelson) with definite radial costae near the anterior and posterior margins but only grooves medially; and *A. levitesta* (Waitakian, Milburn Quarry, Otago; widespread), which is almost smooth except for a few weak ribs or grooves near the margins. All are large (height 150-210 mm) and thin-shelled and are rarely collected in anything like a complete condition, so the range of variation and limits of these nominal species are poorly known. In New Zealand the genus is recorded fossil from Haumurian (Late Cretaceous) to Mangapanian, and Recent from the bathyal zone (see Beu 1973b, p. 315-316 for details of occurrences). The modern species is very similar to *A. levitesta*. Most overseas records of the genus are bathyal but one extant species is recorded as shallow as 29 m (Vokes 1963). New Zealand fossil occurrences are mainly from limestone, marl and greensand inferred to have been deposited in moderately deep, offshore waters.

Figured specimen (Pl. 3i): GS12173, CH/f478, Red Bluff Tuff, neck of Tarawhenua Peninsula, Pitt Island, Teurian (NZGS) x 1.5.

Pl. 3 b, c. *Pycnodonte* (*Notostrea*) *tarda* (Hutton, 1873) [*Gryphaea tarda* Hutton 1873b, p. 35; *Notostrea tarda*; *Ostrea* (*Notostrea*) *tarda*] (Gryphaeidae: Pycnodonteinae).

Small for genus (height 35-60 mm), gryphaeiform, strongly inequivalve with left (lower) valve highly inflated and incurved, right valve flat or

concave. Some shells subequilateral, others strongly oblique. Left valve with shallow posterior radial sulcus. Attachment area absent or very small, confined to apex. Shell with vesicular structure typical of Pycnodonteinae. No sculpture apart from growth lines and ridges. Ligamental area small with relatively large resilifer; left valve with narrow commissural shelf well within shell to take margins of right valve. Chomata restricted to area near hinge, weakly developed in some shells, absent from others. Adductor muscle scar subcircular, situated much closer to hinge than to ventral margin.

Teurian-Waipawan, "Chatham Island" (type—probably from Red Bluff Tuff in the Pukekio-Point Weeding section near Waitangi); Tutuiri Greensand, Tioriori, north Chatham coast where it is very abundant (mistakenly thought to be the type locality by Marwick (1928, p. 462))—also several other localities in Red Bluff Tuff and Matanginui Limestone, Chatham Islands. Not yet recorded from mainland New Zealand.

P. (Notostrea) tarda differs from the poorly known *P. (Notostrea) subdentata* (Pl. 9b, f)—the type species of the subgenus—in its larger size, more strongly inflated and incurved left valve and much weaker chomata. The shape is strongly reminiscent of the Late Triassic to Late Jurassic genus *Gryphaea* Lamarck, 1801, but the presence of vesicular shell material in *P. (Notostrea) tarda* indicates affinities with Pycnodonteinae rather than Gryphaeinae. Stenzel (1971, p. N1094, N1168) considered *Notostrea* to be "valueless" and of uncertain taxonomic position. It is here classed as a subgenus of *Pycnodonte*, differing from that taxon primarily in its elongate rather than subcircular outline, in having a very short hinge and in having the left valve umbo projecting well above the dorsal margin.

P. (Notostrea) lubra Finlay (in Marwick 1928, p. 432; new name for *Gryphaea tarda* "Hutton" of Tate, not of Hutton) is a southern Australian Middle or Late Eocene species closely resembling *P. (N) tarda*. Although described from the Great Australian Bight, *P. lubra* is best known in a thin greensand bed between the two Eocene molluscan assemblages in mudstone at Browns Creek, Johanna, west of Cape Otway, Victoria, recorded by Darragh (1985, p. 100). To our knowledge, these three are the only species referable to *P. (Notostrea)*.

P. (Notostrea) tarda has a very small attachment area or lacks one entirely, suggesting that it lay free on the sea-floor during most of its life.

Figured specimen (Pl. 3b, c): GS1177, CH/f3, Tioriori, Chatham Islands, late Teurian ? (hypotype of Marwick 1928, figs. 93-96) (TM2931, NZGS) x 1.

Pl. 3 a, f. *Crenostrea cannoni* (Marwick, 1928) [*Ostrea cannoni* Marwick 1928, p. 462] (Gryphaeidae: Pycnodonteinae).

Rather small for genus (height 132 mm), subtrigonal, known definitely only by the thick-shelled but only slightly inflated left valve. Umbo subtriangular, projecting strongly above hinge. Shell apparently composed of alternating lamellar and vesicular calcite. Attachment area large. Sculpture highly irregular, of puckers and welts; some suggestion of radial folds. Ligamental area large, triangular, with prominent central resilifer. Chomata very weakly developed, adjacent to ligamental area. Adductor muscle scar suboval, slightly posterior to middle of valve.

Late Teurian-Waipawan, Tutuiri Greensand, Tioriori, north Chatham coast (rare); ? Matanginui Limestone, mouth of Waipapa Stream, Chatham.

Crenostrea cannoni is the oldest known member of the genus, differing from *C. wuellerstorfi* (Pl. 12a, b) in its

more equilateral shape, much larger ligamental area and smaller adductor muscle scar, and in having almost obsolete chomata. *Crenostrea* was long thought to be endemic to New Zealand, but a species of probable Oligocene age has been described from Costa Rica (Woodring 1976).

Figured specimen (Pl. 3a, f): holotype, GS1177, CH/f3, Tioriori, Chatham Island, late Teurian ? (TM4286, NZGS) x 0.67.

Pl. 3 j. *Glyptoactis (Fasciculicardia ?) nuntia* (Marwick, 1928). [*Venericardia nuntia* Marwick 1928, p. 466; *V. (Fasciculicardia) nuntia*] (Carditidae: Venericardiinae).

Small for genus (length 13-17 mm), of rounded outline, posterior end only weakly truncate. Posterior area slightly concave. Lunule small, pouting. Radial sculpture of about 25 prominent costae of triangular section, those on flanks nearly smooth-crested with very broad intercostal spaces, those on posterior area and near anterior end prominently tuberculate and somewhat more closely spaced. Commarginal sculpture of numerous, closely spaced, very fine threads in intercostal spaces. Right hinge with anterior cardinal almost obsolete, fused to lunule, median cardinal very prominent, broadly triangular. Left hinge imperfectly known but having a long, narrow posterior cardinal and, presumably, a small, triangular anterior cardinal.

Waipawan (?), Red Bluff Tuff, sea-cliffs near radio station, Waitangi, Chatham Islands (type) (uncommon).

Glyptoactis nuntia is distinguished from other New Zealand venericardiines by its small size, its rounded outline and its broadly triangular, widely separated radial costae that are almost smooth-crested on the flanks. Although it was referred to *Fasciculicardia* by Maxwell (1969, p. 173), none of the available specimens of this species have the tripartite costae characteristic of *Fasciculicardia* and other subgenera of *Glyptoactis*. However, in most other respects it is similar to *G. (Fasciculicardia) acanthodes* (Pl. 5g, h) and is considered to be consubgeneric. The absence of tripartite ribbing in *G. nuntia* may be related to its relatively small size.

Figured specimen (Pl. 3j): holotype, GS10191, CH/f104, near Waitangi radio station, Chatham Island, Waipawan (?) (TM4319, NZGS) x 3.

Pl. 3 k, l. *Costacallista hectori* (Finlay and Marwick, 1937) [*Notocallista hectori* Finlay and Marwick 1937, p. 101] (Veneridae: Pitarinae).

Rather small for family (length 12-25 mm), ovate, moderately inflated.

Lunule small, scarcely impressed; no escutcheon. Commarginal sculpture of prominent rounded costae, interspaces typically similar in width to costae, or wider. Left hinge with prominent anterior lateral tooth parallel to lunular margin, a thin, vertical anterior cardinal, a triangular median cardinal and a horizontal, lamellar posterior cardinal tooth. Right hinge with deep anterior lateral socket bounded by low lateral teeth, parallel narrow anterior and median cardinals, and a thin, bifid posterior cardinal tooth. Pallial sinus moderately deep, rounded, slightly ascending. Inner margins smooth.

Dannevirke Series, probably about Mangaorapan-Porangan, Castle Hill Shaft, Kaitangata (type); Kauru Formation, Otaio Gorge; South Branch, Waihao River near "Pentland Hills" (common). The type material consists of badly decorticated shells imbedded in very hard matrix, and is rather less elongate than the Otaio Gorge or Waihao specimens, which suggests that the latter material may not be conspecific.

The type species of *Costacallista* is a relatively large Recent Indo-Pacific species, *C. erycina* (Linné, 1758), but in New Zealand the genus is not known later than Bortonian.

Figured specimens (Pl. 3k, l): GS9957, J40/f6608, South Branch, Waihao River near "Pentland Hills", Mangaorapan ? (NZGS) x 2.

Pl. 3 h. *Caryocorbula tophina* (Marwick, 1928) [*Corbula tophina* Marwick 1928, p. 473] (Corbulidae).

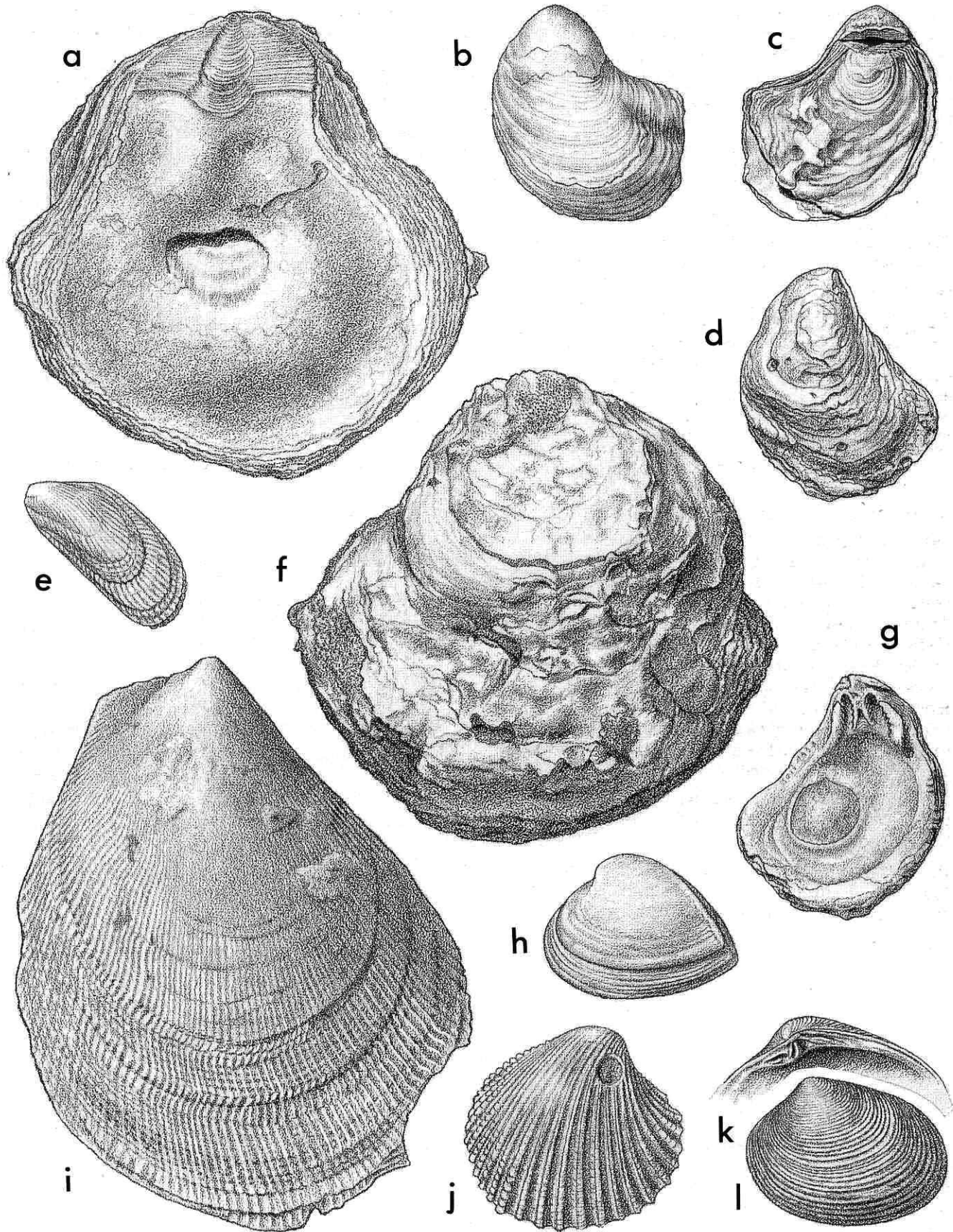
Rather small for genus (length 6.5-8.5 mm), inequivalve, right valve somewhat higher than left but apparently only very slightly longer. Umbones very prominent, broadly rounded; umbonal ridge sharp in both valves forming well defined posterior areas. Sculpture of low, rounded commarginal ridges, typically missing over much of shell because of abrasion, similar in nature on both flanks and posterior areas. Hinge imperfectly known, right valve with a tubercular, tooth-like chondrophore some distance behind beak, fitting into corresponding socket on left valve. Other internal features unknown.

Waipawan (?), Red Bluff Tuff, sea-cliffs near radio station, Waitangi, Chatham Island (type) (uncommon).

Caryocorbula tophina is distinguished from other named New Zealand corbulids by its small size, its subequivalve shape, its prominent umbones and sharp umbonal ridges, and by having commarginal sculpture on the posterior area similar to that on the flanks. *C. nitens* (Otaian - Altonian, Pakaurangi Point, Northland) is closest, but is smaller and more elongate, and has less prominent umbones and finer commarginal sculpture. Corbulids are quite well represented in the New Zealand Cenozoic

Plate 3 Middle Paleocene-Early Eocene (Teurian-Mangaorapan) Mollusca (1).

- a, f. *Crenostrea cannoni* (Marwick), x 0.67.
- b, c. *Pycnodonte (Notostrea) tarda* (Hutton), x 1.
- d, g. *Plicatula* n.sp., x 1.5.
- e. *Hormomya(?) willetsi* (Marwick), x 3.
- h. *Caryocorbula tophina* (Marwick), x 4.
- i. *Acesta* n.sp., x 1.5.
- j. *Glyptoactis (Fasciculicardia) nuntia* (Marwick), x 3.
- k, l. *Costacallista hectori* (Finlay and Marwick), x 2.



fauna, but only one species, *Caryocorbula zelandica* (Opoitian-Recent), is still extant. This has a recorded depth range of 0-90 m (Powell 1979, p. 428), but some fossil species of *Caryocorbula* seem to have extended down into deeper waters (c. 200 m).

Figured specimen (Pl. 3h): holotype, GS10191, CH/f104, near Waitangi radio station, Chatham Island, Waipawan (?) (TM4771, NZGS) x 4.

Pl. 4 i. *Perotrochus allani* Marwick, 1928 [p. 474-475] (Pleurotomariidae).

Size moderate for genus (height 60 mm), trochiform. Protoconch not known; teleoconch of about 8 whorls, those on spire lightly convex to obtusely angled; last whorl prominently subangled, base lightly convex with a shallow central depression but no true umbilicus. Spiral sculpture of fine threads above selenizone and somewhat coarser ones below, 5 and 8 respectively on penultimate whorl. Adapical spirals on early whorls finely nodulose, otherwise smooth. Base with numerous additional fine spiral lirae becoming obsolete adaxially. Aperture rhomboidal, columella oblique, slightly arcuate, strongly twisted near adapical end. Outer lip with narrow slit near middle, apparently extending back only 0.1 whorl or so of circumference.

Teurian-Waipawan (?), Red Bluff Tuff, sea-cliffs near radio station, Waitangi, Chatham Island (type) (rare); base of Pukekio-Point Weeding section, Chatham Island (rare).

Pleurotomariids are very rare in the New Zealand Cenozoic, and only two other species have been described to date. *P. marwicki* Fleming, 1970 (Altonian, Tarakohe Quarry, Takaka) is larger than *P. allani*, has a less rounded profile and has more numerous, more prominent spiral cords. *P. masoni* Maxwell, 1978 (Duntroonian, Hakataramea Valley) is also much larger than *P. allani*, is more depressed than *P. allani* or *P. marwicki*, and has much weaker basal spiral sculpture. Extant species of *Perotrochus* (and its relative *Entemnotrochus*) are eagerly sought-after by collectors; most are from tropical or subtropical regions and from moderately deep waters (typically outer shelf or upper bathyal zones), although two species live in deep water in the New Caledonia-Kermadec Islands area, and one extends as far south as Betty Guyot, Three Kings Rise, off northern New Zealand (Bouchet and Métivier 1982).

Figured specimen (Pl. 4i): holotype, GS10191, CH/f104, near Waitangi radio station, Chatham Island, Waipawan (?) (TM4905, NZGS) x 1.

Pl. 4 o. *Bathybembix* (?) n. sp. (Trochidae: Margaritinae).

Size moderate for family (height 28 mm), turbiniform, spire elevated. Protoconch not known; teleoconch of about 6 whorls, those on spire biangulate, the adapical angulation near middle of whorl, the other somewhat less prominent and close to lower suture. Last whorl with 2 additional, much weaker angulations on base. Spiral sculpture of 2 narrow cords marking keels on spire whorls with another, much weaker one appearing between abapical keel and lower suture on penultimate whorl, emerging on base as the upper basal angulation, accompanied by 2 even weaker cords below. Axial sculpture on early whorls of narrow, strongly prosocline costellae that form small, sharp tubercles at intersections with spiral keels. On later whorls costellae becoming obsolete except for short ridges on upper part of ramp, but tubercles remaining prominent on keels, those on lower keel smaller and more numerous than those above. Basal angulations only feebly nodulose. Aperture circular, prosocline, peristome discontinuous, outer lip reflected to form narrow varix, 1 or 2 varices persisting at earlier stages of growth.

Teurian-Waipawan (?), Red Bluff Tuff, Tarawhenua Peninsula, Pitt Island (uncommon); Pt Weeding, Chatham Island (uncommon).

This distinctive species is only doubtfully referred to *Bathybembix*, as typical members of the genus do not have a reflected outer lip or varix. A reflected outer lip is present in the type species of *Turricula* Dall, 1881 but this is distinguished from the Chathams species by having vermiculate background sculpture. *Bathybembix* itself is a deep- and cool-water genus at the present day (Hickman 1980, p. 16), so its presumed occurrence with distinctly warm-water molluscs in the Red Bluff Tuff would be somewhat anomalous.

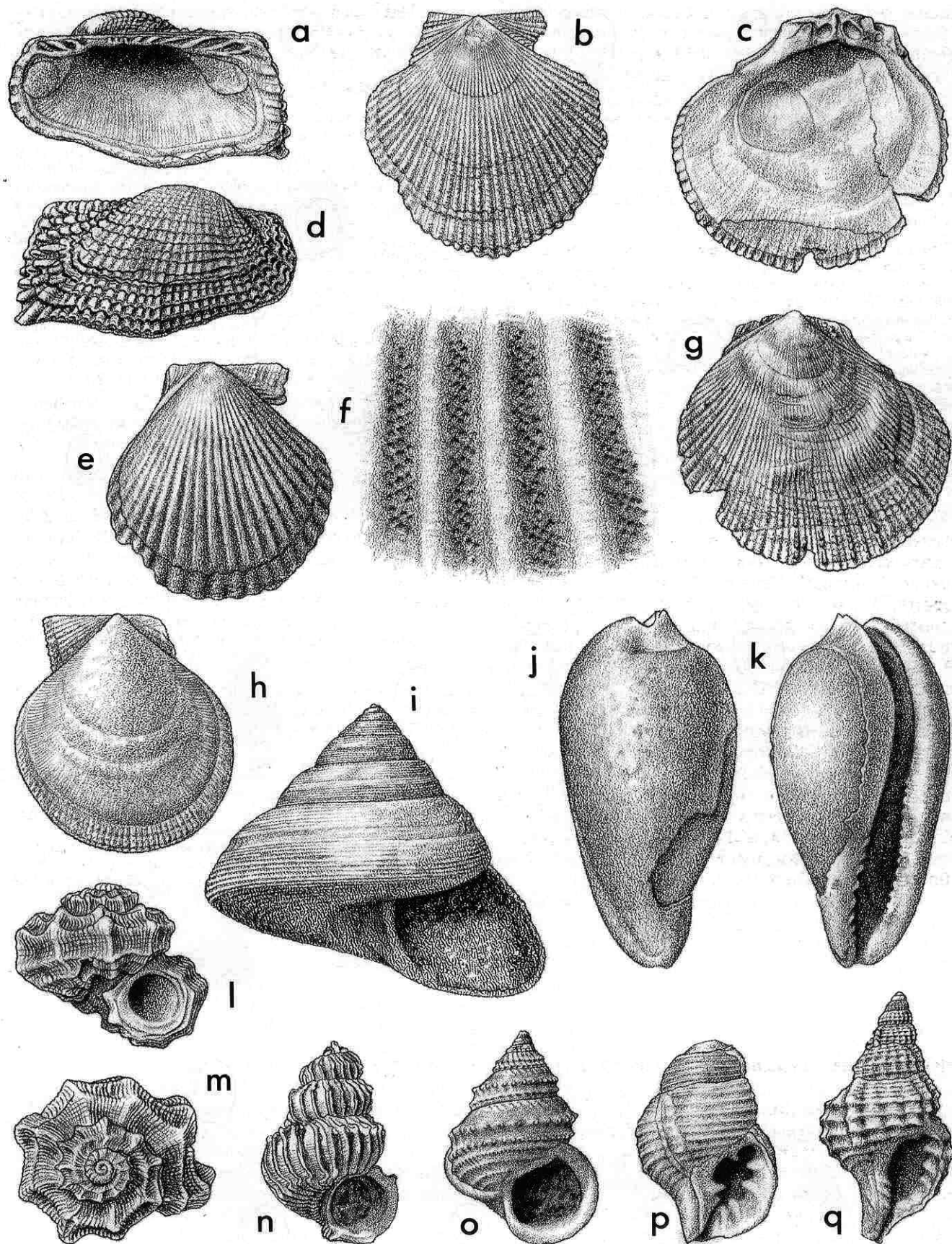
Figured specimen (Pl. 4o): neck of Tarawhenua Peninsula, Pitt Island, Teurian (Otago University Geology Department) x 1.5.

Pl. 4 l, m. *Liotina turua* Maxwell, 1978 [p. 32-33] (Liotiidae).

Size moderate for genus (diameter c. 7 mm), depressed turbiniform, apex flattened. Protoconch of about 1.2 smooth whorls. Teleoconch whorls 3.5, early whorls depressed, later ones moderately elevated. A prominent keel appearing adapically at an early stage of growth, forming a broad subhorizontal shelf, then gradually descending to near middle

Plate 4 Middle Paleocene-Early Eocene (Teurian-Mangaorapan) Mollusca (2).

- a,d. *Acar* n.sp., x 8.
- b. *Serripecten tiorioriensis* Marwick, x 1.5.
- c,g. *Spondylus* n.sp., x 1.5.
- e,f. *Chlamys mercuria* Marwick, x 3; and sculpture enlarged, x 16.5.
- h. *Eburneopecten* n.sp., x 2.
- i. *Perotrochus allani* Marwick, x 1.
- j,k. *Cypraea* (*Zoila*) n.sp., x 1.5.
- l,m. *Liotina turua* Maxwell, x 5.
- n. *Cirsotrema* (*Tioria*) *youngi* Marwick, x 2.
- o. *Bathybembix* n.sp., x 1.5.
- p. *Kotakaia simplex* Beu, x 2.
- q. *Sassia* (*Sassia*) n.sp. A, x 1.5.



of whorl, accompanied by a second keel between it and upper suture. A prominent peribasal keel and 2 somewhat weaker ones appearing on last whorl. Spiral sculpture, apart from cords marking the keels on later whorls, of 1 or 2 cords within umbilicus, and much finer threads between keels. Axial sculpture on early whorls of narrow, prosocline costae which bifurcate adapically; on later whorls of very prominent, broadly triangular costae which extend into umbilicus; 12-13 on penultimate whorl, 8-9 on last whorl. Between costae are numerous lamellae which initially diverge from sides of costae, but later become parallel to them, and are reticulated by spiral threads. Aperture circular, nacreous within; peristome continuous, outer lip with heavy rounded varix. Umbilicus narrower in adults than in juveniles, margin serrated by axial costae.

Mangaorapan ?, Kauru Formation, South Branch, Waihao River, near "Pentland Hills", associated with *Spondylus* n. sp., *Plicatula* n. sp. and *Costacallista hectori* (see above).

Liotina turua is the only species of this characteristically warm-, shallow-water genus known from New Zealand, although the related genus *Munditia* Finlay, 1926 is represented in Neogene and modern faunas by several species.

Figured specimen (Pl. 4l, m): holotype, GS9957, J40/f6608, Waihao River, Mangaorapan ? (TM5470, NZGS) x 5.

Pl. 4 j, k. *Cypraea (Zoila)* n. sp. (Cypraeidae).

Size moderate for family (height 45-53 mm), slender, constricted anteriorly. Protoconch not distinguishable from rest of shell, apical whorls forming a narrowly conical spire fused to and scarcely protruding beyond the posterior prolongation of the inner lip. No sculpture. Aperture narrow, inner and outer lips almost parallel except near anterior end where they diverge somewhat above the narrow siphonal channel. Posterior end of inner lip a sharp, curved ridge fused to spire. Denticles on inner and outer lips rather weak, absent from posterior third or so. Columella with well developed fossula near anterior end, flat or slightly convex above.

Waipawan (?), Red Bluff Tuff, coast northeast of Flowerpot Harbour, Pitt Island, Chathams, associated with warm-water molluscs including *Spondylus*, *Ctenoides* and another cypraeid.

Cypraeacea are typically tropical or subtropical in distribution at the present day, and have a very patchy fossil record in New Zealand. At least four species (the oldest recorded from the New Zealand region) occur in the Red Bluff Tuff on Pitt Island, confirming evidence from other fossil groups that the Late Paleocene was one of the warmest periods in the New Zealand Cenozoic. *Cypraea (Zoila)* n. sp. is the oldest known species of the subgenus, differing from the type species *C. friendi* Gray, 1831 (Recent, southern Western Australia to South Australia) in its smaller size, more slender shell, narrower spire and more constricted anterior end, and in lacking a ventral callus pad. Other fossil records of *Zoila* are from the Late Miocene of southeast Australia and from the Late Miocene-Pleistocene of India and the Indo-Malay Archipelago (Wilson and McComb 1967).

Figured specimen (Pl. 4j, k): GS12159, CH/f471, coastal cliffs near The Bluff, Pitt Island, Waipawan (?) (NZGS) x 1.5.

Pl. 4 n. *Cirsotrema (Tioria)* *youngi* Marwick, 1928 [p. 484]. Type species of *Tioria* Marwick, 1928 (Epitoniidae).

Size moderate for family (height c. 25 mm). Protoconch not known; teleoconch of 6 or 7 whorls, shouldered at about 0.8 whorl height on spire; last whorl with prominent basal disc. Axial sculpture of prominent, slightly prosocline lamellae, reaching from suture to suture on spire,

produced into small triangular spines on shoulder angle, and reaching across base to fasciole. On base, crests of lamellae are folded over towards aperture. Penultimate whorl with 21-28 lamellae. No definite varices. Spiral sculpture of very fine grooves with low, flattened interspaces, between axial lamellae and extending onto their back (abapertural) sides. Umbilicus narrow, apparently almost entirely closed in adult. Aperture circular, peristome continuous, outer lip with a small spine at shoulder angle and another at junction with fasciole.

Late Teurian (?), Tutuiri Greensand, Tioriori, north Chatham Island (type) (rare).

Cirsotrema youngi is the only gastropod recorded from this unit, probably because—unlike most gastropods—it has a calcitic rather than an aragonitic shell and so has escaped diagenetic solution. Most other New Zealand species of *Cirsotrema* have a similar mode of occurrence. *Tioria* differs from typical *Cirsotrema* mainly in lacking distinct varices, in having the crests of the basal lamellae turned over and in having the fasciole separated from the inner lip. Although two additional species have been referred to *Cirsotrema (Tioria)*, viz. *C. (Tioria) marshalli* (Bortonian, Hampden) and *C. (Tioria) forresti* Dell, 1956 (Recent, Hawke's Bay), neither seems to be closely related to *C. youngi*, and *C. forresti* may be a synonym of *C. zelebori* (pers. comm. B.A. Marshall, National Museum).

Figured specimen (Pl. 4n): holotype, GS1177, CH/f3, coast north of Tioriori, Chatham Island, late Teurian ? (TM6847, NZGS) x 2.

Pl. 4 q. *Sassia (Sassia)* n. sp. A (Ranellidae: Cymatiinae).

Shell 26-32 mm high (large for such an early species of the subgenus), relatively tall and narrow, with low, narrow varices at each 0.67 whorl down whole teleoconch, spire about equal in height to aperture and canal, whorls almost evenly rounded, and a moderately long, open siphonal canal directed weakly to left (incomplete in all material). Sculpture of simple, even, moderately prominent, cancellate spiral cords and axial costae, forming low nodules at their intersections, the sutural ramp and sculptural interspaces bearing several low, indistinct spiral cords and many fine growth ridges. Aperture oval; interior of outer lip weakly reflected over terminal varix, 6 nodules (the uppermost the largest) on inner edge, and with a shallow posterior sinus at the top; inner lip bearing 2 low parietal ridges, a nodule on centre of columella, and a row of 3 low, slightly oblique nodules on base of columella. Protoconch incomplete on available material, small, turbiniform, of at least 2.5 smooth, inflated whorls.

Teurian, Red Bluff Tuff, "Rocky Side" Bay, neck of Tarawhenua Peninsula, Pitt Island, Chatham Islands; moderately common.

This new species is a simply sculptured, typical but relatively large, early ("primitive") species of *Sassia (Sassia)*, resembling such European Paleocene species as *S. faxensis* (Ravn), but differing in its larger size, taller spire, and longer anterior canal (*Tritonium fenestratum* Ravn 1902, p. 22, pl. 2, fig. 7, 8, not of G. Vincent, 1878; renamed *Triton faxense* by Ravn 1933, p. 58, pl. 6, fig. 7a, b, 16a, b). Very few of the many Cretaceous species previously referred to "*Triton*" (or other early generic names in Ranellidae) really belong in this family, and the few that do are all simple, primitive *Sassia* species closely resembling *S. faxensis* and the Pitt Island Paleocene species (Beu 1988, p. 86, 87). The sole exception we are aware of is *Distorsio praegranosa* (Cottreau), discussed below. The fossil record therefore shows that only *Sassia* (among true Ranellidae) occurs in Cretaceous rocks, appearing first during the Turonian Stage, and all Cenozoic and living Ranellidae have apparently descended from *Sassia*.

A similar but shorter and wider shell with a more excavated abapertural variceal face is present in NZGS collections from the View Hill Volcanics, White's Creek, Eyre River, Canterbury (Mangaorapan). Primitive *Sassia* species were probably widespread in New Zealand on volcanic hard-ground substrates during Paleocene and Eocene time. *S. decagonia* (Bortonian) has more angled whorls and much sparser sculpture, and the other new species described below (Pl. 7 t; McCulloch's Bridge, South Canterbury; Kaiatan) has more angled whorls and much more complex apertural armature than the Paleocene and Early Eocene species.

Figured specimen (Pl. 4q): GS12173, CH/f478, neck of Tarawhenua Peninsula, Pitt Island, Teurian (NZGS) x 1.5.

Pl. 4 p. *Kotakaia simplex* Beu, 1988 [p. 92]. Type species of *Kotakaia* Beu, 1988 (Personidae).

Small for family (16-18 mm high; probably originally 22 mm high), with evenly rounded whorls, simple spiral sculpture, low wide varices every 0.67 whorl down teleoconch, and a heavily but simply armed aperture. Protoconch not seen. Sculpture of low, widely spaced spiral cords, 5 on spire whorls and about 12 on last whorl and neck, with several more very weak ones on siphonal canal; the better-preserved specimens have all spiral interspaces filled by a low, wide secondary cord; no axial sculpture visible, other than varices. Aperture elongate-oval, strongly constricted by heavy armature. Outer lip thick, protruding well beyond terminal varix, tapering rapidly to a thin edge, bearing 4 large, narrowly rounded ridges inside. Inner lip smooth except for a single high, narrow parietal ridge, forming (with uppermost ridge inside outer lip) a strongly constricted posterior sinus at top of aperture; and a row of 3 (or, in one specimen, 4) ridges on base of columella. Basal columellar ridges situated on a raised callus ridge protruding strongly into aperture, decreasing markedly in prominence as they descend left edge of short, straight, widely open, left-directed siphonal canal. All apertural ridges long, truly spiral features extending well inside aperture. Outer (left) edge of inner lip thick and well raised above previous whorl.

Teurian, Red Bluff Tuff, "Rocky Side" bay, neck of Tarawhenua Peninsula, Pitt Island, Chatham Islands,

uncommon; sympatric with *Sassia* n. sp. A (above) in a volcanic hard-ground environment.

This simply shaped, undistorted, simply sculptured, but heavily armed little shell is one of the most curious Personidae to come to light so far. It could have been a contender for the ancestor of the Personidae, had Cottreau (1922, p. 66, pl. 9, fig. 4-7) not described, in *Eutritonium praegranosum*, a Madagascan Campanian (Late Cretaceous) species of *Distorsio* (sensu stricto), to judge from the relatively large size (34 x 20.5 mm), strong coiling distortion, and coarsely cancellate sculpture evident on Cottreau's internal moulds. An interesting connotation of this Campanian *Distorsio* species is that *Distorsio* and *Sassia* (see above) are both now recognised in Late Cretaceous rocks, so Personidae apparently evolved independently of the Ranellidae, and Beu (1988) recognised Personidae as a separate family of Tonnacea.

The genus *Personopsis* Beu, 1988 (= *Personella*, not of Conrad) differs from *Distorsio* in its smaller size, and in having the basal columellar ridges situated directly on the columella, not protruding into the aperture on a raised ridge as in *Distorsio*. *Kotakaia simplex*, with its strongly protruding basal columellar ridge, is clearly related more closely to *Distorsio* than to *Personopsis*, but its small size, regular coiling, and simple sculpture make the genus *Kotakaia* necessary for the Pitt Island species. The earliest undoubted *Personopsis* appears to be *Eutritonium rutoti* Vincent, 1930 (see particularly Krach 1963, p. 102, pl. 23, fig. 6) from the Montian (early Middle Paleocene, about the same age as or a little older than the Pitt Island fossils) of Europe; all other *Personopsis* are from Eocene to Pliocene rocks. Therefore, contrary to earlier assumptions (e.g., Pilsbry 1922, p. 357), *Personopsis* was not involved in the ancestry of *Distorsio*.

Figured specimen (Pl. 4p): Holotype, GS12173, CH/f478, neck of Tarawhenua Peninsula, Pitt Island, Teurian (TM6785, NZGS) x 2.

CHAPTER 7. MIDDLE EOCENE FAUNAS (PORANGAN AND BORTONIAN STAGES): PLATES 5, 6

INTRODUCTION (Figure 12)

Far more is known about the molluscan fauna that existed in New Zealand during the Middle Eocene than about those from any other comparable period in the Paleocene or Eocene. The reasons for this seem to lie in the paleogeographic history of New Zealand during the

Paleogene. In a benchmark paper, Wilson (1956) presented evidence for marine transgression onto the South Island, commencing in the Late Cretaceous and culminating in a period of maximum submergence in the Oligocene. He envisaged the transgression as having been essentially steady, although he did not rule out the

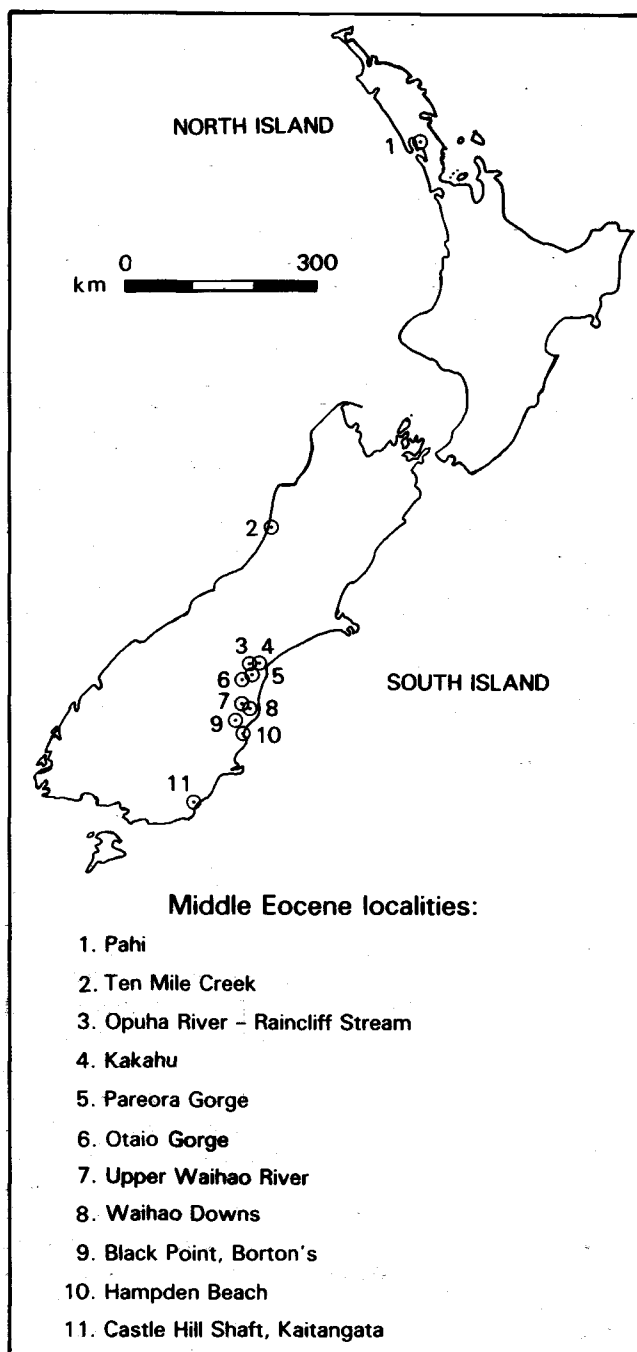


Figure 12 The main molluscan fossil localities of Porangan and Bortonian (Middle Eocene) age.

possibility of "minor regressions". Subsequent detailed studies of relevant sections on the east coast of the South Island have shown that the Paleogene sequence is interrupted by several hiatuses, some of them of local extent, others sufficiently widespread to be regarded as regional. One of the latter separates Middle Eocene rocks (typically Bortonian, but in places late Porangan) from significantly older beds (at most places Mangaorapan or Heretaungan where reliably dated) and has been recognised at various places on the east coast from North Canterbury to Dunedin district, in Westland, and on Chatham Island. Evidence for a substantial break in deposition (accompanied at least locally by erosion of part of the Dannevirke sequence) comes from micropaleont-

ology, and from sedimentology (e.g. abrupt or rapid lithological changes, particularly marked by an increase in terrigenous material; an intensely burrowed contact zone; presence of phosphorite nodules; and reworking of microfossils). This well-marked hiatus may be attributable to an alleged rapid drop in sea-level at the Early-Middle Eocene boundary (c. 49.5 myr B.P.) suggested by Vail and Hardenbol (1979) (see also Haq et al. 1987) (but note that this boundary has a date of 52.5 my on the CCP timescale), itself possibly related to a fall in sea-temperatures at about this time (Shackelton and Kennett 1975). Loutit and Kennett (1981, p. 53) correlated this fall in sea-level with the Heretaungan-Porangan boundary in New Zealand, although the Early-Middle Eocene boundary in New Zealand is now placed at the Mangaorapan-Heretaungan boundary in the CCP timescale (Edwards et al. 1988).

Irrespective of the ultimate cause of this hiatus, it seems likely that the shore-line retreated seawards for a time (perhaps for a few hundred thousand years), then gradually advanced again as the transgression resumed. Over much of North Otago and South Canterbury the rocks laid down during the early phase of this transgression consist of shallow-water sandstone (typically glauconitic) with common molluscs. Except for a limited area of limestone in south Westland (Nathan 1977, p.642) coeval beds on the West Coast of the South Island consist of coal measures (upper part of Brunner Coal Measures) and overlying sandstone (Island Sandstone), the latter unit containing small molluscan faunules at a few localities. No Middle Eocene molluscs have been recorded from the East Coast between mid-Canterbury and Gisborne district where sediments of this age are of deeper-water facies, typically mudstone (locally bentonitic), marl or limestone. Middle Eocene rocks in Northland include greensand, mudstone and limestone. A moderately diverse molluscan faunule is recorded from Pahi, Kaipara Harbour, but faunules from elsewhere in Northland are much smaller and poorly preserved.

Pre-Bortonian faunules

In their classic monograph on the Wangaloan molluscs, Finlay and Marwick (1937, p. 95-111) also described a much smaller, poorly preserved faunule (or more probably, faunules), which they termed the "Matau Fauna", from Castle Hill Shaft, Kaitangata, east Otago. They concluded that this faunule is considerably younger than Wangaloan, and assigned it a Bortonian age, although they allowed the possibility that it could be substantially older. This assemblage received little further attention until Marwick (1960) described a much better localised and generally better-preserved faunule from the Kauru Formation downstream from Otaio Gorge, South Canterbury. Because of its stratigraphic position, and the presence of *Colposigma*, *Perissodonta* and *Pseudofax* (none of which are known from the Bortonian), and on the basis of differences between Otaio Gorge species and Bortonian congeners, Marwick concluded that it is significantly older than Bortonian, probably of late Dannevirke Series age. He correlated it tentatively with the Matau faunule and with one from the so-called "Island Sandstone" in the lower Waihao Valley.

The Otaio Gorge fanule contains 33 species, including

Cucullaea waihoaensis, *Cubitostrea* aff. *gudexi*, *Eucrassatella* aff. *australis*, *Glyptoactis* aff. *bartrumi*, *Oxyperas flemingi*, *Costacallista hectori*, *Hedecardium collinsi*, *Colposigma gairi*, *Monalaria gracilis filata*, *Perissodonta mortoni*, *Pseudofax* cf. *filius* and *Athleta lata*. There is no microfossil evidence for the age of this assemblage, but the presence of *Cubitostrea* suggests that it is no older than Middle Eocene, for this cosmopolitan genus is not known before the Lutetian (Stenzel 1971, p. N1142). The Early-Middle Eocene boundary in New Zealand is currently placed at the Mangaorapan-Heretaungan boundary (Edwards et al. 1988), so the Otaio Gorge faunule could be Heretaungan or Porangan (assuming that it is pre-Bortonian) (Maxwell in Fordyce et al. 1985, p. 13). It is here arbitrarily assigned a Porangan age.

There is even less internal evidence for the age of the Matau or lower Waihao faunules, although both contain the buccinid genus *Pseudofax*, which is only known prior to the Bortonian. In addition, the former assemblage includes *Costacallista hectori* and *Athleta lata*. For convenience, these three faunules are assumed to be of about the same age.

Bortonian faunules

North Otago—South Canterbury

Bortonian molluscs have been collected from a considerable number of localities in the North Otago-South Canterbury area, the most important being Black Point (Bortonian stratotype), Hampden Beach, upper Waihao River, Waihao Downs, Pareora River, Kakahu, Opuha River and Raincliff Stream. These faunules come from a wide range of biotopes and collectively give a good idea of the molluscan fauna that lived in the region at that time.

The shallowest assemblage is from the upper reaches of the South Branch, Waihao River and is dominated both numerically and taxonomically by bivalves. The following species are characteristic—*Nucula* (*Nucula*) n.sp., *Glycymerita subglobosa*, *Lentipecten* n.sp., *Cubitostrea gudexi*, *Miltha* n.sp. aff. *neozelanica*, *Divaricella* (*Divalucina*) aff. *huttoniana* (differing from Recent shells only in their smaller size), *Eucrassatella australis*, *Lutetia* n.sp. (only New Zealand record), *Hedecardium* cf. *brunneri*, *Scalpomactra* n.sp., *Peronaea* n.sp., *Tellinella* n.sp., *Dosinia* (*Kereia*) *mackayi*, *Placamen* n.sp., *Callistotapes* n.sp., *Thraciopsis* n.sp., *Zeacolpus gagei* and *Monalaria concinna*. This assemblage, which probably represents a mixture of biotopes, seems to have accumulated in very shallow waters, possibly just below low tide. Several elements, including *Glycymerita*, *Cubitostrea*, *Eucrassatella*, *Hedecardium* and *Dosinia*, are also present in somewhat deeper-water assemblages, associated with volutes and turrids (e.g. Black Point, Kakahu, Raincliff Stream).

Faunules from the Waihao Greensand at Waihao Downs and Pareora River are representative of a deeper-water environment. They lack most of the shallow-water bivalve taxa and are dominated by gastropods, particularly mesogastropods and neogastropods, and probably lived at mid-shelf depths. They include *Limopsis campa*, *Cucullaea waihoaensis*, *Duplipecten waihoaensis*, *Glyptoactis acanthodes*, *Carinacca allani*, *Friginatica*

prisca, *Galeodea modesta*, *Sassia decagonia*, *Austrofusus acuticostatus*, *Fascioplex* spp., *Mauira biconica*, *Athleta necopinata*, *Zemacies* spp., *Insolentia sertula* and *Speightia spinosa*.

The diverse faunule from the Hampden Formation at the mouth of Kakaho Stream, Hampden Beach, originally described by Marshall (1919), seems to be of even deeper-water facies, probably equivalent to the outer shelf or upper slope. It includes many unusual species, but most specimens unfortunately are either crushed or are inclined to “explode” during storage, probably because of the oxidation of sulphide minerals. The following species are among the 100 or so recorded from Hampden—*Pseudoportlandia solenelloides*, *Bathyarca bellatula*, *Notolimopsis hampdenensis*, *Duplipecten parki*, *Kurinuia areolata*, *Spirocolpus rudis*, *Carinacca allani*, “*Uberella*” *haasti*, *Cirsotrema kuriense*, *Monalaria concinna*, *Dicroloma zelandica*, *Exilia hampdenensis*, *Ancillina kakano*, *Conus pseudarmoricus*, *Marshallena neozelanica*, *Gemmula* spp., *Zemacies marginalis*, *Turehua dubia*, and *Superstes marshalli*. The three species of verticordiids described from Hampden (including *Kurinuia areolata*) were originally assigned to *Trigonia*, but as in most parts of the world (except Australia and New Guinea) the Trigoniidae are not known to have survived the Cretaceous in New Zealand.

Westland

Except for a small area in South Westland, marine Middle Eocene sediments on the west Coast of the South Island are restricted to the southern portion of a prominent physiographic and tectonic feature known as the Paparoa Trough, which stretches from near Ross to north of Westport (Nathan et al. 1986, p. 31-32). Paleontological evidence shows that the Middle-Late Eocene transgression took place in a roughly south-north direction along the axis of the Trough, rather than more-or-less normal to the present coastline as was the case on the east coast (Suggate 1950; Nathan et al. 1986, p. 34). The basal marine unit is a near-shore, shallow-water, massive calcareous sandstone (Island Sandstone) overlying Brunner Coal Measures. Macrofossils are locally common but of low diversity; *Monalaria* cf. *concinna* occurs at Ten Mile Creek, north of Greymouth, accompanied by an elongate tellinid that seems to be conspecific with *Tellinella* n.sp. from South Canterbury Bortonian localities. Another characteristic Middle Eocene species, *Cubitostrea* cf. *gudexi*, occurs in fine conglomerate at Nine Mile Bluff.

Northland

Although molluscan faunules of possible Bortonian age have been recorded from several localities in Northland (Hay 1960, p. 39-40) most are very poorly preserved and of low diversity. The faunule from Pahi, Kaipara Harbour, described by Fleming (1950) is by far the most diverse recorded to date, although the preservation leaves much to be desired. It includes *Saccella semiteres*, *Pseudotindaria*(?) *ferrari*, *Limopsis* cf. *campa*, *Cubitostrea gudexi*, *Glyptoactis bartrumi*, *Monalaria concinna*, *Eocypraea novaezealandiae*, *Tatara pahiensis*, *Notogenota pahiensis* and *Speightia spinosa*. The presence of *Cubitostrea*, *Monalaria* and *Speightia* indicates correlation

of this shallow-water assemblage with Bortonian faunules from North Otago and South Canterbury.

Composition of the Bortonian molluscan fauna

The Bortonian marine molluscan fauna is one of the most distinctive in the New Zealand Cenozoic (Fleming 1962c, p. 72) largely because of the presence of several distinctive genus-group taxa that are apparently restricted to the stage or are last recorded from it. In addition, many Bortonian species are quite distinct from their congeners from younger or older faunas. The following taxa are known only from the Bortonian, although some were probably present earlier but have not been recorded because of the restricted nature of known pre-Bortonian faunules—*Lutetia*, *Tellinella* (younger species previously assigned here belong in *Serratina*), *Dosinia* (*Kakahuia*), *Thraciopsis*, *Keilostoma*, *Rimella*, *Fascioplex* and *Speightia*. Taxa last known from the Bortonian include *Cubitostrea*, *Costacallista*, *Propesinum*, *Monalaria*, *Priscoficus* and *Athleta*. Among the numerous taxa that are first recorded from the Bortonian are *Saccella*, *Pseudoportlandia*, *Sarepta*, *Duplipecten*, *Lentipecten*, *Placamen*, *Callistotapes*, *Kuia*, *Spisula*, *Peronaea*, *Offadesma*, *Carinacca*, *Tanea*, *Magnatica* (sensu stricto), *Dicroloma*, *Poirieria*, Mitridae, Conidae and *Tatara*.

Much of the distinctiveness of the Bortonian fauna results from the apparent failure of many genus-group taxa to survive into the succeeding Kaiatan Stage. Stratigraphic resolution is not good enough to tell if these taxa became extinct in a step-wise fashion, or if they died out more-or-less synchronously. However, the disappearance of several taxa of known or presumed warm-water affinity (e.g. *Tellinella*, *Costacallista*, *Rimella*, *Priscoficus* and *Athleta*) suggest a drop in sea-temperatures at or near the end of the Bortonian. Loutit and Kennett (1981, p. 53) correlate the Bortonian - Kaiatan boundary with a postulated fall in sea-level at about 39.5 Ma in the Vail timescale (but note that this boundary is now dated at 42.5 m.y.; Edwards et al. 1988), but in the Waihao district possible evidence for such a fall (i.e. the so-called "phosphatic" band at McCulloch's Bridge) occurs some distance below the stage boundary.

The Bortonian molluscan fauna includes a moderately large number of taxa (most of them extinct) that seem to be endemic to New Zealand (e.g. *Notolimopsis*, *Duplipecten*, *Scalpomactra*, *Kuia*, *Dosinia* (*Kakahuia*), *Turia*, *Tropicolpus* (*Amplicolpus*), *Zeacolpus*, *Monalaria*, *Magnatica* (sensu stricto), *Austrofuscus*, *Falsicolus*, *Fascioplex*, *Mauira*, *Zeacuminia*, *Eoturris*, *Tatara* and *Superstes*), as well as some that also occur in the Eocene of south-east Australia (e.g. *Poroleda*, *Hedecardium*, *Marama* (*Hina*), *Pareora*, *Spirocolpus*, *Friginatica*, *Archierato*, *Amalda* (*Gracilispira*) and *Rugobela*). These are matched, if not outnumbered, by taxa with a very wide, probably cosmopolitan distribution (e.g. *Ennucula*, *Nucula*, *Lamellinucula*, *Saccella*, *Jupiteria*, *Sarepta*, *Limopsis*, *Anomia*, *Limea*, *Pycnodonte*, *Cubitostrea*, *Miltha*, *Moerella*, *Peronaea*, *Caryocorbula*, *Tanea*, *Thracia*, *Asthenothaerus*, *Cerithiella*, *Niso*, *Galeodea*, *Sassia*, *Volvarinella*, *Cirsotrema* and *Turbonilla*) or that are largely restricted to subtropical or tropical regions at the present day (e.g. *Pteria*, *Tellinella*, *Placamen*, *Costacallista*, *Rimella*, Cypraeidae, Ovulidae, *Typhis*,

Conidae, *Marshallena*, *Gemmula*, *Fusiaphera* and *Granosolarium*). In addition there are several extinct taxa with congeners in the Northern Hemisphere, particularly Europe and North America, e.g. *Lutetia*, *Keilostoma*, *Carinacca*, *Priscoficus*, *Exilia*, *Ancillina*, *Eocithara* and *Turehua*. Other taxa are of less obvious biogeographic significance, e.g. *Speightia*, which is closely related to *Clinuropsis* from the Paleocene of Belgium and Zaire, and to *Andicula* from the Early Eocene of Peru (Powell 1966, p. 25).

The appearance of numerous taxa in the Middle Eocene (mostly in the Bortonian) may be evidence of a massive influx of molluscs into the New Zealand region at this time, or may merely reflect the paucity of suitable lithofacies in most sequences of Dannevirke Series rocks. In all probability, both factors have contributed to the relatively sudden increase in diversity in the Middle Eocene. The considerable number of warm-water taxa in the Bortonian indicates subtropical conditions, and it may be that the resumption of marine transgression in the Middle Eocene was associated with a rise in sea temperatures at this time.

REPRESENTATIVE MIDDLE EOCENE MOLLUSCA

Pl. 5 a, b. *Pseudoportlandia solenelloides* (Marshall, 1919) [*Sarepta solenelloides* Marshall 1919, p. 233; *Nuculana* (*Pseudoportlandia*) *solenelloides*] (Nuculanidae: Nuculaninae).

Moderately large for family (length 20-27 mm), relatively thick-shelled. Lunule very narrow, lanceolate; escutcheon much broader but weakly differentiated. Commarginal sculpture of linear grooves with broad flat interspaces proximally, rest of shell smooth except for growth ridges. Hinge relatively heavy, anterior series with 17-22, posterior series with 15-19 teeth of chevron cross-section, separated by a deep triangular resilifer. Anterior adductor muscle scar much larger than posterior scar; pallial line with a weak, triangular sinus.

Bortonian, Hampden Formation, Hampden Beach, North Otago (type) (common).

Pseudoportlandia tahuia (Kaiatan, McCulloch's Bridge) differs from *P. solenelloides* by being smaller (maximum length 21 mm), having more steeply descending dorsal margins and having a narrower, more rounded posterior end. Zinsmeister (1984, p. 1504) suggested that *P. solenelloides* and *P. tahuia* require a new genus, but until such time as the numerous nuculanid genus-group taxa are thoroughly revised, these species are retained in *Pseudoportlandia* Woodring, 1924, which is based on a Pliocene Jamaican species [*P. clara* (Guppy, 1873)]. *Pseudoportlandia* was long thought to be restricted to the Arnold Series in New Zealand, but it is now considered to include two or three Neogene species as well (Maxwell 1988a, p. 39).

Figured specimen (Pl. 5a, b): holotype, Hampden Beach, North Otago, Bortonian (TM4117, NZGS) x 2.

Pl. 5 d. *Duplipecten waihaoensis* (Suter, 1917) [*Pecten* (*Pseudamusium*) [sic] *waihaoensis* Suter 1917, p. 69; *Lentipecten* (*Duplipecten*) *waihaoensis*]. Type species of *Duplipecten* Marwick, 1928 (Pectinidae).

Size moderate for family (height 50-60 mm), right valve more inflated than left; anterior and posterior gapes well developed. Ears prominent, those on left valve having colinear dorsal margins, and separated from disc by shallow grooves; those on right valve with divergent dorsal margins (finely serrate on well preserved shells) and separated from disc

by broad channels which dip below dorsal margins of disc distally. Byssal notch well developed; no ctenolium. Sculpture on right valve of fine growth lines and faint radial striae; left valve with growth lines and weak radial striae in some shells, others with 12-14 broad, low, flattened costae becoming obsolete distally; interspaces as broad as costae, some with a weak radial cord appearing during growth.

Bortonian, Waihao Greensand, South Branch, Waihao River near Waihao Downs (type) (locally common).

Pectens conforming to the above diagnosis (i.e. including individuals with well developed radial costae in the left valve) are present in the middle part of the Waihao Greensand in the Waihao Downs section. Higher in the section, particularly in a pecten-rich bed near the top of the Bortonian, occur pectens identical in most respects to *D. waihaoensis* but having the left valve devoid of radial sculpture other than weak striae. These are assigned to *D. parki*, which is recorded from several Bortonian and Kaiatan localities in North Otago (type locality, Hampden Beach), South Canterbury, Westland and Chatham Island. Although originally assigned to *Lentipecten* (sensu stricto), *D. parki* is very similar to *D. waihaoensis* and the two species probably have an ancestor-descendant relationship, with *D. parki* replacing the latter species in the late Bortonian. *Duplipecten* was originally classed as a subgenus of *Lentipecten*, but the type species differ in a number of important shell characters that indicate they are not closely related. Loss of radial sculpture has occurred in many groups of pectens and is not in itself a reliable guide to phyletic relationships in the family.

Figured specimen (Pl. 5d): GS9886, J40/f8823, abandoned railway cutting, Waihao Downs, Bortonian (NZGS) x 1.

Pl. 5 c, e. *Cubitostrea gudexi* (Suter, 1917) [*Ostrea gudexi* Suter 1917, p. 71; *Lopha gudexi*; *Lopha pahiensis* Finlay 1928b, p. 266] (Ostreidae: Ostreinae).

Size moderate for family (height 20-70 mm), shape highly variable and irregular, but typically inequilateral, oblique. Strongly inequivalve, left (lower) valve markedly inflated, some shells with rather obscure crescentic keel defining a posterior area; attachment area moderately large. Right valve typically slightly convex or almost flat, but largest specimens with pronounced submedian sulcus distally. Sculpture highly discrepant, right valve smooth except for growth ridges; left valve with prominent, irregular, bifurcating and intercalating radial costae crossed by growth ridges, typically from 7-20 costae in small or medium-sized shells (20-40 mm high) but over 25 in largest specimens (55 mm). Ligamental area small, chomata short, rather inconspicuous, confined to proximal region. Adductor muscle scar lachrymiform, posterior to middle of valve. Inner margins of right valve smooth, those of left valve coarsely crenulate.

Porangan (?), Bortonian; Waihao Greensand, Kakahu, Bortonian (type of *O. gudexi*); Pahi Greensand, Pahi, Northland, Bortonian (type of *L. pahiensis*); not uncommon at several localities with shallow-water assemblages in Northland, Westland, North Otago and South Canterbury.

Cubitostrea gudexi is distinguished from other New Zealand oysters primarily by its strongly discrepant sculpture. The genus seems to have been very widespread during the Eocene, and is recorded from Europe, India, North America and Patagonia. Although it is not known after the Bortonian in New Zealand, *Cubitostrea* persisted until the Oligocene in Europe (Stenzel 1971, p. N1142).

Figured specimens (Pl. 5c, e): GS9959, J40/f6610, South

Branch, Waihao River near "Pentland Hills", Bortonian (NZGS) x 1.

Pl. 5 f, i. *Eucrassatella australis* (Hutton, 1873) [*Astarte australis* Hutton 1873b, p. 25; *Spissatella australis*; *Crassatellites tripliciter* Laws 1935b, p. 23] (Crassatellidae).

Moderately large for family (length 50-80 mm), robust, subtrigonal; dorsal margins steeply descending, almost straight, anterior and ventral margins convex, posterior margin rounded-truncate. Umbonal ridge rounded, more strongly defined proximally than distally, demarcating a relatively narrow, somewhat flattened or slightly concave posterior area. Lunule and escutcheon prominent, strongly impressed. Commarginal sculpture of low, rounded costae on umbones, extending up to 15 mm or so from beaks, remainder of shell with growth lines and grooves. Some individuals with weak radial costellae near ventral margin, otherwise devoid of radial sculpture. Hinge plate prominent, triangular; left valve with narrow, transversely grooved, anterior cardinal tooth separated from lunule by shallow groove, an equally narrow median cardinal tooth and a short, low posterior cardinal tooth that barely diverges from escutcheon margin; posterior lateral tooth a low ridge on ventral edge of hinge plate, separated from escutcheon margin by broad, shallow groove which accommodates right escutcheon margin. Right valve with narrow anterior cardinal tooth largely fused to lunular margin, and a prominent though narrow median cardinal tooth; anterior lateral a low short swelling on ventral margin of hinge plate with a shallow socket above to take distal end of left lunule. Resilifer large, triangular, not extending to ventral margin of hinge plate. Adductor muscle scars subequal, strongly impressed; pedal retractor scar subcircular, strongly impressed, on underside of anterior end of hinge plate. Ventral shell margins smooth or finely crenulate.

Mangaorapan?; Porangan?; Bortonian-Kaiatan; Waihao Greensand, Kakahu, Bortonian (type locality of *A. australis*); Waihao Downs, Bortonian (type locality of *C. tripliciter*); South Branch, Waihao River near "Pentland Hills"; Otaio Gorge; McCulloch's Bridge. Not uncommon in shallow-water, sandy bottom assemblages.

Eucrassatella australis differs from *E. ampla* (Pl. 12d, e) in its much smaller size, its more equilateral, subtrigonal shape and in the presence of marginal crenulations in some individuals. Some specimens of *E. marshalli* (Kapitean-Waipipian) approach *E. australis* in shape, but they differ in having a smaller, less well-defined lunule, a much wider and deeper groove separating the left anterior cardinal from the lunule, a resilifer that extends to the ventral margin of the hinge plate, and in lacking marginal crenulations entirely. *E. australis* has long been assigned to *Spissatella* Finlay, 1926, but it is closer in size, shape and sculptural characters to typical species of *Eucrassatella*. Large specimens of *E. australis* are characteristic of shallow-water (inner or middle shelf) assemblages; small shells (less than 20 mm long) occur in deeper-water facies (e.g. at McCulloch's Bridge).

Figured specimen (Pl. 5f, i): GS9959, J40/f6610, South Branch, Waihao River near "Pentland Hills", Bortonian (NZGS) x 1.

Pl. 5 g, h. *Glyptoactis (Fasciculicardia) acanthodes* (Suter, 1917) [*Venericardia acanthodes* Suter 1917, p. 72-73; *V. (Fasciculicardia) acanthodes*] (Carditidae: Venericardiinae).

Size moderate for family (length 25-37 mm), ovate-subquadrate, posterior end only weakly truncate; posterior area weakly defined. Lunule small, strongly pouting. Radial sculpture of 21-24 prominent costae with broadly triangular-sectioned bases and elevated crests, those on flanks with much wider interspaces than those on posterior area or near anterior end. Medial costae flanked by much weaker ridges producing the tripartite (or "fasciculate") sculpture characteristic of the

genus. All costae with laterally compressed nodules or tubercles on crests producing a distinctly serrate profile, those on posterior area (except for second and third costae from posterodorsal margin) much less prominent than on rest of shell. Commarginal sculpture of fine wrinkle-like ridges and numerous very fine threadlets between costae. Left valve with a very small tubercular anterior lateral tooth at end of lunular groove, small triangular anterior cardinal tooth and long, curved posterior cardinal; right valve with short, narrow anterior cardinal tooth fused to lunule and a prominent, broadly curved-triangular median cardinal tooth. Distal end of left lunule produced into small tubercular lateral tooth fitting into socket on right valve.

Bortonian, Waihao Greensand, Waihao Downs (type) (common); Hampden Beach (rare).

G. (Fasciculicardia) subintermedia (Pl. 23g) is similar to *G. acanthodes* in general appearance, but grows to a much larger size, has more numerous radial costae (28-31) and has a broader left anterior cardinal tooth which is almost fused to the lunule rather than separated by a definite socket. *G. healyi* (Bortonian, Pahi, Kaipara Harbour) is similar in age to *G. acanthodes* but has more numerous (30-33), more closely spaced radial costae with much more pronounced secondary costellae. The presence of tripartite costae in these species (and in *G. benhami* (Pl. 9c, d)) sets them apart from other New Zealand venericardiines and suggests closer relationship to *Glyptoactis* Stewart, 1930 than to *Venericardia* Lamarck, 1801, which has simple costae. Chavan (in Moore 1969, p. N556) separated *Glyptoactis* and its relatives from *Venericardia* at the subfamilial level, but this radical classification is not followed here. The distribution of *Glyptoactis* (*Fasciculicardia*) in the New Zealand Cenozoic suggests it was a warm-water group (see discussion on *G. subintermedia*).

Figured specimen (Pl. 5g, h): GS1988, J40/f8457, abandoned railway cutting, South Branch, Waihao River near Waihao Downs, Bortonian (NZGS) x 1.5.

Pl. 5 n, o. *Placamen* n. sp. (Veneridae: Chioninae)

Small for family (length 7-10 mm), subtrigonal, not greatly inflated. Lunule large, impressed, lamellose; escutcheon well defined, particularly in left valve. Commarginal sculpture of very prominent, distant ridges that apparently do not bend back towards umbones. Interspaces broadly concave, weathered surfaces showing fine subsurface radial costellae. Left hinge with thin anterior cardinal tooth, a narrowly triangular, bifid median cardinal tooth, and a thin posterior cardinal tooth. Right hinge with slightly curved, thin anterior cardinal tooth, a narrowly triangular

bifid median cardinal tooth and a narrow, bifid posterior cardinal tooth. Pallial sinus shallow, rounded. Ventral margin finely crenulate.

Bortonian, South Branch, Waihao River near "Pentland Hills" (not uncommon); Raincliff Stream (uncommon).

P. morgani (Duntroonian, Castle Hill Basin), the only described New Zealand species, is larger than the new species and has more prominent commarginal costae with recurved crests. Other records of the genus are from Pakaurangi Point, Northland (Otaian-Altonian) and Weka Pass, Canterbury (Altonian). The type species, *P. placidum* (Philippi, 1844), occurs in southern Australia, including Tasmania, but most extant species are from the Indo-Pacific region.

Figured specimen (Pl. 5n, o): GS9959, J40/f6610, South Branch, Waihao River near "Pentland Hills", Bortonian (NZGS) x 3.

Pl. 5 k, m. *Dosinia* (*Kereia*) *mackayi* Marwick, 1927 [p. 589-590] (Veneridae: Dosiniinae).

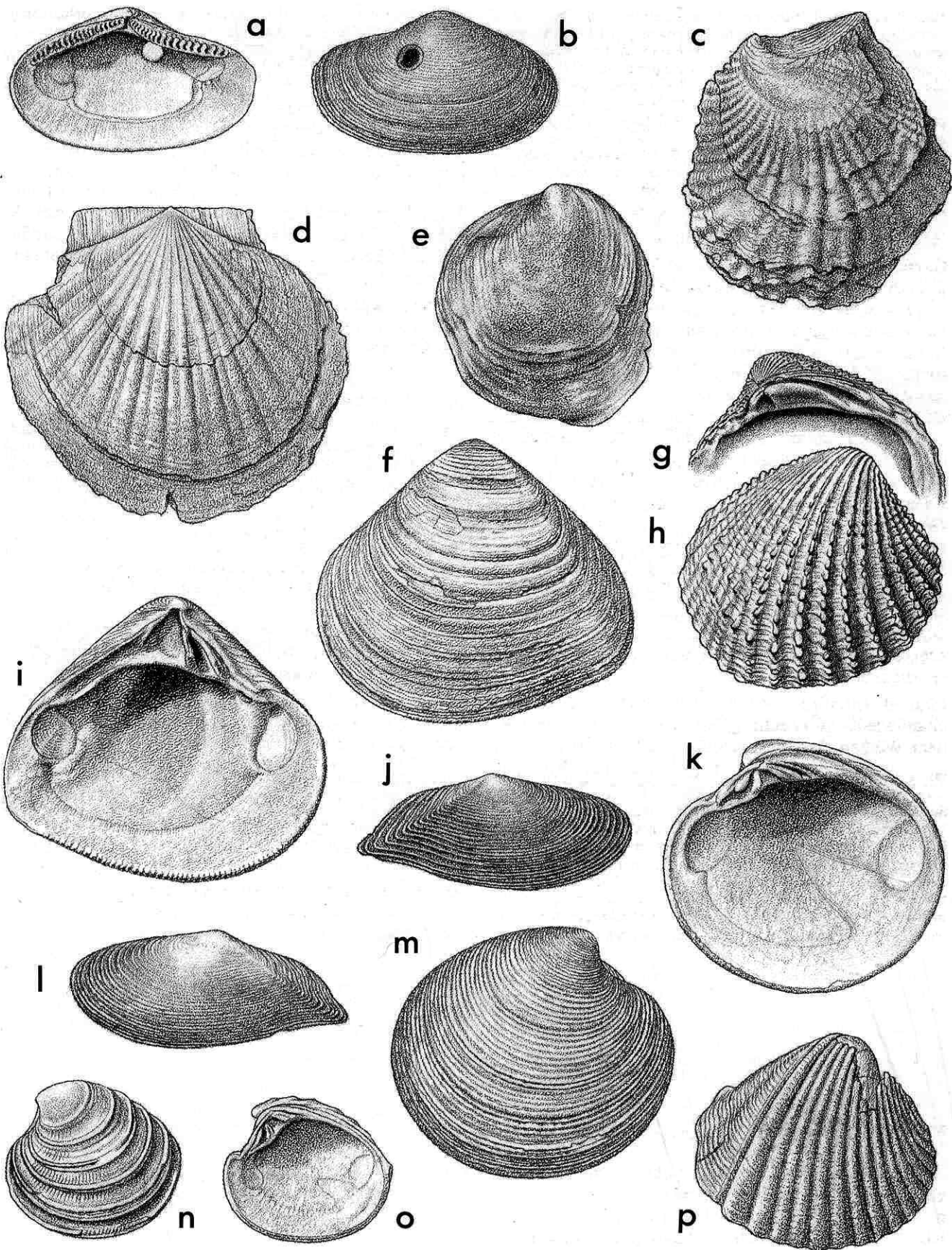
Small for genus (height 20-30 mm), subcircular, moderately inflated. Lunule small, pouting; escutcheon better developed in left than in right valve. Sculpture of closely spaced, fine lamellae, abraded from many specimens. Left hinge with a small anterior lateral tooth, well separated from cardinals, a lamellar anterior cardinal tooth, a narrowly triangular, weakly bifid median cardinal tooth (with posterior portion more prominent) and a long, lamellar posterior cardinal tooth. Right hinge with an anterior socket, narrowly triangular anterior and median cardinal teeth (the latter somewhat the larger in most specimens) and a strongly bifid, triangular posterior cardinal tooth. Pallial sinus triangular, strongly ascending.

Bortonian, Waihao Greensand, Black Point, Bortons (type) (uncommon); South Branch, Waihao River, near "Pentland Hills" (common).

Dosinia mackayi is distinguished from younger species of the subgenus by its small size and its closely spaced commarginal sculpture. *Dosinia* (sensu lato) is first recorded from the Wangaloan in New Zealand and is well represented in shallow-water faunules throughout the Cenozoic, but is not known in the Northern Hemisphere prior to the Oligocene. Taken at face value this suggests that it originated in the Southern Hemisphere and only much later made its way (possibly via South America) to the Northern Hemisphere, the opposite situation to the boreocentric scenario usually proposed for molluscan dispersal.

Plate 5 Middle Eocene (Porangan-Bortonian) Mollusca (1).

- a,b. *Pseudoportlandia solenelloides* (Marshall), x 2.
- c,e. *Cubitosrea gudexi* (Suter), x 1.
- d. *Duplipecten waihaoensis* (Suter), x 1.
- f,i. *Eucrassatella australis* (Hutton), x 1.
- g,h. *Glyptoactis* (*Fasciculicardia*) *acanthodes* (Suter), x 1.5.
- j,l. *Tellinella* n.sp., x 2.
- k,m. *Dosinia* (*Kereia*) *mackayi* Marwick, x 2.
- n,o. *Placamen* n.sp., x 3.
- p. *Kurinuia areolata* (Marshall), x 3.



Figured specimen (Pl. 5k, m): GS9959, J40/f6610, South Branch, Waihao River, near "Pentland Hills", Bortonian (NZGS) x 2.

Pl. 5 j, l. *Tellinella* n. sp. (Tellinidae: Tellininae).

Rather small for family (length 15-25 mm), very elongate, beaks posterior to middle, left valve more inflated than right. Anterodorsal margin long, straight; posterodorsal margin much shorter, junction with backwards-sloping posterior end obtusely angled. Anterior margin narrowly convex, ventral margin broadly convex except for slight concavity near posterior end, accentuating the short, right-twisted rostrum formed at junction with posterior margin. Umbonal ridge well marked, defining a narrow posterior area; left valve with additional weaker ridge running to middle of posterior margin. Sculpture discrepant, considerably more prominent in right valve, particularly over distal half of shell, consisting of narrow, low commarginal ridges. Hinge very narrow, left valve with low anterior and posterior laterals scarcely differentiated from shell margin, a narrowly triangular, bifid median cardinal tooth and a very thin posterior cardinal tooth. Right valve with long, narrow anterior and posterior lateral teeth separated from margins by narrow sockets, a narrow anterior cardinal tooth and a narrowly triangular, bifid posterior cardinal tooth. Pallial sinus extending to near middle of shell, rounded, ventral limb only partly confluent with pallial line.

Bortonian, South Branch, Waihao River near "Pentland Hills"; Opihi River, South Canterbury; Kakahu; Ten Mile Creek, Westland. Moderately common at the first locality, less so at the others.

This new species is readily distinguished from other New Zealand tellinids by its rather small size, its very elongate shape, its narrowly rostrate posterior end and its markedly discrepant sculpture. Several other New Zealand tellinids have been assigned to the warm-water genus *Tellinella*, but they differ in shape, pallial and muscle characters from typical members of the genus and are here included in *Serratina*. The species described here is the only local species that can be assigned to *Tellinella* with any confidence.

Figured specimens (Pl. 5j, l): GS9959, J40/f6610, South Branch, Waihao River near "Pentland Hills", Bortonian (NZGS) x 2.

Pl. 5 p. *Kurinuia areolata* (Marshall, 1919) [*Trigonia areolata* Marshall 1919, p. 234]. Type species of *Kurinuia* Marwick, 1942 (Verticordiidae).

Size moderate for family (length 15-20 mm), ovate, strongly inflated, interior nacreous; beaks markedly prosogyrous. Lunule small, deeply impressed; posterior area well differentiated. Radial sculpture of 15-16 prominent rounded costae with interspaces similar in width to or distinctly narrower than costae, on flanks and anterior end. Costae smooth or with fine commarginal ridges anteriorly. Posterior area with a prominent radial costa near dorsal margin and a much narrower costa (or groove on some shells) anteriorly; remainder sculptured with closely spaced commarginal ridges. Internal features poorly known; right valve with a prominent triangular cardinal tooth and a strong posterior lateral tooth. Ventral margin coarsely crenulate.

Bortonian, Hampden Formation, Hampden Beach (type) (rare).

This distinctive bivalve was originally described as a species of *Trigonia*, probably because of the nacreous interior and the strongly differentiated posterior area. This would have been an exceptionally interesting occurrence if this assignment was correct, as the only other post-Cretaceous records of the family are from Australia and New Guinea (see Darragh 1986 for a review). However, *K. areolata* lacks the characteristic trigoniid dentition and is prosogyrous rather than

orthogyrous or opisthogyrous. Two other species of "*Trigonia*" were described from Hampden—*T. neozelanica* and *T. densicostata*—but both are now referred to the Verticordiidae.

Figured specimen (Pl. 5p): holotype, Hampden Beach, North Otago, Bortonian (TM4795, NZGS) x 3.

Pl. 6 f. *Keilostoma malingi* Marwick, 1942 [p. 273] (Diastomatidae ?).

Size moderate for family (height 10-13 mm), turriculate, spire elevated. Protoconch mamillate, of about 1 smooth whorl. Teleoconch whorls 8-9, early ones convex, later ones almost straight-sided; periphery of last whorl rounded. Sculpture commencing on about 4th whorl, consisting of imbricated (or terraced) spiral ridges stepped on adapical edge, 5-7 on spire whorls, 10-11 on last whorl. No axial sculpture. Aperture constricted posteriorly, broadly and shallowly excavated anteriorly. Inner lip callused, outer lip with a broad, low, flattened varix.

Bortonian, Opuha River (type); Raincliff Stream, South Canterbury (not uncommon at both localities).

Although long placed in the Rissoidae or Rissoinidae, *Keilostoma* has been provisionally referred to the Diastomatidae by Ponder (1985, p. 104). The genus ranges from Late Cretaceous to Oligocene and has a wide geographic distribution. *K. malingi* is very similar to the type species, *K. turricula* (Bruguière, 1792) from the Lutetian of the Paris Basin. It is the only known New Zealand gastropod with well developed terraced (or ratchet) sculpture, a character that apparently aids burrowing in soft sediments (Signor 1983).

Figured specimen (Pl. 6f): GS13813, J38/f56, Raincliff Stream, South Canterbury, Bortonian (NZGS) x 4.

Pl. 6 g. *Dicroloma* (sensu lato) *zelandica* Marshall, 1919 [p. 228-229] (Aporrhaidae).

Size moderate for family (height c.30 mm), basically elongate-ovate but adults greatly modified in shape by apertural processes. Protoconch mamillate with apex somewhat flattened, of 4 smooth, strongly convex whorls. Teleoconch of 5-6 whorls, strongly and evenly convex at first, developing a weak median angulation on 5th whorl; last whorl increasing sharply in diameter, with sharply defined median and peribasal keels. Axial sculpture commencing as weak, almost straight, strongly prosocline threads, followed by strongly opisthocyrt costellae reaching from suture to suture on spire but stopping at peribasal angulation on last whorl of subadult shells, and becoming obsolete on last or penultimate whorl of adults. Spiral sculpture commencing as 7 or 8 fine, rounded cords with interstitial threads appearing during growth, one cord becoming stronger than others on 5th whorl at median angulation, and another relatively strong cord at peribasal angulation on subadult shells; base of last whorl with about 8 low cords with some interstitial threads, upper 4 or so stronger than others. Aperture moderately large, columella vertical, almost straight, probably very short in subadult shells, but produced anteriorly in adults to form a long, narrow, slightly curved siphonal canal. Inner lip with callus smear in young shells, moderately callused in adults; outer lip probably thin with a broad, deep arcuate sinus posteriorly in immature shells, but in adults considerably thickened and bearing 2 very prominent digitations corresponding to keels. Posterior digitation directed away from and slightly behind aperture, anterior digitation directed forwards; each of similar length to siphonal canal and bearing a shallow longitudinal groove along its inner face.

Bortonian-Kaiatan; Bortonian, Hampden Beach (type); McCulloch's Bridge; Kapua Tuff, Waihao River. Not uncommon in the lower part of the Hampden Formation at Hampden Beach, but very difficult to collect; relatively common in the Kapua Tuff but no specimen known with a complete outer lip.

Dicroloma zelandica is one of the most unusual and interesting of all New Zealand Eocene gastropods, for all other known records of the genus are from the

Mesozoic, particularly from the Jurassic. However, apart from its apertural characters, *D. zelandica* is not particularly like the type species, *D. lorieri* (Orbigny, 1847) (mid-Jurassic, France), which lacks definite axial sculpture, but has broadly V-shaped growth lines. Nonetheless, it seems that *D. zelandica* represents a relict group that persisted in the New Zealand region until at least the Late Eocene, long after the genus had become extinct elsewhere.

Figured specimen (Pl. 6g): Hampden Beach, Bortonian (NZGS—specimen figured by Marshall and Murdoch 1920, pl. 7, fig. 13) x 1.5.

Pl. 6 a, b. *Monalaria concinna* (Suter, 1917) [*Struthiolaria tuberculata concinna* Suter 1917, p. 9]. Type species of *Monalaria* Marwick, 1924 (Struthiolariidae).

Rather small for family (height 30–40 mm). Protoconch not known; teleoconch of 5–6 whorls, first 3 or so whorls strongly convex, later ones shouldered at about 0.6 whorl height on spire, last whorl excavated, with 2 (or in some shells, 3) narrow keels on base. Axial sculpture absent from early whorls (apart from fine growth lines), appearing on 3rd or 4th whorl as opisthocline, strongly opisthocyrt costae, reaching almost from suture to suture at first but eventually becoming restricted to shoulder angle where they form prominent, well spaced, sharp tubercles; 10–11 on last whorl. Basal keels with much weaker, more numerous tubercles. Adult shells typically with 1 or 2 previous varices retained on later whorls. Spiral sculpture commencing as 6–8 fine threads, which become relatively prominent on 3rd or 4th whorl. Interstitial threads appearing at about this stage, gradually increasing in strength while primaries decrease, so that last whorl is covered with numerous fine subequal threads. Aperture ovate, inner lip with moderately thick callus which does not obscure the straight, subvertical columella. Outer lip similar to that of *Conchothyra australis* (Pl. 2g, h), i.e. almost straight from suture to shoulder angle and strongly convex below, with a broad, shallow anterior canal. Outer lip callus-development variable, apparently stronger in specimens from shallow-water facies than from deep-water ones.

Bortonian, Waihao Greensand, Waihao Downs (type) and recorded from numerous localities in North Otago, South and mid Canterbury, Westland and Northland. Moderately common in shallow-water, sandy bottom assemblages, rarer in deeper-water faunules (e.g. Hampden Beach).

Monalaria concinna is one of the most distinctive Middle Eocene molluscs from New Zealand, and is readily distinguished from other struthiolariids by its mid-spire sculpture of strongly opisthocyrt costae and relatively strong spiral cords, its axial sculpture of sharp tubercles on later whorls, and its strongly sinuous outer lip. A second species of *Monalaria*, currently subdivided into two “subspecies”, has been described. *M. gracilis gracilis* (Dannevirke Series ?, Kaitangata) is smaller and more slender than *M. concinna* and has smaller, more closely spaced tubercles on the shoulder angle. *M. gracilis filata* (Porangan ?, Otaio Gorge) is more like *M. concinna* in shape but has apertural callus developing at a much smaller size (i.e. at about 15 mm).

Figured specimen (Pl. 6a, b): GS5502, J38/f6601, Opuha River, South Canterbury, below gorge, Bortonian (NZGS) x 1.5.

Pl. 6 h. *Carinacca allani* (Marwick, 1924) [*Natica (Carinacca) allani* Marwick 1924d, p. 554–555] (Naticidae: Naticinae).

Size moderate for family (height 13–28 mm), ovate, spire about 0.25 height of shell, outline almost straight. Protoconch depressed, of about 3.5 smooth whorls. Teleoconch whorls gently convex, sutures only lightly

impressed. Axial sculpture of growth lines only; spiral sculpture of very weak striae, most obvious just below suture. Inner lip almost straight, parietal callus thick with short entering ridge adapically, spreading down to coalesce with broad, low funicle near middle of lip. Outer lip strongly prosocline, inclined at about 25° from vertical. Umbilicus broad, bordered by a prominent ridge with a rounded outer edge and a sharp inner margin.

Bortonian-Kaiatan; Bortonian, Waihao Greensand, Waihao Downs (type); Kakahu; Bortons; Hampden Beach; Pareora River; McCulloch’s Bridge. Common at type locality, uncommon to rare elsewhere.

Carinacca allani is very similar to *C. waihaoensis* (Pl. 8c), but is rather less globose and has a more elevated spire and a narrower umbilicus. The two forms overlap somewhat in stratigraphic range and possibly represent members of a gradually evolving lineage.

Carinacca is a relatively distinctive naticid genus characterised by the presence of a prominent circumumbilical ridge. It is recorded only from the Bortonian and Kaiatan in New Zealand, and is also present in the Middle Eocene of California (Marincovich 1977, p. 393).

Figured specimen (Pl. 6h): GS11148, J40/f8858, South Branch, Waihao River near Waihao Downs. Bortonian (NZGS) x 2.

Pl. 6 d, e. *Propesinum fornicatum* (Suter, 1917) [*Sinum fornicatum* Suter, 1917, p. 11; *Sigaretotrema fornicatum*; *S. insociale* Marwick 1960, p. 20] (Naticidae: Poliniceinae).

Rather small for family (height 9–16 mm); auriform, spire low, subconical. Protoconch subplanorboid, of about 3 smooth whorls. Teleoconch of 1–1.5 rapidly increasing whorls; spire whorls convex, last whorl with well rounded periphery, base concave, narrowly umbilicate. Sutures scarcely impressed. Axial sculpture of growth lines, spiral sculpture of narrow, rounded or flat-topped cords with interstitial threads, interrupted by growth lines, more prominent on spire than on base. Aperture ovate, very large, strongly prosocline, outer lip inclined at about 30° to vertical; basal lip shallowly excavated. Parietal callus narrow, moderately thick; inner lip reflected over upper part of umbilicus.

Mangaorapan?; Porangan?—Bortonian; Bortonian, Maerewhenua River, North Otago (type of *S. fornicatum*); Otaio Gorge (type of *S. insociale*); Kakahu; South Branch Waihao River near “Pentland Hills”. Rather rare at all localities.

Propesinum fornicatum is superficially similar to *Eunaticina linnaeana* (Pl. 47s) but differs in having a much lower spire, a slightly lower protoconch, a scarcely impressed suture, more rapidly expanding teleoconch whorls, a narrower umbilicus and a much more oblique aperture. *S. insociale* allegedly differs from *P. fornicatum* in having a less oblique aperture, but the holotype of *S. insociale* (the only known specimen) is a small, poorly preserved specimen that seems to have the outer lip as oblique as typical specimens of *P. fornicatum*. Although long referred to *Sigaretotrema*, this species has little resemblance to the type species, *S. michaudi* (Michelotti, 1847) (Miocene, Europe), which has a globular, high-spined shell with a moderately oblique aperture. It is, however, very similar to the type species of *Propesinum* Iredale, 1924, *P. umbilicatum* (Quoy and Gaimard, 1832) (Recent, Tasmania) and is considered to be congeneric. *Propesinum* was synonymised with *Sigaretotrema* by Finlay and Marwick (1937, p. 55) but we consider them to be distinct taxa.

Figured specimen (Pl. 6d, e): holotype, Maerewhenua River, near Livingstone, North Otago, Bortonian (TM6854, NZGS) x 2.

Pl. 6 i. *Galeodea (Galeodea) modesta* (Suter, 1917) [*Galeodes modesta* Suter 1917, p. 19-20] (Cassidae: Cassinae).

Size moderate for genus (height 32-45 mm), ovate, spire about 0.25 height. Protoconch broadly conical, of about 4 smooth, convex whorls. Teleoconch whorls 4-5, prominently shouldered near middle on spire; last whorl with 3 or 4 additional, less prominent keels and a strongly twisted neck. Axial sculpture of prominent nodules or tubercles on shoulder angle, somewhat weaker ones on keel immediately below and much weaker ones on other keels; 10-12 per whorl on shoulder angle, those on lower keels typically more numerous and not corresponding to those above. Spiral sculpture of numerous fine threads, somewhat stronger on lower part of base and on neck than elsewhere. Aperture elongate-ovate, constricted at both ends, siphonal canal narrow, bent to left and away from aperture. Outer lip slightly inclined to vertical, with a prominent, flattened varix, inner edge with 13-15 short lirae. Inner lip heavily callused, projecting freely over columella, bearing 1 or 2 narrow lirae adapically and numerous short, irregular wrinkles below.

Bortonian, Waihao Greensand, Kakahu (type); Waihao Downs. Rare at both localities.

Galeodea modesta is readily distinguished from *G. apodemetes* (Pl. 20q) by its finer spiral sculpture and by its heavily "armoured" aperture. Another Bortonian species, *G. geniculosa* (Hampden Beach), also has an armoured aperture but has considerably coarser spiral sculpture; however, it may not be a distinct species in view of the considerable variation noted in living cassids. An undescribed species from the Slip Point Siltstone, Clifden (Clifdenian) is most similar to *G. modesta*, differing mainly in having a protoconch of only 1.5 whorls, finer shoulder tubercles and a less prominently armoured aperture.

Figured specimen (Pl. 6l): GS9886, J40/f8823, abandoned railway cutting, Waihao Downs, Bortonian (NZGS) x 1.5.

Pl. 6 j. *Priscoficus alectodens* Marwick, 1942 [p. 275] (Ficidae).

Size moderate for family (height 35-60 mm), pyriform, spire about 0.25 height. Protoconch apparently dome-shaped, of about 2.5 smooth whorls. Teleoconch of about 4 whorls, sharply shouldered above middle on spire; last whorl with 2 additional prominent keels, gradually contracted below to long, almost straight neck. Axial sculpture commencing as fine costellae reaching virtually from suture to suture but later becoming restricted to small, sharp tubercles on keels, those on shoulder keel stronger and less numerous than those below. Tubercles becoming less numerous on later whorls, c.13-15 on shoulder keel of last whorl. Spiral sculpture of narrow, low cords with some interstitial threads. Aperture pyriform, constricted anteriorly to form siphonal canal. Inner lip with thin callus smear, outer lip thin, angled by keels.

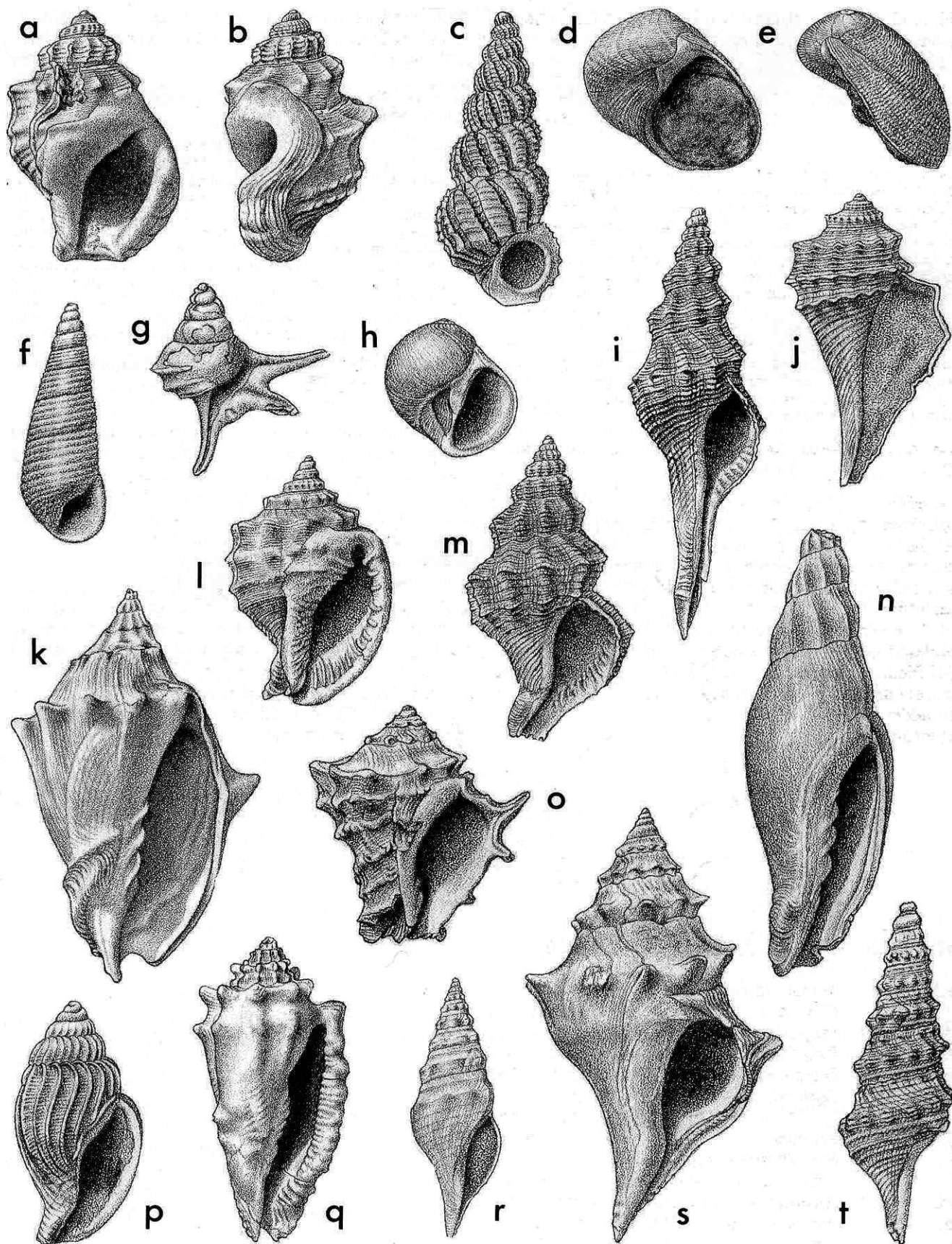
Bortonian, Hampden Formation, Hampden Beach (type); Kakahu; Black Pt, Bortons; Ngapara; Pareora River. Rare at all localities.

Priscoficus allani Marwick, 1960 (Porangan?, Otaio Gorge) was based on juvenile shells but seems to be very similar to *P. alectodens* and may not be distinct. *P. obtusa* (Pl. 2w) has clasping teleoconch whorls (i.e. the shoulder angle is obscured by the sutural ramp of the succeeding whorl) and has coarser tubercular sculpture and a more capacious aperture than *P. alectodens*.

Priscoficus differs from *Ficus* in having prominently keeled rather than evenly convex teleoconch whorls, and prominent nodular or tubercular sculpture in contrast to the predominantly spiral sculpture (and in some species fine axial sculpture) typical of the latter genus. *Priscoficus* is not known after the Bortonian in New Zealand; it is also recorded from Paleocene to Early Eocene in Europe and North America.

Plate 6 Middle Eocene (Porangan-Bortonian) Mollusca (2).

- a,b. *Monalaria concinna* (Suter), x 1.5.
- c. *Cirsotrema (Cirsotrema) kuriense* Marwick, x 2.
- d,e. *Propesinum fornicatum* (Suter), x 2.
- f. *Keilostoma malingi* Marwick, x 4.
- g. *Dicroloma (sensu lato) zelandica* Marshall, x 1.5.
- h. *Carinacca allani* (Marwick), x 2.
- i. *Falsiculus bensoni* (Allan), x 1.5.
- j. *Priscoficus alectodens* Marwick, x 1.5.
- k. *Mauira biconica* (Suter), x 1.
- l. *Galeodea (Galeodea) modesta* (Suter), x 1.5.
- m. *Austrofusus (Austrofusus) acuticostatus* (Suter), x 2.
- n. *Waihaoia thomsoni* Marwick, x 1.5.
- o. *Fascioplex liraecostata* (Suter), x 1.5.
- p. *Eocithara (Marwickara) waihaoensis* Laws, x 2.
- q. *Athleta necopinata* Suter, x 1.5.
- r. *Insolentia (?) sertula* (Suter), x 1.5.
- s. *Speightia spinosa* (Suter), x 1.
- t. *Gemmula reticulata* (Marshall), x 3.



Figured specimen (Pl. 6j): GS11150, J39/f7686, Pareora River near Mt Horrible, Bortonian (NZGS) x 1.5.

Pl. 6 m. *Austrofuscus (Austrofuscus) acuticostatus* (Suter, 1917) [*Siphonalia nodosa acuticostata* Suter 1917, p. 81] (Buccinidae).

Rather small for genus (height 25-30 mm), broadly fusiform, spire half height. Protoconch conical, of about 4 whorls, last 0.5 whorl with narrow opisthocyrt costellae. Teleoconch whorls 6 or 7, angled medially on spire, last whorl with well developed peribasal angulation, strongly excavated below with a short, curved neck. Axial sculpture of prominent rounded costae, slightly tubercular at angulations, reaching from lower suture to upper part of sutural ramp on spire whorls, dying out rapidly on upper part of base; 11 or 12 on penultimate whorl. Spiral sculpture of numerous narrow cords with interstitial secondary and tertiary threads, finely crenulated by growth lines. Aperture ovate, with narrow siphonal canal sharply bent to left; outer lip somewhat thickened internally, bearing about 15 narrow lirae within.

Bortonian, Waihao Greensand, Waihao Downs (type) (uncommon).

Austrofuscus acuticostatus has also been recorded from McCulloch's Bridge (Kaiatan) but the species occurring there is distinct, differing in its larger size, less slender shape, more strongly angled teleoconch whorls and coarser spiral sculpture. Except for a doubtful record from the Waipawan of Chatham Island, this is the oldest known species of *Austrofuscus*, an endemic genus that includes numerous species, many of them highly distinctive and having short stratigraphic ranges. *A. acuticostatus* differs from younger species in its relatively small size, slender shape, fine spiral sculpture and somewhat thickened, distinctly lirate outer lip.

Figured specimen (Pl. 6m): GS11216, J40/f068, South Branch Waihao River, near Waihao Downs, Bortonian (NZGS) x 2.

Pl. 6 i. *Falsicolus bensoni* (Allan, 1926) [*Fusinus bensoni* Allan 1926, p. 339-340] (Fasciolaridae).

Size moderate for genus (height 50-70 mm), fusiform, spire about half total height. Protoconch not known but probably conical, of about 3 whorls. Teleoconch of 7-8 whorls, typically sharply angled medially on spire but angulation becoming obsolete on last whorl of some shells; sutural ramp flat or slightly concave. Last whorl strongly excavated with long, straight or somewhat twisted neck. Axial sculpture of rounded orthocline costae with concave interspaces of similar or greater width, reaching from suture to suture on earliest whorls but quickly becoming obsolete on upper part of ramp on later whorls and on some shells becoming restricted to rather sharp peripheral tubercles on last whorl or so; 9-11 on penultimate whorl. Some shells with axial sculpture—other than growth lines—absent from last whorl. Spiral sculpture commencing as a narrow peripheral cord with 1 or 2 of similar strength between it and lower suture, and fine threads on sutural ramp, some of which become as prominent as the primaries on later whorls. Threads also present between primaries on later whorls. Last whorl with 15-18 additional narrow cords, some with interstitial threads, on base and neck. Aperture pyriform, with a long, almost straight siphonal canal; columella almost straight except for blunt twist near top of canal. Inner lip with thin callus smear; outer lip thin, finely lirate within.

Bortonian, Waihao Greensand, Waihao Downs (uncommon).

Falsicolus alta may be the same as this species, but the available material (Bortonian, Hampden Beach) is too poorly preserved to compare satisfactorily with Waihao shells. *F. solida* (Kaiatan, McCulloch's Bridge, Westland and Nelson) is similar in size and overall shape but has evenly convex or only feebly angled teleoconch whorls, so that axial costae do not become tubercular on later whorls.

Falsicolus is an endemic genus which is first recorded from the Red Bluff Tuff on Pitt Island (Waipawan) and ranges as high as Kapitean. Typical species of the genus have strongly angled teleoconch whorls with prominent conical or vertically compressed peripheral tubercles but others, including *F. alta* and *F. solida* have axial sculpture of rounded costae, occasionally tubercular on the periphery but not as prominently so as in the former group. Still others [*F. gemmata* (Pl. 25t) and *F. ectypa*] have distinct gemmate sculpture produced by the intersection of axial and spiral elements. Such sculptural heterogeneity suggests that the genus should be subdivided into at least three subgenera. *Falsicolus* is extinct but the fossil occurrences indicate that it ranged from about mid-shelf to upper bathyal depths.

Figured specimen (Pl. 6i): GS11216, J40/f068, South Branch, Waihao River, near Waihao Downs, Bortonian (NZGS) x 1.5.

Pl. 6 o. *Fascioplex liraecostata* (Suter, 1917) [*Galeodes (Pugilina) liraecostata* Suter 1917, p. 19; ?*Rapana neozelanica* Suter 1917, p. 38-39]. Type species of *Fascioplex* Marwick, 1934 (Melongenidae).

Small for family (height 25-35 mm), biconic, spire low, about 0.25 total height. Protoconch not known. Teleoconch of about 5 strongly clasping whorls in which the sutural ramp extends up to, or slightly below the peripheral keel of the previous whorl. Last whorl with a very prominent peripheral keel and 3-5 well spaced keels of similar or somewhat lesser strength below. Axial sculpture of prominent triangular scale-like spines which are open aperturally, confined to keels, those on peripheral keel stronger than those below and turned upwards on many specimens; 10 or 11 on penultimate whorl. Last half whorl or so with a subsutural row of very short, closely spaced triangular scales. Spiral sculpture other than keels of numerous threads over whole surface. Aperture ovate with a short, constricted siphonal canal; inner lip thinly callused, outer lip thin, with short internal grooves at positions of keels. Columella concave adapically, twisted to left at inception of siphonal canal; bearing 2 thin, closely spaced plaits on twist. Fasciole prominent, scaly, with a well defined pseudumbilicus between it and inner lip.

Bortonian, Waihao Greensand, Kakahu (type of *G. liraecostata*); "Waihao River" (type of *R. neozelanica*); South Branch, Waihao River near Waihao Downs; Black Point, Bortons; Pareora River. Moderately common to uncommon at listed localities.

The relationship of this species to the other two nominal species of *Fascioplex*, i.e. *F. neozelanica* (Kakahu) and *F. browni* (Waihao Downs) remains to be determined. The holotype of *F. neozelanica* is badly worn, but specimens attributed to this species by Marwick (1934) are similar to *F. liraecostata* in shape and axial sculpture but lack keels on the base and neck and have a much less prominent fasciole (and consequently a less obvious pseudumbilicus). Nonetheless, it seems probable that the two "species" grade into one another and are not worth separating. *F. browni* is known only by the holotype, which differs from typical specimens of *F. liraecostata* in having a much higher spire, axial sculpture of lamellar growth ridges (in addition to peripheral spines) and at least seven prominent spiral cords on base and neck. These differences suggest that *F. browni* is a distinct species.

Fascioplex is an endemic genus, so far recorded only from the Bortonian, but it resembles (in miniature) *Melongenina* species in the Cenozoic and living faunas of south-eastern USA.

Figured specimen (Pl. 6o): hypotype of Marwick (1934, pl. 1, fig. 9), locality uncertain but probably Waihao Downs, Bortonian (NZGS) x 1.5.

Pl. 6 p. *Eocithara (Marwickara) waihaoensis* Laws, 1935b [p. 29]. Type species of *Marwickara* Laws, 1935 (Harpidae).

Small for family (height 23 mm), elongate-ovate, spire 0.4 total height. Protoconch not definitely known. Teleoconch of 4 convex, weakly shouldered whorls, last whorl with a short neck; sutures impressed. Axial sculpture of narrow, sharp-crested costae with broad interspaces, opisthocyrte on spire, sinuous on last whorl, reaching across base; 20 on penultimate whorl. Spiral sculpture of fine cords between costae, intersected by growth lines. Aperture ovate, columella twisted to left at inception of short, open, shallowly notched siphonal canal. Inner lip narrowly but rather thickly callused, bearing a weak V-shaped parietal denticle. Outer lip sinuous with bevelled varix, weakly denticulate within. Fasciole moderately prominent, rounded.

Bortonian, Waihao Greensand, Waihao Downs, i.e. from South Branch, Waihao River (type) (very rare).

No other species of *Eocithara* have been described from New Zealand, but an as yet unnamed harpid from White's Creek, North Canterbury (Mangaorapan) probably belongs here; it differs from *E. waihaoensis* in its larger size (height 30 mm), lower spire, stronger spiral sculpture, and more prominent fasciole (Rehder 1973, p. 231). Another possible member of the genus is the very poorly preserved specimen from Gisborne district (Duntroonian) that was originally identified as *Morum (Oniscidia)* sp. (Marwick 1931, p. 13, pl. 10, fig. 185; Fleming 1966b, pl. 113, fig. 1381). Until recently these were the only New Zealand species thought to belong in the typically warm-water family Harpidae but it is now known that the genus *Morum*, long considered to be a cassid, is a harpid (Hughes 1986). *Morum* is represented in the Oligocene to Middle Miocene of New Zealand by at least three species of the subgenus *Oniscidia* (see below).

Figured specimen (Pl. 6 p): holotype, Waihao Downs, South Canterbury, Bortonian (AMTM265, Auckland Institute and Museum) x 2.

Pl. 6 q. *Athleta necopinata* Suter, 1917 [p. 40; *Plejona necopinata*; *Notoplejona necopinata*]. Type species of *Notoplejona* Marwick, 1926, synonymised with *Athleta* Conrad, 1853 by Darragh (1971, p. 166-167) (Volutidae: Athletinae).

Small for family (height 30-50 mm), broadly fusiform, spire moderately elevated, about 0.3 total height. Protoconch small, narrowly dome-shaped, of about 3 whorls, last whorl with axial costellae. Teleoconch whorls 5 or 6, convex at first then developing a narrow sutural shelf; last whorl elongate, gently convex, gradually contracted. Axial sculpture commencing as narrow costae reaching from suture to suture, soon developing laterally compressed triangular tubercles on shoulder angle and some distance below (just above suture on spire whorls), costae eventually becoming obsolete in between so that later whorls typically have 2 rows of tubercles without definite interconnecting costae; 8-10 on last whorl. Spiral sculpture of weak threads on spire whorls, more prominent on last whorl, where they consist of low, rounded or flat-topped cords with narrow interspaces, obsolete near middle of whorl on some shells. Aperture rather narrow, anterior end deeply notched, posterior end with shallow sinus. Inner lip heavily callused, some shells with a triangular spur near middle of outer margin of callus; columella almost straight, padded near middle on mature shells and bearing 5 or 6 weak plaits, the anterior one somewhat stronger than the others. Outer lip reflected, with prominent varix, its outer edge crudely nodulose, inner edge finely crenulate. Fasciole ridge-margined.

Bortonian, Waihao Greensand, Waihao Downs (type); Kakahu; Black Point, Bortons; Kakanui River; Pareora

River. Moderately common to uncommon at listed localities.

Athleta necopinata is the most elaborately sculptured New Zealand volute and is unlikely to be confused with anything else except perhaps the poorly known *A. lata*, which was described from Castle Hill Shaft, Kaitangata (Porangan?) and later recorded from Otaio Gorge (Marwick 1960, p. 23). *A. lata* seems to differ from *A. necopinata* in having a lower spire and finer spiral sculpture and in lacking a definite sutural shelf.

Athleta is recorded from Europe, North America, Africa, Asia and Australia and has a stratigraphic range of Late Cretaceous to Recent (Darragh 1971, p. 168), but in New Zealand it is not known after the Bortonian.

Figured specimen (Pl. 6q) : GS11150, J39/f7686, Pareora River near Mt Horrible, Bortonian (NZGS) x 1.5.

Pl. 6 k. *Mauira biconica* (Suter, 1917) [*Galeodes biconica* Suter 1917, p. 18-19; *Fulgoraria (Alcihoë) biconica* Suter 1917, p. 39-40; *Mauia biconica*; *Mauia curvispina* Marwick 1926a, p. 273; *Mauira curvispina*] (Volutidae: Zidoninae).

Size moderate for family (height 70-80 mm), broadly biconic, spire 0.25-0.4 total height. Protoconch mamillate, of about 2 whorls with apical spike. Teleoconch whorls sharply angled, but angulation on spire whorls of most shells obscured by sutural ramp of succeeding whorl. Sutural ramp flat or slightly convex; sides of last whorl straight or gently convex, contracted gradually. Axial sculpture on early whorls of narrow costae with sharp tubercles at angulation, later whorls with prominent peripheral tubercles that are scarcely prolonged abapically and vary in length and curvature; 8 or 9 on last whorl. Spiral sculpture of numerous very fine threads preserved on only a few shells. Aperture capacious, columella almost straight with 4 prominent subequal plaits; inner lip thinly callused, outer lip probably slightly reflected. Siphonal notch deep, oblique; fasciole prominent, raised, ridge-margined.

Bortonian, Waihao Greensand, Kakahu (type of *G. biconica*); "Waihao River", probably Waihao Downs (type of *F. biconica*); Waihao Downs (type of *M. curvispina*); Hampden Formation, Hampden Beach; Pareora River. Moderately common to uncommon at listed localities.

Apart from its larger size, the type of *M. curvispina* differs from that of *M. biconica* (which is not adult) only in having a slightly more convex last whorl and longer, more strongly curved spines, differences that are not in themselves sufficient to discriminate species in the Volutidae. The relationship of *M. biconica* to other nominal Bortonian species of *Mauira* is less clear, however. *M. waihaoensis* (also from Waihao Downs) was based on a shell with a relatively tall spire in which the peripheral angulation is clear of the succeeding whorl, and is very similar, if not identical to *M. angusta* (Kakahu). Future work will probably show that *M. angusta* and *M. waihaoensis* are additional synonyms of *M. biconica*. *M. maoriana* (also from Kakahu, and the type species of *Mauira*) seems to be a distinct, rather bizarre species in which the tubercles are in a more anterior position so that on the last whorl they emerge from the aperture.

Mauira is an endemic genus which is first recorded from the "Matau" faunule of Castle Hill Shaft, Kaitangata (Porangan?) and is represented in many shallow-water Bortonian faunules, but then disappears from the fossil record, only to apparently reappear in the Altonian.

Figured specimen (Pl. 6k): GS11148, J40/f8858, South Branch, Waihao River near Waihao Downs, Bortonian (NZGS) x 1.

Pl. 6 n. *Waihaioia thomsoni* Marwick, 1926a [p. 277] (Volutidae: Zidoninae).

Size moderate for genus (height 52-62 mm), narrowly fusiform, spire 0.4 total height. Protoconch not known. Teleoconch of about 6 or 7 whorls, early whorls convex, later whorls broadly shouldered near middle, angulation increasing in prominence for 2 or 3 whorls then gradually weakening, becoming obsolete on last whorl of some shells; last whorl elongate, broadly excavated with a short, slightly curved neck. Axial sculpture commencing as narrowly rounded costae with much broader interspaces, 8-9 per whorl, reaching from suture to suture, becoming thickened at shoulder angulation on later whorls, in some shells reduced to peripheral nodules on last whorl, in others becoming obsolete on last whorl. Spiral sculpture of very numerous, exceedingly fine striae, retained only on unabraded parts of shell. Aperture narrow, elongate; columella gently convex, bearing 4 or 5 narrow, well spaced plaits. Siphonal notch shallow, fasciole low, rounded. Outer lip thin.

Bortonian, Waihao Greensand, Waihao Downs, probably South Branch, Waihao River (type); Pareora River (uncommon). Distinguished from *W. allani* (Pl. 8p) by its more slender shell and in having the axial costae changing into peripheral nodules or becoming obsolete on the last whorl.

Figured specimen (Pl. 6n): GS5467, J39/f7508, Pareora River, near Evan's Crossing, Bortonian (NZGS) x 1.5.

Pl. 6 t. *Gemmula reticulata* (Marshall, 1919) [*Turris reticulatus* Marshall 1919, p. 231] (Turridae: Turrinae).

Rather small for subfamily (height c. 25 mm), fusiform, spire about 0.6 total height. Protoconch not known, but probably conical with axial costae on the last 2 or 3 whorls. Teleoconch of 7-8 whorls, strongly angled at about 0.4 whorl height on spire, sutural ramp steep, concave with a low subsutural swelling; last whorl with weak peribasal subangulation, excavated below, probably with moderately long neck. Axial sculpture of prominent rounded or subrectangular peripheral nodules and much weaker, low nodules just below suture corresponding to those on periphery but set forwards; 12-16 nodules on penultimate whorl; other axial sculpture of growth lines. Spiral sculpture of narrow cords or threads, typically rather subdued, but in the figured specimen 1 cord between periphery and lower suture much more prominent than others. Aperture broken in available specimens, but presumably pyriform with a moderately long, unnotched siphonal canal; inner lip distinctly impressed posteriorly; outer lip apparently thin, smooth within; anal sinus deep, narrowly U-shaped, apex on peripheral keel.

Bortonian, Hampden Formation, Hampden Beach (type) (uncommon).

Gemmula reticulata is distinguished from other New Zealand species of *Gemmula* by having the peripheral keel angled rather than rounded or flattened, by its relatively coarse peripheral tubercles, by its relatively fine spiral sculpture and by the absence of internal lirae on the outer lip.

Figured specimen (Pl. 6t): Hampden Beach, Bortonian (NZGS, ex Marshall and Murdoch Colln.) x 3.

Pl. 6 r. *Insolentia* (?) *sertula* (Suter, 1917) [*Surcula sertula* Suter 1917, p. 53] (Turridae: Turrinae).

Size moderate for family (height 23-50 mm), fusiform, spire about half total height. Protoconch not known. Teleoconch of about 9 whorls, weakly shouldered near middle on spire, sutural ramp steep, slightly concave with low subsutural fold; last whorl broadly excavated, contracted to moderately long neck. Axial sculpture on early whorls of very short, low, rounded costae reaching from middle of ramp to lower suture; on later whorls costae changing gradually into low, broad, rounded nodules on shoulder and eventually becoming obsolete; 8 or 9 per whorl. Spiral sculpture subdued, consisting of a narrow cord on

lower edge of subsutural fold, another on shoulder angle and 8-10 of similar strength on base and neck of last whorl; also background sculpture of very numerous, exceedingly fine threadlets over shell surface. Aperture narrowly pyriform, columella almost straight, oblique. Inner lip smooth, slightly impressed adapically; outer lip thin with a rather shallow anal sinus, its apex rounded and near middle of ramp.

Porangan?; Bortonian, Waihao Greensand, Waihao Downs (type) (not uncommon); Hampden Beach; Pareora River; Otaio Gorge (?).

This species is somewhat doubtfully referred to *Insolentia* because its anal sinus is broader and less symmetrical than in typical species of the genus. It superficially resembles some species of *Comitas* but differs in having a much shallower sinus.

Figured specimen (Pl. 6r): South Branch, Waihao River, near Waihao Downs, Bortonian (NZGS, ex C.R. Laws Colln.) x 1.5.

Pl. 6 s. *Speightia spinosa* (Suter, 1917) [*Euthriofusus spinosus* Suter 1917, p. 24]. Type species of *Speightia* Finlay, 1926 (Speightiidae).

Moderately large (height 55-90 mm), broadly biconic, spire about 0.4-0.5 total height. Protoconch not known. Teleoconch of 7 or 8 whorls, sharply keeled a short distance above suture on spire; last whorl with rounded peribasal subangulation, broadly excavated below; neck moderately long, slightly curved. Axial sculpture of prominent, vertically compressed, rounded tubercles on peripheral keel; 9-11 per whorl. Spiral sculpture of subdued cords and threads below keel. Aperture pyriform; columella straight or slightly concave adapically, twisted to left at inception of moderately long siphonal canal. Inner lip moderately thickly callused with a narrow entering ridge near adapical end. Outer lip thin, smooth within, with a moderately broad, shallow anal sinus on ramp, its apex much closer to keel than to suture.

Bortonian, Waihao Greensand, Waihao River (type)—probably South Branch near Waihao Downs; Hampden Beach; Black Point, Bortons; Pareora River. Not uncommon at most localities.

Speightia is a monotypic genus so far known only from Bortonian faunules of offshore facies, but it is apparently closely related to *Clinuropsis* Vincent, 1913 (Paleocene, Belgium, Zaire) and *Andicula* Olsson, 1929 (Early Eocene, Peru). Powell (1942) proposed the family Speightiidae for these three genera and placed it near the Turridae, although the relationship may not be as close as is implied. Species included in the family superficially resemble some buccinids, e.g. *Penion*, but speightiids are readily distinguished by their relatively pronounced anal sinus.

Figured specimen (Pl. 6s): paratype, GS480, J40/f8372, Waihao River, probably South Branch near Waihao Downs, Bortonian (TM5753, NZGS) x 1.

Pl. 6 c. *Cirsotrema kuriense* Marwick, 1942 [p. 275, as *kuriensis*] (Epitoniidae).

Size moderate for genus (height 25-30 mm), spire elevated. Protoconch not known. Teleoconch whorls strongly convex, sutures obscured by lateral extensions of costae; last whorl with well defined basal disc. Axial sculpture of prominent prosocline costae reaching from suture to suture on spire and across basal disc to fasciole on last whorl. Costae narrow with much wider interspaces on early whorls, but becoming relatively much broader with narrow interspaces on later whorls; costae composed of numerous lamellae fused together, rounded on crests, abapertural face slightly concave. Varices at irregular intervals, scarcely distinguishable from other costae on later whorls; 9-11 costae (including varices) per whorl. Spiral sculpture of 5 or 6 low, flattish cords on spire whorls, considerably more prominent on costal crests than in interspaces, and very fine interstitial threads. Last whorl with additional strong cord

marking edge of basal disc, and fine threads between costae on base. Aperture subcircular, heavily variced, basal lip truncate. Fasciole well marked.

Bortonian, Hampden Formation, Hampden Beach (uncommon). Probably most closely related to *C. caelicola* (Altonian, Kakanui) but much smaller, having

more closely spaced axial costae at a similar stage of growth and having more prominent spiral cords on the axial costae.

Figured specimen (Pl. 6c): holotype, Hampden Beach, North Otago, Bortonian (TM6852, NZGS) x 2.

CHAPTER 8. LATE EOCENE FAUNAS (KAIATAN AND RUNANGAN STAGES): PLATES 7, 8.

INTRODUCTION (Figure 13)

In contrast to the Middle Eocene molluscan faunules described in the previous chapter, those of Late Eocene age (Kaiatan and Runangan Stages) come from a rather limited range of facies. Except for a possible component of the Lorne faunule (see below), no significant shallow-water assemblages are known, and our knowledge of the fauna is based almost entirely on relatively deep-water faunules. The marine transgression that had recommenced in the early Middle Eocene continued throughout the Late Eocene (albeit with a probable short-lived stillstand or reversal in the late Bortonian), with the result that most sediments deposited during this period are fine-grained (mudstone, marl and limestone) and of deep-water facies, and contain few if any macroinvertebrates. An additional problem is that the thickest and most widespread Late Eocene rock unit, the Kaiata Formation, was deposited under partly anoxic conditions so with a few exceptions molluscan faunules in it are sparse and of low diversity.

The regional depositional pattern was complicated in the Oamaru district by local volcanism that produced seamounts or mounds (Waiareka Volcanic Formation), with associated bryozoan limestone (Totara Limestone) or Oamaru Diatomite. Virtually all we know about Runangan molluscs is based on collections from these three units, particularly the Waiareka Volcanic Formation.

Westland and Nelson

The Paparoa Trough continued to subside during the Late Eocene and was joined by smaller subsiding basins near Reefton, Murchison and Nelson, so that by the end of the Eocene, the West Coast was reduced to "an archipelago of low-lying islands" separated by moderately

deep seas of restricted circulation (Nathan et al. 1986, p. 31, 63). Carbonaceous, calcareous sandstone (Island Sandstone) was deposited in places (e.g. in the Punakaiki-Fox River area), but the most widespread unit is the Kaiata Formation, which consists primarily of dark brown, massive or faintly bedded, calcareous, carbonaceous mudstone (Kaiata Mudstone Member) attaining a thickness of 2000 m in the deepest parts of the Paparoa Trough, and about 1000 m in the other basins. A thick clastic wedge of coarse sandstone and conglomerate (Omotumotu Member), interbedded with Kaiata Mudstone on the east side of the Paparoa Trough, was formed during rapid, fault-controlled uplift along the margin of the basin.

The best outcrop of Kaiata Formation is in the sea-cliffs and shore platform from Point Elizabeth, north to Rapahoe Beach, near Greymouth. This section includes the hypostratotype of the Kaiatan Stage, and the holostratotype of the Runangan Stage. Molluscs are typically very sparse, but a pocket from high in the Kaiatan part of the section contained a moderately diverse, well-preserved faunule including *Pseudoportlandia* n.sp., *Procardia* cf. *dolicha*, *Uberella* n.sp. aff. *cicatrix*, "*Uberella*" *haasti*, *Exilia* cf. *waihaoensis*, *Falsiculus* *solida*, *Austrofusus* *bicarinatus*, *Amalda* (*Gracilispira*) n.sp., *Ancillus* n.sp., *Volutomitra* (*Waimatea*) *inconspicua*, *Eoturris* cf. *complicata*, *Zemacies* cf. *marginalis*, *Tholitoma* n.sp., *Microdrillia* n.sp. and *Cordieria* cf. *rudis*. This is very similar to the McCulloch's Bridge faunule (see below) except for the presence of a few genera (e.g. *Procardia*, *Tholitoma* and *Microdrillia*) not recorded from the Waihao locality. The similarity of the two faunules suggests similar depositional environments, i.e. outer shelf or upper bathyal zones, a conclusion consistent with microfossil

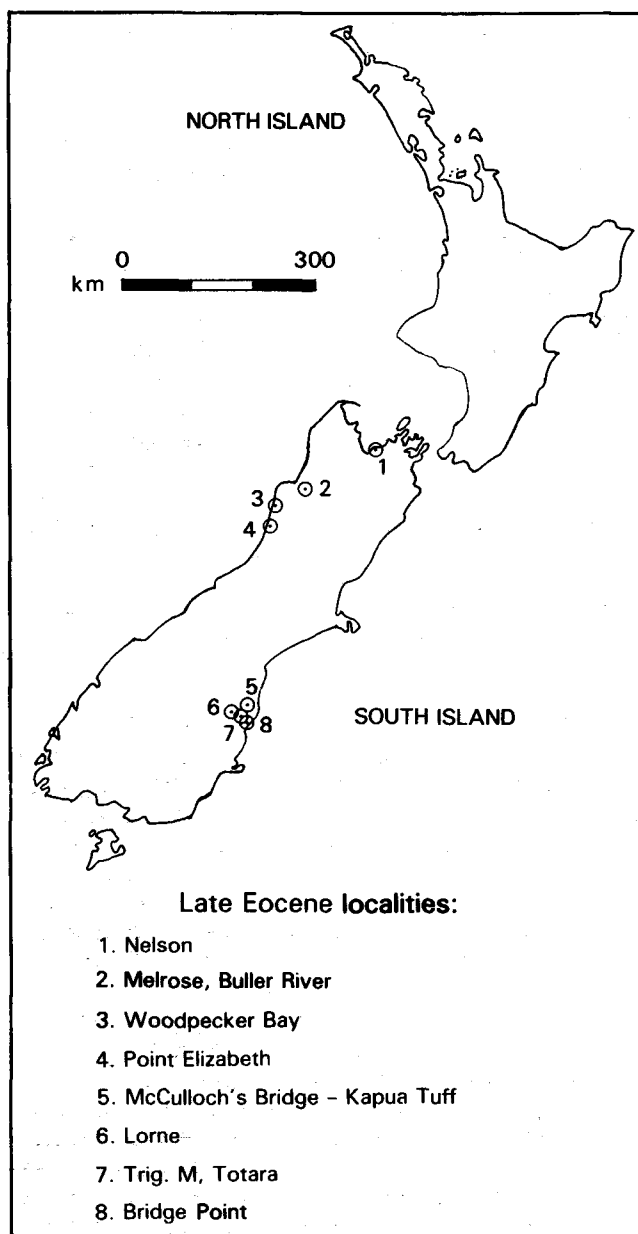


Figure 13 The main molluscan fossil localities of Kaiatan and Runangan (Late Eocene) age.

evidence (Hoskins in Nathan 1974, p. 16). Some of these species are also present in a less diverse faunule from Melrose, Buller River, between the Reefton and Murchison Basins. Faunules from Kaiata Formation elsewhere in these basins are of low diversity, and most are dominated by the turritellid *Spirocolpus* cf. *waihaoensis*.

In the Nelson City area the Braemar Formation is the local equivalent of the Kaiata Formation (Nathan et al. 1986, p. 33). It has yielded a few small molluscan faunules, the richest being a probable Kaiatan one from Bishopdale quarry with *Pinna* aff. *distans*, *Polinices* (*Polinella*) cf. *esdailei*, *Exilia* cf. *waihaoensis*, *Falsiculus* cf. *solida* and *Waihaoia* sp. A very small collection from an excavation for Nelson Public Hospital is noteworthy for including the earliest known "*Hinnites*" from New Zealand (Vella 1962, p. 155).

The only determinable mollusc recorded from the

Omotumotu Member is a limpet closely resembling the extant intertidal rock-dweller *Cellana strigilis*. Its presence in the Kaiata Formation implies emplacement by some mass-flow process, and suggests that a careful examination of outcrops of Omotumotu Member for other shallow water molluscs would be profitable.

Molluscan faunules from the Island Sandstone at Perpendicular Point near Punakaiki, and at Woodpecker Bay, mouth of Fox River, consist of calcitic species, e.g. *Serripecten* n.sp., *Janupecten* cf. *uttleyi*, *Pinna* sp. and *Cirsotrema* sp., and evidently lived in a much shallower environment than those from the Kaiata Formation.

Waihao River, South Canterbury

By far the most diverse molluscan faunule yet recorded from the New Zealand Eocene is from a thin bed (about two metres thick) at the top of the Waihao Greensand near McCulloch's Bridge, Waihao River. This locality has long been known and is the source of numerous species described by most of the leading workers on New Zealand Cenozoic molluscs. The recorded faunule from this bed of glauconitic sandstone, which is only a few metres above the Bortonian-Kaiatan boundary, totals more than 200 species, including *Saccella semiteres*, *Pseudoportlandia tahuia*, *Limopsis waihaoensis*, *Notolimopsis hampdenensis*, *Parvamussium* n.spp., *Caestocorbula* n.sp., *Spirocolpus waihaoensis*, *Zeacolpus lornensis*, *Pareora sublaevis*, *Polinices* (*Polinella*) *esdailei*, *Carinacca waihaoensis*, *Friginatica suturalis*, "*Uberella*" *haasti*, *Neverita pontis*, *Sassia cyphoides*, *Cirsotrema* n.sp., *Exilia waihaoensis*, *Falsiculus solida*, *Austrofuscus* n.sp., *Latirulus* n.sp., *Poirieria denticulifera*, *Amalda* (*Gracilispira*) *morgani*, *Ancillus* n.sp., *Volutomitra* (*Waimatea*) *inconspicua*, *Peculator* (*Parvimitra*) *plicatellus*, *Waihaoia allani*, *Conilithes tahuensis*, *Marshallena neozelanica*, *Marshallaria spiralis*, *Eoturris complicata*, *Gemmula* spp., *Cochlespira* (*Tahusyrinx*) *maora*, *Cordiaia rudis*, *Zeacuminia tahuia* and *Wangaloa ngaparaensis*. This assemblage has some similarity—particularly at the genus-group level—to the Bortonian one from Hampden Beach, probably partly because of its low position in the Kaiatan, but also as a result of a similarity in depositional environment; it differs, however, in the absence of several important Bortonian taxa, e.g. *Monalaria*, *Fascioplex* and *Speightia*, all of which occur at Hampden.

The McCulloch's Bridge assemblage indicates deposition in quiet, moderately deep waters (outer shelf or upper slope) and under warm conditions, possibly equivalent to those prevailing in northern New South Wales at the present day (Maxwell in prep.).

The Ashley Mudstone, which overlies the Waihao Greensand at McCulloch's Bridge and elsewhere in South Canterbury, typically contains only sparse, poorly preserved molluscs, but a moderately diverse, well preserved faunule has been collected from a thin bed of pyroclastics (Kapua Tuff) in the upper part of the unit, upstream from the bridge. This faunule, which is from near the top of the Kaiatan in this section, has some species in common with the McCulloch's Bridge faunule, but for the most part it is very different because of the much firmer substrate afforded by the tuff, and because it probably lived in considerably deeper waters.

Characteristic species include *Ennucula* n.sp., *Parathyasira* n.sp., *Spectamen* n.sp., *Calliotropis* n.sp., *Spirocolpus waihaoensis*, *Zeacolpus lornensis*, "*Uberella*" *haasti*, *Dicroloma zelandica*, *Austrofusus bicarinatus*, *Amalda* (*Alocospira*) n.sp., *Waihaoia allani*, *Parasyrinx* (*Lirasyrinx*) n.sp., *Cordieria rudis*, *Superstes marshalli*, *Spiratella* spp., and *Gadilina* n.sp. The relative abundance of archaeogastropods (particularly *Spectamen* n.sp.) and of the aporrhaid *Dicroloma zelandica* give this assemblage a very distinctive aspect.

North Otago

The Late Eocene is represented in North Otago by four rock units, Raki Siltstone (equivalent to the Ashley Mudstone), Waiareka Volcanic Formation (probably several discrete accumulations of volcanogenic rocks rather than a single, laterally continuous unit), Oamaru Diatomite and Totara Limestone. Most of the molluscs recorded from this region are from the Waiareka Volcanic Formation or from tuffaceous beds within the Totara Limestone. A few small faunules have been collected from the Oamaru Diatomite (e.g. the type material of the bivalve *Dimya westonensis* Maxwell) (Maxwell in Edwards in prep.), and an oyster is recorded from the Raki Siltstone (Gage 1957, p. 33). The richest faunule (over 100 species) is from a highly distinctive, green tuffaceous agglomerate at the foot of Williams' Bluff, between Weston and Ngapara, a locality long known as "Lorne" after the former nearby railway station (Marwick 1926b). This faunule, which is from a large block fallen from very near the top of the Waiareka Volcanic Formation, has long been thought to be Kaiatan, but a Runangan age is likely (A.R. Edwards, pers. comm.); in either case, it is considerably younger than the early Kaiatan McCulloch's Bridge faunule. We have accepted a late Kaiatan age for the purposes of lists and range charts. The Lorne assemblage apparently owes its diversity to mixing of several different biotopes—it includes a siphonariid limpet (indicative of an intertidal habitat) and a *Bolma* similar to the extant mid-bathyal species *B. recens* (Dell). An origin as a mass debris flow is consistent with the unusual lithology—basalt clasts ranging in size from pebbles to boulders, in a bright green tuffaceous mudstone matrix.

The Lorne faunule has several species in common with McCulloch's Bridge, but for the most part it is strikingly different and is dominated by epifaunal species preferring a firm or hard substrate. Protobranchs, naticids, olivids and turrids—all of which are well represented at the Waihao locality—are rare or absent at Lorne. Characteristic species include *Quadrilateria januaria*, *Notogrammatodon inexpectatus*, *Tucetona lornensis*, *Chlamys* n.sp., *Serripecten enfieldensis*, *Limatula trulla*, *Anatoma* n.sp., *Emarginula* n.sp., *Astraea* n.sp., *Bolma* aff. *marshalli*, *Spirocolpus tophinus*, *Zeacolpus lornensis*, *Pareora sublaevis*, *Sigapatella vertex*, *Lachryma vulcania*, *Trivia pinguior*, *Xenophora* n.sp., *Sassia cyphoides*, *S. (Haurokoa) marwicki*, *Falsicolus obruta*, *Volutomitra (Waimatea) inconspicua*, *Rugobela humerosa* and *Tatara revoluta*. Pteropods are exceptionally common and diverse (at least eight species) and include *Lornia limata*, *Spiratella* spp., *Clio* n.sp. and *Hyalocypris annulata*.

A less diverse assemblage—unequivocally of Runangan

age—is recorded from the Waiareka Volcanic Formation at Bridge Point, near Kakanui, about 17 km south of Lorne. This is the type locality of *Cardilona bensoni* Marwick (referred to the verticordioid genus *Pecchiolia* by Maxwell (1978)) and possibly of *Serripecten venosus* (Hutton); other molluscs from Bridge Point include *Lima* n.sp., *Nemocardium (Pratulium) semitectum*, *Marama (Hina)* n.sp. aff. *tumida*, *Danilia neozelanica*, *Zeacolpus lornensis*, *Rugobela humerosa* and *Aturia* sp.

The only other diverse Runangan faunule from North Otago is from a thin tuffaceous bed in Totara Limestone near the summit of Trig M, Totara, about halfway between Lorne and Bridge Point. Molluscs from this locality are mostly fragile and of small size (less than 15 mm) and appear to have lived in quieter and deeper waters than those from Bridge Point. The faunule includes *Quadrilateria januaria*, *Limopsis waihaoensis*, *Calliotropis fenestrata*, *Calliobasis eos*, *Danilia neozelanica*, *Argalista proimpervia*, *A. leniumbilicata*, *Spirocolpus tophinus*, *Zeacolpus lornensis*, *Polinices (Polinella) esdailei*, *Lachryma vulcania*, *Trivia pinguior*, *Rugobela humerosa*, *Cordieria* cf. *rudis* and *Tatara flemingi*.

Composition of the Late Eocene molluscan fauna

The Late Eocene molluscan fauna differs from the Middle Eocene fauna mainly in lacking several distinctive genus-group taxa that are either restricted to the Bortonian or are last recorded from that stage (e.g. *Cubitostrea*, *Tellinella*, *Costacallista*, *Keilostoma*, *Monalaria*, *Priscoficus*, *Athleta* and *Speightia*). Not all of these absences can be explained away by the lack of suitable shallow-water molluscan faunules in the Late Eocene, as at least some taxa (*Monalaria*, *Priscoficus* and *Speightia*) are present in the deep-water Hampden Beach faunule, which is environmentally comparable with the one from McCulloch's Bridge. The most important absence, however, is of the family Struthiolariidae, which is represented in the Bortonian by the widespread, depth-tolerant *Monalaria concinna*, but then disappears from the record only to reappear (as *Struthiolaria*) in the Whaingaroan. This may mean that the family became restricted to shallow or very deep waters during the Late Eocene, or that *Struthiolaria* evolved outside the New Zealand region and came here with many other putative Oligocene arrivals. In either case it seems very unlikely that *Struthiolaria* evolved from *Monalaria*; derivation from *Conchothyra* or a related taxon seems more probable.

Relatively few taxa seem to be restricted to the Kaiatan or Runangan (considered together here because of the uncertain age of Lorne and because undoubted Runangan faunules are relatively sparse), e.g. *Isolimea*, *Erycina* (*Hemilepton*), *Pecchiolia*, *Eoscobinella*, *Tahudrillia*, *Plesiocerithium* (sensu lato), *Kapuatriton*, *Elodiamea* and *Fustiaria* (sensu stricto). It would, however, be unwise to place much reliance on any of these taxa for biostratigraphic indicators.

The following taxa are first recorded from the Late Eocene, mostly from the early Kaiatan (i.e. at McCulloch's Bridge): *Lima*, *Parathyasira*, *Condyllocuna*, *Spissatella*, *Spectamen*, *Calliotropis*, *Calliostoma*, *Calliobasis*, *Argalista*, *Astraea*, *Linemera*, *Attenuata*, *Cheilea*, *Xenophora*, *Trivia* (sensu lato), *Ficus*, *Sassia*

(*Haurokoa*), *Xymene*, *Colubraria*, *Peculator* (*Parvimitra*), *Amalda* (*Alocospira*), *Orthosurcula*, *Parasyrinx* (*Lirasyrinx*), *Tenuiacteon*, *Clio*, *Philine* and *Gadilina*.

Taxa last recorded from the Late Eocene include *Duplipecten*, *Caestocorbula*, *Carinacca*, *Ancillus*, *Cochlespira* (*Tahusyrix*), *Tholitoma*, *Cordieria*, *Triploca* and *Superstes*.

The Late Eocene fauna includes much the same mixture of widespread, warm-water, Australasian and endemic taxa as that of the Middle Eocene. The Australasian element (more specifically, the New Zealand—southeast Australian element) is particularly marked, undoubtedly because faunas of similar age are recorded from both areas for the first time since the Middle Paleocene. According to Darragh (1985, fig. 6) about 28% of the south-east Australian Late Eocene fauna has New Zealand affinities. This similarity exists not only at the genus-group level, but extends to the species level. Two species of gastropods, *Pseudomalaxis asculpturatus* and *Rugobela humerosa*, originally described from the Late Eocene of New Zealand, have been recorded from south-east Australia (Buonaiuto 1975; Long 1981, p. 46). Other New Zealand species, e.g. *Quadrilatera januaria*, *Pareora sublaevis* and *Triploca waihaoensis* are very similar to their coeval Australian congeners. Further work will probably increase the number of species known to be common to both areas.

The presence of such taxa as *Arca*, *Quadrilatera*, *Spondylus*, *Bolma*, *Cheilea*, *Ficus*, *Colubraria*, *Gemmula*, *Cochlespira*, *Marshallena* and *Cordieria* indicates a subtropical climate for southern New Zealand during the Late Eocene.

REPRESENTATIVE LATE EOCENE MOLLUSCA

Pl. 7 a, b. *Quadrilatera januaria* (Marwick, 1926) [*Fossularca januaria* Marwick 1926b, p. 310-311; *Arcopsis januaria*] (Noetiidae).

Rather small for family (length 7-18 mm), subrectangular, strongly inflated, posterior area not clearly differentiated. Sculpture highly discrepant, left valve with about 35 narrow, beaded costellae, interspaces with finer, beaded secondary (and even tertiary) costellae crossed by numerous fine growth lines and, at irregular intervals, interrupted by much stronger growth ridges. Right valve with fine, low, closely spaced commarginal ridges crossed by very numerous radial costellae, apparently forming minute tubercles at intersections, but appearing almost smooth in some shells because of abrasion. Cardinal area long, narrow, with a shallow, triangular, vertically striate ligament pit below beaks. Hinge teeth short, appearing to radiate from near middle of shell, extending most of length of hinge. Margins smooth.

Kaiatan-Whaingaroan; Kaiatan (?), Waiareka Volcanic Formation, Lorne (type); Trig M, Totara; Bridge Point, Kakanui; Deborah Volcanic Formation, Gee's Point, Kakanui. Rare at Gee's Point, moderately common at other localities.

Quadrilatera januaria is readily distinguished from other New Zealand arcoid bivalves by its small size, its rounded ends, its discrepant sculpture, its small, triangular ligament pit and its smooth internal margins. This is the only New Zealand species of this typically warm-water genus and of the Family Noetiidae to have been described to date, but other species are known from the Early Eocene of North and South Canterbury.

Arcoids of this type have long been referred to either *Fossularca* Cossmann, 1887 or to *Arcopsis* Koenen, 1885,

but Ward and Blackwelder (1987, p. 136) have recently drawn attention to Deshayes' (1860, in 1856-1860, p. 866) much earlier but hitherto overlooked name *Quadrilatera* for this group. Neave (1940, p. 1) cited Sandberger, 1863 as the author of *Quadrilatera*, as did Vokes (1980, p. 18) who suggested that it is possibly a synonym of *Fossularca* and should probably be regarded as a "*nomen oblitum*". (*Nomina oblita*, i.e. forgotten names, are no longer rejected under the current International Code of Zoological Nomenclature).

Figured specimen (Pl. 7a, b): GS9481, J41/f8025, Lorne, Kaiatan (NZGS) x 3.

Pl. 7 c, d. *Limopsis waihaoensis* Allan, 1926 [p. 346] (*Limopsidae*).

Small for genus (height 7-11 mm), oval, slightly oblique, thin-shelled. Dorsal margins straight, subequal, or posterior one slightly the longer, sloping gently from small umbo. Anterior and ventral margins convex, junction with slightly convex posterior margin rounded or obtusely subangled. Commarginal sculpture of weak grooves and ridges. Radial sculpture also weak, strongest near posterior end, of indistinct threads that are typically visible only where they weakly crenulate the commarginal ridges. Exterior with an overall polished appearance. Hinge narrow, asymmetrical, arched or subangled behind beak, 5 or 6 teeth in both anterior and posterior series. Cardinal area long, narrow, with fine longitudinal ridges; resilifer small, triangular. Anterior adductor muscle scar ovate, at lower end of hinge; myophoric ridge weakly to strongly developed. Posterior scar twice as large, ovate to subquadrate. Inner margins sharply bevelled, smooth.

Kaiatan-Runangan; Kaiatan, Waihao Greensand, McCulloch's Bridge (type); Totara Limestone, Trig M, Totara; Oamaru Diatomite. Abundant at McCulloch's Bridge, uncommon at other localities.

L. waihaoensis is easily distinguished from most New Zealand species of *Limopsis* by its small size and its feeble sculpture. *L. propeinvalida* (Otaian, Pakaurangi Point, Northland) and *L. invalida* (Waipipian, Pitt Island) are very similar, however, and are distinguished only by minor shape and sculptural differences. All three species are from moderately deep-water (outer shelf or upper slope) assemblages.

Figured specimen (Pl. 7c, d): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 6.

Pl. 7 g, h. *Tucetona lornensis* (Marwick, 1923) [*Glycymeris lornensis* Marwick 1923, p. 66-67; *G. (Grandaxinea) lornensis*] (*Glycymerididae*: *Melaxinaeinae*).

Rather small for genus (height 35-45 mm), ovate, subequilateral, posterior area slightly depressed. Radial sculpture of 34-38 prominent rounded or somewhat flattened costae with narrow interspaces, those on posterior area slightly weaker than on flanks. Commarginal sculpture of numerous fine growth ridges discernible only on early part of well preserved shells, and somewhat stronger ridges at later stages of growth. Cardinal area highly variable in size, ligamental chevrons fine and rather closely spaced; hinge teeth strongly inclined. Inner margin strongly crenulate.

Kaiatan-Whaingaroan; Kaiatan, Waiareka Volcanic Formation, Lorne (type); Trig M, Totara; Deborah Volcanic Formation, Gee's Point, Kakanui; Cookson Volcanics, Lottery River, North Canterbury(?).

Tucetona lornensis is distinguished from younger species of *Tucetona* by its considerably smaller size and its relatively narrow intercostal spaces. *Tucetona* occurs widely in the Indo-West Pacific region and is represented in the modern New Zealand fauna by *T. laticostata*

(Tongaporutuan ? – Recent), which lives in coarse sand and gravel down to 75 m (Powell 1979, p. 365). Fossil occurrences indicate that this preference for a firm or hard substrate is characteristic of the genus. New Zealand species have usually been referred to *Grandaxinea* Iredale, 1931, but this is now regarded as a synonym of *Tucetona* Iredale, 1931 (Matsukuma 1980; 1986, p. 81); *Tucetona* is treated by Matsukuma as a full genus in Subfamily Melaxinaeinae.

Figured specimens (Pl. 7g, h): GS9481, J41/f8025 and GS831, J41/f8467, Lorne, Kaiatan (NZGS) x 1.5.

Pl. 7 i. *Serripecten venosus* (Hutton, 1873) [*Pecten venosus* Hutton, 1873b, p. 30; *Chlamys venosa*] (Pectinidae).

Small for genus (height 35–40 mm), right valve more inflated than left. Ears prominent, dorsal margins on right valve serrate, divergent, byssal notch well developed; dorsal margins on left valve colinear. Radial sculpture on disc of right valve of 10–13 prominent convex primary costae commencing at or near apex, those near dorsal margins scaly at an early stage of growth, others remaining smooth until 25–30 mm from apex when they become sparsely scaly. From 1–3 finely scaly secondary costellae appearing between costae at 20–25 mm from apex, and “tertiary” ones at a somewhat later stage, some of them arising from flanks of primary costae. Radial sculpture on left valve more variable than on right, some shells with primary costae remaining very prominent throughout growth; in others becoming narrower and of lower relief and even subdividing, and eventually becoming similar in strength to interstitial costellae, so there may be 85 or so subequal scaly costae distally. Ears of both valves with 5 or 6 fine, scaly radial costae.

Runangan, “Oamaru” (type), possibly from Waiareka Volcanic Formation, Bridge Point, Kakanui where it is common; Trig M, Totara; Teschemaker’s Quarry.

Serripecten venosus belongs to a complex and poorly understood group of pectens of Late Eocene to Early Oligocene age, particularly well represented in the limestones and associated tuffs of North Otago. It is easily distinguished from the other species, most of which are undescribed, by having relatively few prominent primary costae that remain smooth throughout most of their growth.

Figured specimen (Pl. 7i): GS11214, J42/f126, Bridge Point, Kakanui, Runangan (NZGS) x 1.

Pl. 7 j, k. *Caestocorbula* n. sp. (Corbulidae).

Size moderate for family (length 10–12 mm), trigonal, subequilateral, strongly inflated, markedly inequivalve, right valve considerably the larger, overlapping along ventral and posterior margins. Right valve with typical corbulid “duplex” shell, inner layer considerably smaller than outer layer, line of concrescence well marked on interior. Umbones very prominent, with large nepioconch (a protruding early growth stage) raised above rest of valve. Anterodorsal margin descending steeply, almost straight, posterodorsal margin less steep, somewhat concave; posterior end narrow, truncate. Umbonal ridge rounded, posterior area slightly concave. Sculpture of prominent, rounded commarginal costae with narrower interspaces, widest somewhat behind middle, narrowing towards either end and weakening on posterior area. Left valve subelliptical, nepioconch large, projecting, sculptured with irregularly spaced commarginal costae, remainder of valve with weak growth ridges and 1 or 2 narrow radial ridges. Some articulated shells retaining a small, subquadrate siphonal plate lodged in space between posterior ends of left and right valves. Hinge of right valve with a peg-like cardinal tooth immediately beneath beak and a sunken triangular resilifer behind. Left valve with a deep triangular socket to take right cardinal and a projecting, triangular chondrophore behind. Adductor muscle scars relatively large, subcircular; pallial line with shallow, arcuate sinus.

Bortonian-Kaiatan, Pahi Greensand, Pahi; Waihao Greensand, McCulloch’s Bridge (common).

The new species is superficially very similar to the widespread *Notocorbula humerosa* (Duntroonian-Kapitean) but differs in being more elongate antero-posteriorly, in having a more distinctly rostrate posterior end, in having a larger resilifer in the right valve and, most importantly, in the presence of a siphonal plate. It is on the basis of this last character that this species is referred to *Caestocorbula* Vincent, 1910 rather than to *Notocorbula* Iredale, 1930 (Vokes 1944). *Caestocorbula* is not known to have survived the Eocene, but strong circumstantial evidence suggests that it gave rise to *Notocorbula* through loss of the siphonal plate.

Figured specimen (Pl. 7j, k): GS9508, J40/f8803, McCulloch’s Bridge, Kaiatan (NZGS) x 4.

Pl. 7 e, f. *Pecchiolia bensoni* (Marwick, 1943) [*Cardilona bensoni* Marwick 1943, p. 186]. Type species of *Cardilona* Marwick, 1943, a synonym of *Pecchiolia* Savi and Meneghini, 1850 (Verticordiidae).

Moderately large for family (length 30 mm), cordate, very strongly inflated, posterior margin slightly alate dorsally. Umbones very prominent, prosogyrous, strongly incurved, projecting beyond anterior margin. Lunule triangular, slightly convex, bounded by a deep groove. Radial sculpture of about 36 low, rounded costae with narrow interspaces; commarginal sculpture of weak growth ridges. Hinge of right valve with prominent chondrophore, otherwise edentulous. Left valve not known. Other internal features unknown.

Runangan, Waiareka Volcanic Formation, Bridge Point, Kakanui (type) (rare). Also doubtfully recorded from the “Isis bed”, All Day Bay, Kakanui (Waitakian).

Although still poorly known, *Pecchiolia bensoni* is unlikely to be confused with any other New Zealand bivalve. Marwick (1943, p. 185–186) proposed *Cardilona* as a genus of the obscure family Cardiliidae, but *C. bensoni* is so similar to species of the verticordiid genus *Pecchiolia* that there can be little doubt that this is where it belongs (Maxwell 1978, p. 28). The main difference between *P. bensoni* and other species of the genus is that the latter have more tightly coiled umbones that effectively obscure the lunule. *Pecchiolia* ranges from at least Late Eocene to Pliocene in Europe, and is also recorded from the Late Eocene of Wilmington, North Carolina (*P. dalliana* Harris in van Winkle and Harris 1919, p. 16, pl. 2, fig. 7).

Figured specimen (Pl. 7e, f): holotype, GS2141, J42/f6437, Bridge Point, Kakanui, Runangan (TM4716, NZGS) x 1.

Pl. 7 n. *Cellana* n. sp. (Nacellidae).

Size moderate for genus (length 50 mm), apex moderately elevated, corroded on only example, situated at about 0.3 anterior-posterior distance. Radial sculpture of 25 simple, rounded costae, strongest posteriorly and weakening towards front. No secondary radials. Commarginal sculpture of growth lines and ridges. Internal features not known.

Runangan, Omotumotu Member (Kaiata Formation), Leah Creek, Westland.

This limpet is included to demonstrate the fortuitous nature of much fossil preservation. Extant species of *Cellana* are intertidal rock-dwellers and the genus therefore has a very poor fossil record. The Leah Creek specimen is the oldest recorded from New Zealand, the next oldest being *C. taberna* Powell, 1973 from Curiosity Shop, Rakaia River (Waitakian). Its preservation

apparently is the result of mass debris-flow of shallow-water sediments into a deeper-water environment.

Cellana is primarily an Indo-Pacific genus at the present day, but its distribution extends southwards to New Zealand and the subantarctic islands (Powell 1973; Lindberg and Hickman 1986). The Runangan species is remarkably similar to the southernmost living species, *C. strigilis* (Hombron and Jacquinot, 1841), which has been subdivided into several subspecies by Powell (1955; 1973). It differs from these mainly in having no secondary costae, but as only one specimen has been collected, its range of variation is unknown.

Figured specimen (Pl. 7n): GS12418, J32/f31, Leah Creek, Westland, Runangan (NZGS) x 3.

Pl. 7 m. *Calliostoma* (sensu lato) *waiareka* (Laws, 1935) [*Maurea* (*Mucrinops*) *waiareka* Laws 1935c, p. 32] (Trochidae: Calliostomatinae).

Small for genus (height 10-13 mm), trochiform, spire conic, flat-sided, 0.6 total height. Protoconch not known, presumably like other species, of little more than 1 whorl. Teleoconch of about 7 flat-sided whorls with a very indistinct suture; last whorl with strongly angled periphery, base weakly convex. Spiral sculpture apparently commencing as 2 weak threads on abapical part of whorl, additional spirals appearing during growth, penultimate whorl with 5 narrow, well spaced, low cords, the 2 abapical pairs with a single interstitial thread, the lower of which becoming almost as strong as the cords on last whorl. All spirals distinctly beaded, except for fine thread appearing between 2nd and 3rd cords (counting from adapical end) on last whorl. Base with 3 weak threads near periphery and 8-10 nodulose cords between them and aperture, most of them stronger than cords on whorl sides. Aperture subquadrate, columella oblique, slightly concave.

Kaiatan, Waiareka Volcanic Formation, Lorne (type) (uncommon).

Calliostoma waiareka is similar to *C. acutangulum* (Duntroonian, Castle Hill Basin) in shape but has a much less distinct suture, and lacks definite radial sculpture on the base. The regularly conic shape, flat-sided whorls, and weakly defined suture, and the absence of definite axial sculpture set it apart from other mid-Cenozoic species,

but like them it is distinguished from most of the late Cenozoic calliostomatines by its relatively small size. This is the oldest definite member of the genus to have been named from New Zealand but an underscribed species is present in the View Hill Volcanics at White's Creek, North Canterbury (Mangaorapan) (B.A. Marshall, pers. comm.). Although most New Zealand members of the subfamily are currently assigned to *Maurea* or *Fautor*, the relationships of these taxa to *Calliostoma* needs clarification, and pending the completion of a revision of Calliostomatinae currently being carried out by B.A. Marshall (National Museum of New Zealand) we have assigned nearly all of them to *Calliostoma* (sensu lato).

Figured specimen (Pl. 7m): GS9481, J41/f8025, Lorne, Kaiatan (NZGS) x 3.

Pl. 7 l. *Spirocolpus waihaoensis* (Marwick, 1924) [*Turritella waihaoensis* Marwick 1924e, p. 328]. Type species of *Spirocolpus* Finlay, 1926 (Turritellidae).

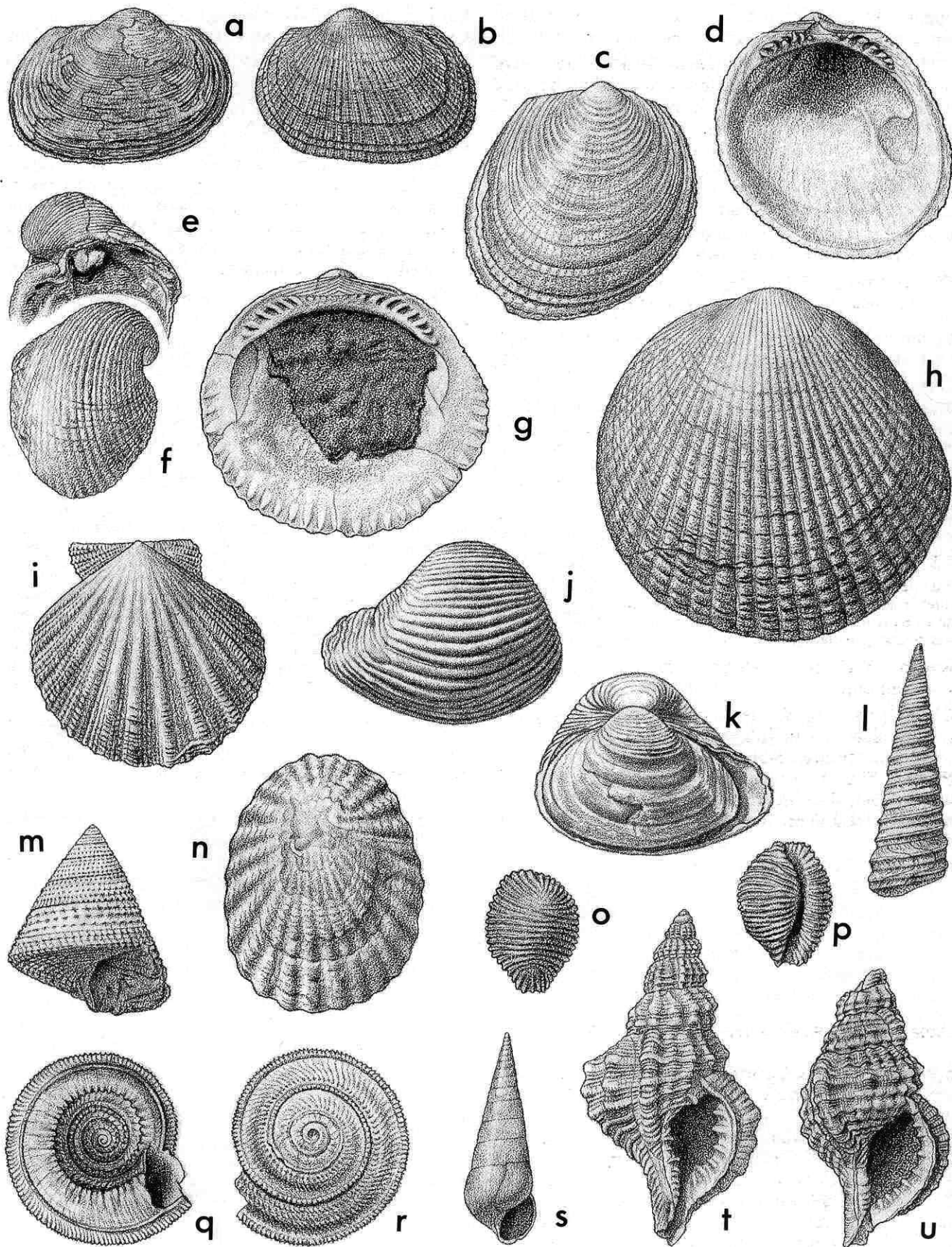
Size moderate for family (height 25-35 mm), turriculate, spire moderately elevated. Protoconch small, narrowly conical, of about 3 smooth, convex whorls. Teleoconch of up to at least 14 whorls, early ones flat-sided or gently convex, later whorls becoming biangulate because of development of strong keels. Base of last whorl almost flat, peribasal angle only weakly marked by spiral cord. Primary cord C starting at beginning of teleoconch, B appearing almost immediately after; A appearing after 2 or 3 whorls. B and C subequal for a short time, A remaining weak, but A and C becoming dominant and similar in strength while B scarcely increases. D rather weak. Secondary spiral sculpture highly variable, almost completely absent from some shells (which consequently have a polished appearance), consisting of numerous fine threads in others. A few weak spirals on base. B finely beaded on early whorls of some shells, beading only exceptionally persisting onto adult whorls. Aperture quadrate, outer lip with deep tongue-shaped sinus, its apex above middle of whorl, abapical limb steeper than adapical limb, otherwise almost symmetrical.

Bortonian-Kaiatan; Waihao Greensand, McCulloch's Bridge, Kaiatan (type); Kakahu; Waihao Downs; Pareora River. Abundant at McCulloch's Bridge, uncommon at other listed localities.

Spirocolpus—possibly *S. waihaoensis*—is locally very

Plate 7 Late Eocene (Kaiatan-Runangan) Mollusca (1).

- a,b. *Quadrilatera januaria* (Marwick), x 3.
- c,d. *Limopsis waihaoensis* Allan, x 6.
- e,f. *Pecchiolia bensoni* (Marwick), x 1.
- g,h. *Tucetona lornensis* (Marwick), x 1.5.
- i. *Serripecten venosus* (Hutton), x 1.
- j,k. *Caestocorbula* n.sp., x 4.
- l. *Spirocolpus waihaoensis* (Marwick), x 1.5.
- m. *Calliostoma* (sensu lato) *waiareka* (Laws), x 3.
- n. *Cellana* n.sp., x 1.
- o,p. *Trivia pinguior* Marwick, x 3.
- q,r. *Wangaloa ngaparaensis* (Suter), x 3.
- s. *Eulima* (sensu lato) *waihaoensis* Allan, x 3.
- t. *Sassia* (*Sassia*) n.sp. B, x 2.
- u. *Sassia* (*Haurokoa*) *marwicki* (Finlay), x 1.5.



abundant in Kaiata Formation mudstone in the Reefton and Murchison Basins on the west coast of the South Island. *Spirocolpus tophinus* (Kaiatan-Duntroonian) is very similar to *S. waihaoensis*, apparently differing only in having spiral B much weaker (obsolete in most shells) and secondary spiral sculpture consistently almost completely absent. These differences are very slight and the two "species" are probably not worth separating. *S. rudis* (Bortonian, Hampden) has highly variable sculpture but in many specimens A is much weaker than B and C and all primaries are distinctly beaded on early whorls and in a few specimens, even on the later whorls. In addition, *S. rudis* seems to have been much smaller than *S. waihaoensis*, the largest specimens seen being only 25 mm or so in height. The poorly known *S. carsoni* (late Dannevirke Series?) has three prominent, narrow, beaded keels throughout growth.

Spirocolpus ranges from at least late Dannevirke Series to Waitakian in New Zealand, and is represented in the Late Eocene of South Australia by *S. aldingae* (Tate, 1882). The main diagnostic character of the genus is the deep, almost symmetrical sinus; the Australian genus *Colpospira* Donald, 1900 has a similarly deep sinus but the early development of spiral sculpture is different from that of *Spirocolpus*.

Figured specimen (Pl. 7l): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 1.5.

Pl. 7 s. *Eulima* (sensu lato) *waihaoensis* Allan, 1926 [p. 339; *Strombiformis waihaoensis*] (Eulimidae).

Rather large for family (height 15–20 mm), subulate, spire elevated. Protoconch narrowly conical, scarcely distinguishable from teleoconch, of about 3 smooth whorls. Teleoconch of up to 14 gently convex or flat-sided whorls, sutures not very distinct; last whorl contracted rather rapidly, base almost flat, periphery rounded. No sculpture apart from weak growth lines and, at irregular intervals, labial scars. Aperture ovate, constricted adapically; columella gently concave. Outer lip thin, opisthocline, feebly concave on adapical half.

Kaiatan-Runangan; Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (uncommon); Totara Limestone, Trig M, Totara (rare).

Eulimids have relatively featureless shells and fossil species are difficult to assign to the numerous genus-group taxa that have been proposed in the family largely on the basis of anatomical characters. *E. waihaoensis* is one of the largest species recorded from New Zealand; *E. otaioensis* (Otaian, Bluecliffs, South Canterbury) is about the same size but has more strongly convex whorls and more distinct sutures.

Figured specimen (Pl. 7s): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 7 o, p. *Trivia pinguior* Marwick, 1926b [p. 314; *Pusula* (*Ellatrinia*) *pinguior*; *Fossatrinia pinguior*; *Ellatrinia pinguior*] (Triviidae: Triviinae).

Rather small for family (height 6–7.5 mm), ovate, spire visible as a low swelling, dorsum with a weak median longitudinal sulcus. Transverse sculpture of about 20 narrow costae, well developed on some shells, almost obsolete (particularly on dorsum) on others. Some costae continuous across dorsum, others appearing towards margins by bifurcation or intercalation. Aperture rather narrow, gently curved, inner and outer lips almost parallel, their margins denticulated by transverse ribs. Inner lip ridge-like adapically and abapically. Columella traversed by transverse costae, gently convex except for slightly concave fossula at abapical end.

Kaiatan-Runangan, Waiareka Volcanic Formation, Lorne (type); McCulloch's Bridge (?); Trig M, Totara. Rather uncommon at listed localities.

Trivia kaiparaensis (Otaian, Pakaurangi Point, Northland) is very similar to *T. pinguior* but has weak intercostal axial costellae on the dorsum near the outer lip. Both species are sufficiently similar to the type species of *Trivia* (*T. monacha* (Costa, 1778); Recent, Europe) to make assignment to other genera unwarranted. Triviines occur rather sporadically throughout the New Zealand Cenozoic from at least Kaiatan onwards, and their presence in a faunule is probably indicative of at least warm-temperate conditions. (The sole extant New Zealand species, *T. merces*, is confined to the northern half of the North Island). Although long considered as being closely related to the superficially similar Cypraeidae ("cowries"), the Triviidae are now regarded as belonging in the Lamellariacea rather than the Cypraeacea, i.e. the similarity between the two groups is the result of convergence.

Figured specimen (Pl. 7o, p): GS9481, J41/f8025, Lorne, Kaiatan (NZGS) x 3.

Pl. 8 c. *Carinacca waihaoensis* (Suter, 1917) [*Ampullina waihaoensis* Suter 1917, p. 11–12; *Natica* (*Carinacca*) *waihaoensis*]. Type species of *Carinacca* Marwick, 1924 (Naticidae: Naticinae).

Size moderate for family (height 15–20 mm), globose or broadly ovate, spire 0.2–0.3 total height. Protoconch large, depressed dome-shaped, of about 3 smooth whorls. Teleoconch whorls about 2, evenly convex except for an ill-defined sulcus below suture. Last whorl capacious, broadly umbilicate. Spiral sculpture of very fine threads or striae, present only on well-preserved shells, most prominent on last whorl including circumumbilical ridge and within umbilicus. Umbilicus bounded by a prominent, rounded ridge with sharply stepped inner edge. Aperture large, semilunular; inner lip almost straight, moderately thickened in parietal region, narrow adjacent to umbilicus except for weak thickening medially by low funicle. Outer lip strongly prosocline, inclined at about 40° from vertical.

Bortonian-Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (common); Hampden Formation, Hampden Beach (uncommon). Very similar to its probable ancestor *C. allani* (Pl. 6h), but more globose, lower-spined and more broadly umbilicate, and having weakly sulcate teleoconch whorls.

Figured specimen (Pl. 8c): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 e. *Friginatica suturalis* (Hutton, 1877) [*Lunatia suturalis* Hutton 1877b, p. 597; *Natica suturalis*; *Ampullina* (*Megatylotus*) *suturalis*; *Sulconacca suturalis*] (Naticidae: Poliniceinae).

Rather small for family (height 8–17 mm), globose, spire about 0.3 total height. Apex corroded in all known specimens, protoconch probably paucispiral and incompletely calcified. Teleoconch whorls about 4, sharply shouldered, with a narrow sutural shelf on early whorls, a concave sutural channel on later whorls. Outer edge of channel sharply defined. Last whorl globose, umbilicate. Spiral sculpture of ill-defined threads, strongest in sutural channel and umbilicus. Axial sculpture of weak growth lines. Umbilicus moderately large, bounded on outer edge by a shallow sulcus running from base of aperture, margined on inner edge by a low, rounded ridge. Aperture semilunular; inner lip oblique, almost straight, parietal callus rather thin, not spreading over umbilicus. Outer lip prosocline, inclined at about 20° to vertical.

Kaiatan, "Waihao" (type)—probably Waihao Greensand, McCulloch's Bridge where this is one of the most common molluscs; Kapua Tuff, Waihao River.

The various New Zealand species assigned to *Friginatica* (= *Sulconacca* Marwick, 1924) are very similar to one another, and because of considerable intraspecific variation in such characters as spire height, width of sutural channel and strength of circumumbilical sulcus, they are difficult to identify confidently. In particular, it is uncertain if *F. prisca* (Bortonian, Waihao Downs) is really distinct from *F. suturalis*, although topotypes of the former species are typically less globose and have a deeper, broader and more sharply margined sutural channel than McCulloch's Bridge shells. *F. prisca* and *F. suturalis* both have the outer lip retracted at the sutural channel so that it meets the suture almost at right angles—this character distinguishes them from the widespread *F. vaughani* (Duntroonian-Tongaporutuan) in which the outer lip crosses the sutural channel at about 45°, turning into the suture only at the last moment.

Friginatica is most characteristic of middle to outer shelf or upper bathyal assemblages from Bortonian to Recent in New Zealand. The type species is a Recent form from south-eastern Australia.

Figured specimen (Pl. 8e): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 d. *Neverita pontis* (Marwick, 1924) [*Uber* (*Neverita*) *pontis* Marwick 1924d, p. 571; *Polinices* (*Neverita*) *pontis*] (Naticidae: Poliniceinae).

Size moderate for family (height 10–14 mm), ovate, spire about 0.4 total height. Protoconch planorboid, of about 2 smooth whorls. Teleoconch of up to 3.5 whorls, spire whorls gently convex, last whorl strongly convex except for shallowly concave zone just below suture. Suture flush, descending more steeply on last third of last whorl. No sculpture apart from weak growth lines. Aperture semilunar, strongly prosocline; inner lip almost straight, parietal callus moderately thick, continuous with prominent tongue-like pad that nearly fills umbilicus in young shells but leaves a narrow hole in largest specimens. Outer lip strongly prosocline, inclined at about 45° to vertical, almost straight.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (uncommon).

This is the only New Zealand record of this typically warm-water genus. It may be distinguished from *Polinices* (*Polinella*) *esdailei* (see below) by its smaller protoconch, its less widely spreading umbilical callus and its more strongly prosocline outer lip. *Taniella notocenica* (Pl. 20f) has a marked gap between the umbilical callus (or funicle) and the parietal callus, and also has a less strongly prosocline outer lip.

Figured specimen (Pl. 8d): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 a. *Polinices* (*Polinella*) *esdailei* (Marwick, 1924) [*Uber* *esdailei* Marwick 1924d, p. 567] (Naticidae: Poliniceinae).

Size moderate for family (height 15–25 mm), globose or ovate (probably sexually dimorphic), spire up to 0.3 total height. Protoconch depressed dome-shaped, of about 3 smooth whorls. Teleoconch of up to 2.5 whorls, spire whorls convex, last whorl weakly concave below suture, otherwise strongly convex. No sculpture apart from growth lines. Aperture semilunar; inner lip almost straight, parietal callus moderately heavy, spreading anteriorly to fill or nearly fill umbilicus. Umbilical callus not projecting on outer margin, but flush or distinctly concave, bearing a distinct horizontal groove near middle, some shells with a low, rounded but rather irregular ridge above. Outer lip almost straight, inclined at about 20° to vertical.

Kaiatan-Runangan; Waiareka Volcanic Formation, Lorne, Kaiatan (?) (probable type locality); McCulloch's

Bridge; Kapua Tuff, Waihao River; Trig M, Totara. Moderately common at McCulloch's Bridge, less so at other localities.

Polinices (*Polinella*) *esdailei* is rather similar to *P. (Polinella) modestus* (Altonian, North Otago) but differs in having callus barely filling the umbilicus (rather than projecting as in the latter species), and in having a shorter but wider transverse groove on the umbilical callus.

Figured specimen (Pl. 8a): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 b. "*Uberella*" *haasti* (Marwick, 1924) [*Natica* (*Carinacca*) *haasti* Marwick 1924d, p. 554; *Friginatica* *haasti*; *Sulconacca* *haasti*] (Naticidae: Poliniceinae?).

Size moderate for family (height 7–13 mm), globose, spire 0.2–0.3 total height. Apex corroded in all known specimens, protoconch probably paucispiral and incompletely calcified. Teleoconch whorls turned in towards suture apically, forming a narrow sutural shelf that becomes depressed below the rounded shoulder on later whorls. Sutures deeply impressed rather than channeled. Last whorl strongly convex, with a moderately wide umbilicus bordered by a heavy ridge that is somewhat concave in young shells but gently convex in adults. Outer edge of circumumbilical ridge sharply defined and steep in young shells, more rounded in adults; inner edge rounded. Sculpture of weak growth lines and fine spiral threads. Aperture semilunar; inner lip almost straight, thickened abapically where circumumbilical ridge impinges. Parietal callus moderately thick, narrowing quickly below. Outer lip inclined at about 30° to vertical, straight except where it is feebly retracted to suture.

Bortonian-Kaiatan; Waihao Greensand, McCulloch's Bridge, Kaiatan (type); Kapua Tuff, Waihao River; Hampden Formation, Hampden Beach; Point Elizabeth Beach, Westland. Moderately common at McCulloch's Bridge, uncommon at other localities.

This distinctive naticid seems to combine characters of both *Carinacca* and *Friginatica*, but the similarities are mostly superficial, and it probably requires a new genus. The circumumbilical ridge is rather like that present in species of *Carinacca*, but is less rounded in section and lacks the steep step on the inner edge. *U. haasti* also differs from species of *Carinacca* in having what was probably a paucispiral, incompletely calcified protoconch and in having deeply impressed rather than adpressed sutures. *F. suturalis* seems to have had a similar kind of protoconch to *U. haasti*, but it differs in having sharply channeled rather than deeply impressed sutures, and a sulcus rather than a ridge bordering the umbilicus. *U. haasti* is only provisionally assigned to *Uberella*, however, as the type species, *U. vitrea* (Castlecliffian—Recent, New Zealand) is ovate rather than globose, has adpressed sutures, evenly convex teleoconch whorls and a narrow umbilicus, lacks spiral sculpture and an umbilical ridge, and does not have the base of the inner lip thickened. *U. haasti* seems to be most closely related to "*Uberella*" *acerva* (Otaian, Bluecliffs, South Canterbury), differing mainly in having a prominent ridge rather than a faint swelling bordering the umbilicus. Both species seem to have been confined to moderately deep waters (i.e. outer shelf or upper slope depth).

Figured specimen (Pl. 8b): GS11,200, J40/f8853, Kapua Tuff, Waihao River, Kaiatan (NZGS) x 2.

Pl. 7 t. *Sassia* (*Sassia*) n. sp. B (Ranellidae: Cymatiinae).

Size moderate for subgenus (height 30–33 mm), tall and rather narrow, spire half total height. Protoconch small, dome-shaped, of 2.5 smooth

whorls. Teleoconch whorls strongly angled a little above middle on spire, last whorl broadly excavated with a moderately long, slightly twisted neck. Axial sculpture of high, narrowly rounded, closely spaced costae, and at intervals of 0.67 whorl, prominent, narrow, rounded varices down whole teleoconch. Costae reaching across base of last whorl. Spiral sculpture of prominent, fairly wide, round-topped, well spaced cords, 2 on sutural ramp, 2 or 3 on sides of spire whorls, and 10 more on base and neck of last whorl, with narrow threads in interspaces. Cords forming prominent, narrow nodules where they cross axial costae and varices. Aperture oval; siphonal canal moderately long, slightly twisted dorsally. Inner lip narrowly and thinly callused with a minute pseudumbilicus between its abapical end and canal, a large parietal ridge and several transverse ridges and nodules on mid-lower columella. Outer lip weakly flared over terminal varix, with raised outer rim and 6 prominent, narrow nodules on its inner edge.

Kaiatan, Waihao Greensand, McCulloch's Bridge (uncommon).

This coarsely sculptured species represents a very different species group from those of most other New Zealand *Sassia*, and has no known younger relatives. The group of *S. maoria* (Pl. 20o) and *S. parkinsonia* (Pl. 48f) is represented at McCulloch's Bridge (and other Kaiatan and Runangan localities) by *S. cyphoides*, a weakly sculptured species in which spiral cords are the dominant sculpture. The groups of *S. zealta* (Pl. 24l), *S. (Haurokoa) woodi* (Pl. 30b) and *S. clifdenensis* (Pl. 24n) are also all represented at McCulloch's Bridge, mostly by unnamed species (but see *S. (Haurokoa) marwicki*, below). The unnamed species described here more nearly resembles some of the European fossil *Sassia* species and the living *S. apenninica* group than other New Zealand fossil species but it has the same smooth, dome-shaped protoconch as most other *Sassia* species, including the New Zealand species placed by Finlay in *Austrosassia*, rather than the coarsely cancellate protoconch of the *S. apenninica* group. Figured specimen (Pl. 7t): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 7 u. *Sassia (Haurokoa) marwicki* (Finlay, 1924) [*Cymatium marwicki* Finlay 1924b, p. 456; *C. sculpturatum* Finlay 1924b, p. 458; *Austrosassia reticulata* (in part) of Finlay 1931a, p. 10 (not *Streptosiphon reticulatum* Suter, 1917 (Trichotropidae)); *Mayena sculpturata*; *Austrosassia marwicki*] (Ranellidae: Cymatiinae).

Small (height 25-35 mm), tall and very narrow for subgenus, more like typical *Sassia* in shape than are all later consubgenera. Protoconch relatively large (2.5-3 mm in diameter), turbiniform, of about 3 smooth whorls (complete specimens not known). Teleoconch whorls evenly convex and little-inflated on spire, last whorl tapering rapidly to a narrow neck. Axial sculpture of many low, narrow, closely spaced costae with fine threads in interspaces, and prominent, narrow varices at each 0.67 whorl down whole teleoconch. Spiral sculpture of prominent, narrow, widely spaced cords, 3 on spire whorls and 7 on sides of last whorl, with several finer ones on sutural ramp and on neck and canal, as well as fine threads in between cords. Cords forming prominent rounded nodules at intersections with costae (but not on varices), so main sculptural effect is rows of small, evenly spaced nodules; interspaces finely reticulate. Aperture oval with a short, straight siphonal canal without obvious fasciole. Inner lip narrow, thinly callused in parietal area but with thick, raised edge over lower columella; 1 large parietal ridge and 5 ridges on lower columellar area. Outer lip narrowly flared over terminal varix, with well raised rim, bearing 8 small ridges on inner edge.

Kaiatan; Waihao Greensand, McCulloch's Bridge (type of *C. marwicki*); Waiareka Volcanic Formation, Lorne (type of *C. sculpturatum*).

The relatively large protoconch, the straight inner lip with

a raised rim, the flaring of the outer lip over the terminal varix and, in particular, the sculpture of rows of small rounded nodules indicate that *S. marwicki* is closely related (and possibly ancestral) to *S. woodi* (Pl. 30b), and is the earliest species we are aware of in the subgenus *S. (Haurokoa)*. Its narrow shape and turbiniform protoconch indicate an origin from *Sassia* (sensu stricto), apparently in the Australasian region, during the Paleocene or Eocene. The holotype of *C. marwicki* is a small but nicely preserved shell which is still the only specimen known to have been collected from McCulloch's Bridge. The holotype and seven paratypes of *C. sculpturatum* were reputedly from "Kakanui Beach (tuffs below limestone)" (i.e. from the Deborah Volcanic Formation (Whaingaroan) near Everett's Quarry or Gee's Point), but Maxwell (1968) showed that they (and several other species described by Finlay) are almost certainly from the green tuff (Waiareka Volcanic Formation) at Lorne, near Oamaru. Ranellids closely similar to the types of *C. sculpturatum* are not uncommon at Lorne and as we cannot satisfactorily distinguish them from the holotype of *C. marwicki* we, as first revisers, select the name *C. marwicki* to apply to the two nominal species *C. marwicki* and *C. sculpturatum* named by Finlay (1924b).

The most nearly similar species is a small, narrow, still more finely sculptured, unnamed one occurring in Late Eocene rocks west of Cape Otway, Victoria, Australia. The subgenus *Sassia (Haurokoa)* is, to our knowledge, limited to Eocene to basal Pliocene rocks of New Zealand and south-eastern Australia.

Figured specimen (Pl. 7u): GS9481, J41/f8025, Lorne, Kaiatan (NZGS) x 1.5.

Pl. 8 s. *Exilia waihaoensis* Suter, 1917 [*Exilia waihaoensis* Suter 1917, p.25; *Zexilia waihaoensis*; *Z. tenuilirata* Laws 1935b, p. 26; *Z. submarginata* Laws 1935b, p.26]. Type species of *Zexilia* Finlay, 1927, a synonym of *Exilia* Conrad, 1860 (Maxwell 1988a, p. 53) (Turbinellidae: Ptychatractinae?).

Size moderate for genus (height 25-40 mm), narrowly fusiform, spire about half total height. Protoconch narrowly dome-shaped, of about 3 whorls with weak, arcuate riblets on last 0.25 whorl. Teleoconch of up to 9.5 whorls, spire whorls lightly convex or flat-sided, some shells with weak subsutural swelling; last whorl contracted gradually, with a long, straight, slender neck. Axial sculpture of narrow, rounded, gently flexuous costae, reaching from suture to suture on spire whorls, dying out on base of last whorl; 12-20 on penultimate whorl. Spiral sculpture highly variable, some shells with prominent, strap-like lirae, others with much weaker, rounded cords with narrow, even linear interspaces; 5-10 on spire whorls, numerous additional spirals of variable strength on base and neck. Adapical spiral often stronger than others, situated on subsutural swelling and weakly nodulated at intersections with axial costae. Other cords crossing costae without change except for slight thickening. Aperture elongate-pyriform; siphonal canal long, slender; columella straight or with a weak twist above middle. Inner lip slightly impressed adapically, thinly callused below; outer lip thin, flexuous with a broad, shallowly arcuate sinus on upper third.

Bortonian-Kaiatan; Waihao Greensand, McCulloch's Bridge, Waihao River, Kaiatan (type locality of all three nominal species); Waihao Downs; Kapua Tuff, Waihao River; Kaiata Formation, Point Elizabeth Beach, Westland. Not uncommon at McCulloch's Bridge, rare at other localities.

Exilia waihaoensis differs from younger New Zealand species of *Exilia* in its relatively large size and prominent

axial sculpture, and by having a dome-shaped protoconch of about three whorls rather than a mamillate one of about 1.5 whorls. *E. waihaensis* is highly variable, and we consider it to include *Zexilia tenuilirata* and *Z. submarginata*; it may also include *E. crassicostata* (probably Kaiatan, Waihao River) and *Zexilia hampdenensis* (Bortonian, Hampden Beach).

Exilia ranges from Wangaloan to Waiuan in New Zealand; elsewhere it is recorded from Late Cretaceous to Miocene (Bentson 1940). Most New Zealand occurrences are from mid-outer shelf or upper bathyal assemblages. Although long considered to belong in the Fasciolaridae, *Exilia* is more likely to have been a turbinellid (Maxwell 1988a, p. 53).

Figured specimen (Pl. 8s): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 g. *Poirieria denticulifera* Maxwell, 1971 [p. 773-774] (Muricidae: Muricinae).

Rather small for genus (height 17-22 mm), biconic, spire about 0.3 total height. Protoconch narrowly conical, of about 4 lightly convex whorls. Teleoconch of 4.5-5 whorls, bluntly shouldered near middle on spire, last whorl contracted to moderately long neck. Axial sculpture of 5 or 6 thin, low varices on each whorl, folded into prominent, open triangular spines on shoulder; varices on last whorl bearing a much smaller triangular spine near junction of base and neck. Spiral sculpture of weak threads on base of last whorl. Aperture pyriform, constricted abapically to form a moderately long, straight siphonal canal. Inner lip thinly callused, smooth; outer lip slightly flared, with 5 weak denticles within. Fasciole prominent, with a small pseudumbilicus between it and canal.

Bortonian-Kaiatan, Whaingaroan?; Kaiatan, Waihao Greensand, McCulloch's Bridge (type); Waihao Downs; Kakanui (?). Rare at all localities.

Poirieria denticulifera is distinguished from other New Zealand species of the genus primarily by its denticulate outer lip and secondarily by its small size and the presence of but one spine on each varix in addition to the peripheral spine. *P. parva* Maxwell, 1971 (Otaian-Altonian, Northland) is similar in size to *P. denticulifera* but apart from having a smooth outer lip, it differs in having three or four small accessory spines on each varix.

Poirieria is first recorded from the Bortonian in New Zealand, and seems to have been present in the Northern Hemisphere during the Paleocene and Early Eocene (Maxwell 1971, p. 764; Vokes 1971b, p. 37). The genus is a relatively "primitive" and conservative member of the Muricinae that presumably was once widespread, but it is now restricted to the New Zealand region and Argentina. New Zealand occurrences were reviewed by Maxwell (1971).

Figured specimen (Pl. 8g): holotype, GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (TM4927, NZGS) x 3.

Pl. 8 j. *Peculator (Parvimitra) plicatellus* (Marshall and Murdoch, 1923) [*Vexillum plicatellum* Marshall and Murdoch 1923a, p. 123; *Proximitra* (?) *plicatellum*; *Parvimitra plicatellum*; *Parvimitra subplicatellum* Finlay 1930b, p. 64-65; *Parvimitra allani* Finlay 1930b, p. 65-66; *Conomitra plicatella*] (Volutomitridae).

Rather small for family (height 6-8.5 mm), biconic to broadly fusiform; spire of variable elevation but always less than half total height. Protoconch relatively large, of a little more than 1 smooth whorl. Teleoconch of 4-4.5 whorls, spire whorls moderately convex, often weakly shouldered near middle; last whorl contracted gradually, weakly excavated. Axial sculpture highly variable, in some shells consisting of

prominent costae reaching from suture to suture on spire whorls, and persisting onto last whorl; in others costae becoming obsolete on 2nd or 3rd whorl; 15-24 costae on penultimate whorl. Spiral sculpture also variable but always present, ranging from subobsolete threads restricted to base and neck to moderately strong cords present over whole of teleoconch. Aperture narrowly pyriform, columella almost straight, typically bearing 4 narrow plaits, adapical one often weaker than the one below, abapical one much weaker than others and absent from a few specimens. Outer lip thin, smooth within, gently flexuous.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type locality of all three nominal species).

Peculator (Parvimitra) pukeuriensis (Pl. 21p) is very similar to *P. plicatellus*, but differs in being thicker-shelled and in having more distinctly shouldered teleoconch whorls and, in most specimens, weaker spiral sculpture. Cernohorsky (1970a, p. 111) referred this species (but not *P. pukeuriensis*) to the Northern Hemisphere genus *Conomitra* Conrad, 1865, but it is not particularly like the type species of *Conomitra* and is in fact so close to *P. pukeuriensis* as to make assignment to a different genus unwarranted.

Figured specimen (Pl. 8j): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 6.

Pl. 8 i. *Volutomitra (Waimatea) inconspicua* (Hutton, 1885) [*Mitra inconspicua* Hutton 1885b, p. 326; *Vexillum apicicostatum* Suter 1917, p. 27; *Conomitra inconspicua*; *C. apicicostatum*; *Waimatea inconspicua*; *W. apicicostatum*]. Type species of *Waimatea* Finlay, 1926 (Volutomitridae).

Size moderate for family (height 16-23 mm), fusiform, spire about 0.4 total height. Protoconch small, dome-shaped, of about 1.5 smooth whorls. Teleoconch of up to 6.5 whorls, typically turned in towards suture to form narrow sutural shelf, last whorl contracted gradually to a moderately long neck. Axial sculpture when present, confined to first 2 or 3 whorls of most specimens but persisting onto 4th whorl of a few specimens, consisting of narrow costae with interspaces of similar width. Spiral sculpture on spire whorls of fine threads or striae, last whorl with up to 15 weak cords or threads on neck. Rest of shell typically smooth and polished. Aperture elongate, rather narrow; columella straight or gently convex, bearing 4 (in a few specimens 5) narrow plaits, the abapical one considerably weaker than others. Outer lip thin, gently sinuous, smooth within.

Kaiatan, Waihao Greensand, McCulloch's Bridge (probable type locality of both *M. inconspicua* and *V. apicicostatum*); Kapua Tuff, Waihao River; Lorne; Point Elizabeth Beach, Westland; Melrose, Buller River. Common at McCulloch's Bridge, uncommon at other localities.

Volutomitra (Waimatea) amplexa (Bortonian, Waihao Downs and Pareora River) is smaller (height 8-10 mm), more slender and somewhat higher-spined than *V. inconspicua*. *V. banksi* (Pl. 27k) is very similar to *V. inconspicua* in overall appearance, but is much larger (height 27-55 mm) and has a larger protoconch. We follow Cernohorsky (1981, p. 1000) in classing *Waimatea* as a subgenus of *Volutomitra*, but the differences between these taxa are very slight and probably do not justify even subgeneric separation.

The fossil New Zealand species of *Volutomitra* (sensu lato) seem to have lived at much the same depth as *V. banksi* (i.e. in the outer shelf or upper bathyal zones). Figured specimen (Pl. 8i): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 f. *Amalda (Gracilispira) morgani* (Allan, 1926)

[*Ancilla morgani* Allan 1926, p. 342-343; *Baryspira morgani*; *B. (Gracilispira) morgani*] (Olividae: Ancillinae).

Size moderate for genus (height 15-26 mm), ovate, spire conical, somewhat less than half total height. Protoconch mamillate, apparently of about 1.5 whorls, but normally covered by spire callus. Teleoconch of about 4 or 5 whorls, spire whorls weakly concave to gently convex, covered by spire callus; last whorl evenly convex. No sculpture apart from growth lines. Spire callus not very thick, spreading down over upper part of last whorl, a wide uncalled area between it and the anterior callus. Depressed band (immediately above anterior callus) well defined, relatively broad. Parietal callus moderately thick, outer edge straight or gently convex from top of columella to bottom of spire callus, then bending around back of shell to eventually blend with spire callus. Aperture elongate-ovate, with moderately deep U-shaped siphonal notch; columella short, subvertical, bearing 4-7 narrow, rather irregular ridges which extend outside the aperture.

Bortonian-Runangan; Kaiatan, Waihao Greensand, McCulloch's Bridge (type); Waihao Downs; Tokarahi, North Otago; Trig M, Totara, North Otago. Very common at McCulloch's Bridge, rare at other localities.

Amalda morgani differs from other members of the subgenus *Gracilispira* in having a relatively broad depressed band and a parietal callus in which the outer edge is straight or gently convex rather than sigmoidal. The poorly known *A. (Gracilispira) allani* (Porangan?, Otaio Gorge) resembles *A. morgani* in having a broad depressed band, but it seems to have been taller-spined (spire more than half total height).

Figured specimen (Pl. 8f): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 p. *Waihaoia allani* Marwick, 1926a [p. 275]. Type species of *Waihaoia* Marwick, 1926 (Volutidae: Zidoninae).

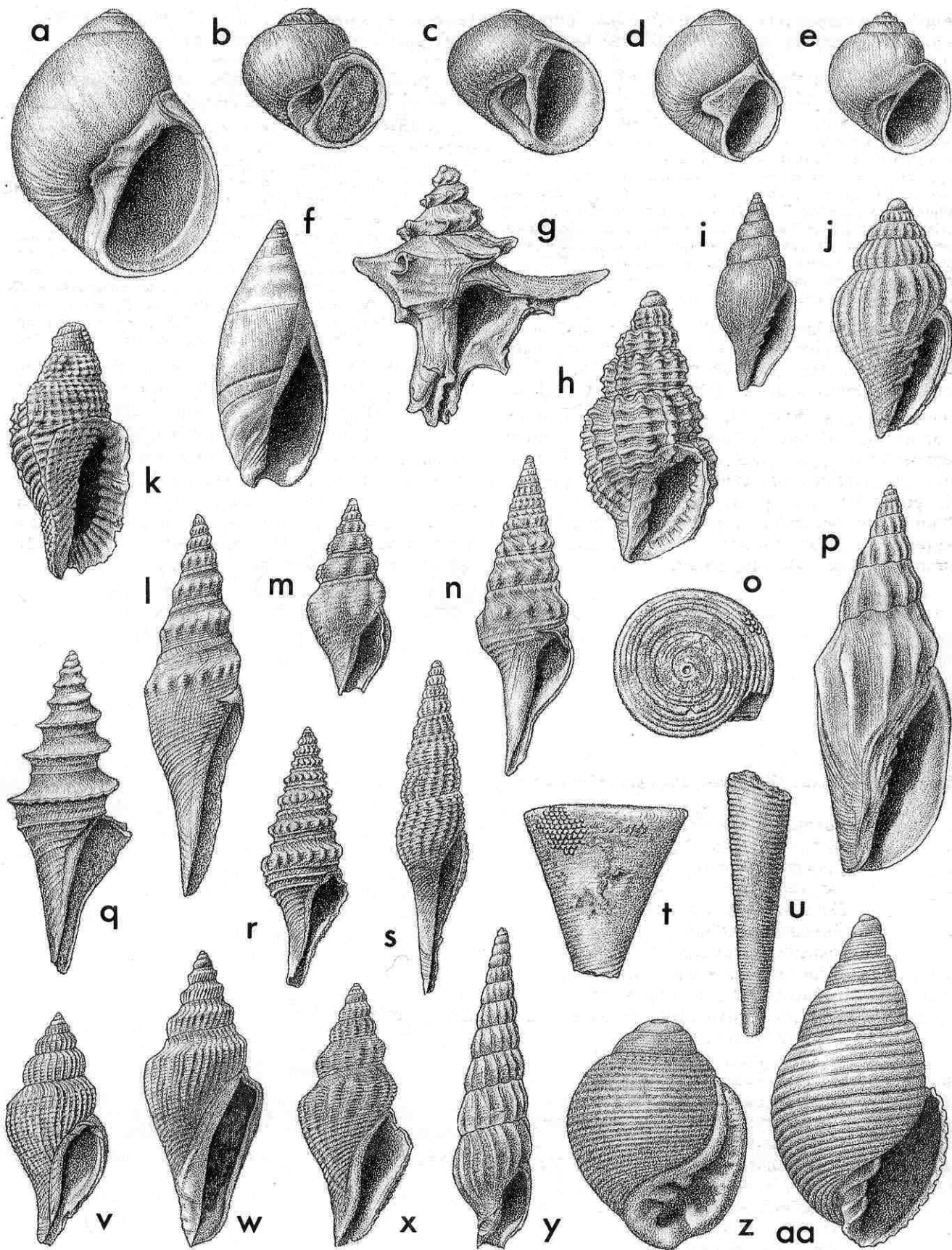
Size moderate for genus (height 45-50 mm), fusiform, spire 0.4 total height. Protoconch of about 3 whorls when complete, but large, bulbous initial whorl missing from most specimens, leaving an apical spike. Teleoconch of 5-6 whorls; early whorls convex, later ones weakly shouldered near middle on spire; last whorl weakly excavated. Axial sculpture of narrow costae reaching from suture to suture on spire, though weakening somewhat on ramp, and extending about halfway across base of last whorl, slightly tubercular on shoulder angle on some shells; 13-17 on penultimate whorl. Spiral sculpture of very fine wavy striae, retained only on well preserved shells. Aperture elongate; siphonal notch shallow, fasciole rounded, weakly developed. Columella padded centrally, bearing 5 plaits, the abapical one the weakest. Inner lip thinly callused; outer lip slightly thickened, weakly convex.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type); Kapua Tuff, Waihao River. Rather uncommon at both localities. The poorly known Runangan species *W. formosa* (Trig M, Totara) may be a synonym.

Waihaoia allani is distinguished from *W. suteri* (Bortonian(?), Waihao Forks) by its less strongly shouldered teleoconch whorls and by having five rather than four columellar plaits. *W. thomsoni* (Pl. 6n) has a more slender shell with axial costae changing into tubercles or becoming obsolete on later whorls.

Plate 8 Late Eocene (Kaiatan-Runangan) Mollusca (2).

- a. *Polinices (Polinella) esdailei* (Marwick), x 2.
- b. "*Uberella*" *haasti* (Marwick), x 2.
- c. *Carinacca waihaoensis* (Suter), x 2.
- d. *Neverita pontis* (Marwick), x 2.
- e. *Friginatica suturalis* (Hutton), x 2.
- f. *Amalda (Gracilispira) morgani* (Allan), x 2.
- g. *Poirieria denticulifera* Maxwell, x 3.
- h. *Fusiaphera marshalli* (Allan), x 5.
- i. *Volutomitra (Waimatea) inconspicua* (Hutton), x 2.
- j. *Peculator (Parvimitra) plicatellus* (Marshall and Murdoch), x 6.
- k. *Tatara revoluta* (Finlay), x 1.5.
- l. *Zemacies marginalis* (Marshall), x 1.5.
- m. *Cordieria rudis* (Hutton), x 3.
- n. *Eoturris complicata* (Suter), x 2.
- o,t. *Conus (senu lato) trigonicus* Tomlin, x 2.
- p. *Waihaoia allani* Marwick, x 1.5.
- q. *Cochlespira (Tahusyrinx) maora* (Marshall and Murdoch), x 3.
- r. *Gemmula bimarginata* (Suter), x 3.
- s. *Exilia waihaoensis* Suter, x 3.
- u. *Hyalocylis annulata* (Tate), x 3.
- v. *Marshallena neozelanica* (Suter), x 2.
- w. *Notogenota finlayi* Powell, x 1.5.
- x. *Marshallaria spiralis* (Allan), x 2.
- y. *Zeacuminia tahuia* Finlay, x 3.
- z. *Superstes marshalli* Finlay and Marwick, x 5.
- aa. *Triploca waihaoensis* Marshall and Murdoch, x 6.



Figured specimen (Pl. 8p): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 1.5.

Pl. 8 o, t. *Conus (sensu lato) trigonicus* Tomlin, 1937 [*Conus (Lithoconus) triangularis* Finlay 1924b, p.479 (not *Conus berghausi* Michelotti var. *triangularis* Sacco, 1894); *Conus trigonicus* Tomlin 1937, p.206 (new name for *C. triangularis* Finlay, preoccupied)] (Conidae).

Rather small for family (height 16-25 mm), conical, spire flat or very depressed. Protoconch not known. Teleoconch of about 6 whorls, periphery sharply angled, sides of last whorl straight or slightly concave. Sculpture of low, narrow spiral cords present over whole surface in some shells, but absent from parts of the last whorl on others. Aperture narrow, inner and outer lips parallel.

Kaiatan; type supposedly from "tuffs below the limestone", Kakanui, but almost certainly from the Waiareka Volcanic Formation, Lorne, where this species occurs rarely (Maxwell 1968).

Conus trigonicus is readily distinguished from other New Zealand cones by its very depressed or even flat spire, its relatively broad shape and its relatively prominent spiral sculpture. *C. abruptus* (Otaian-Altonian, Pakaurangi) also has a very depressed spire, but it is more slender than *C. trigonicus* and has far less prominent and less ubiquitous spiral sculpture. As Finlay (1924b, p. 479) pointed out, *C. trigonicus* seems to be most closely related to *C. dennanti* Tate, 1892 (mid-Cenozoic, Victoria).

Cone shells are among the most characteristic molluscs of present-day tropical or subtropical seas, although a few species are present in cooler waters (e.g. Victoria; northern New Zealand). The earliest definite New Zealand record of the family is from the Bortonian (Hampden Beach); at least three species are known from the Kaiatan and Runangan, but there are very few records from the Landon Series (see Pl. 15k, n). Cones are relatively common and diverse from Otaian to Clifdenian and rather less so from Lillburnian to Kapitean. Thereafter the family almost completely disappears from the fossil record, probably because of late Cenozoic cooling.

Figured specimen (Pl. 8o, t): holotype, probably from Lorne, near Oamaru, Kaiatan (AMTM 201, Auckland Institute and Museum) x 2.

Pl. 8 y. *Zeacuminia tahuia* Finlay, 1930 [*Terebra sulcata* Marshall 1919, p.232 (not *Terebra swainsoni* var. *sulcata* Pease, 1868); *Zeacuminia tahuia* Finlay 1930a, p.47 (new name for *Terebra sulcata* Marshall, preoccupied)]. Type species of *Zeacuminia* Finlay, 1930 (Terebridae).

Size moderate for genus (height 20-32 mm), spire elevated. Protoconch conical, of about 5 strongly convex whorls, last whorl with a fine supra-sutural thread and narrow, arcuate costellae, remainder smooth. Teleoconch of up to 13 weakly to moderately convex whorls, most specimens with a broad, shallow sulcus adapically; last whorl contracted rapidly with a short, twisted neck. Axial sculpture of narrow, sharp-crested opisthocyrt costae with broad concave interspaces, reaching from suture to suture on spire but dying out on periphery or upper part of base of last whorl; 13-17 on penultimate whorl. Spiral sculpture of very fine grooves and threads, usually absent because of abrasion. Aperture small, ovate; columella twisted to left at inception of short, shallowly notched siphonal canal. Inner lip impressed, outer lip thin, concave. Fasciole prominent, ridge-margined.

Bortonian-Kaiatan; Bortonian, Hampden Formation, Hampden Beach (type) (rare); Waihao Greensand, McCulloch's Bridge (common); Kapua Tuff, Waihao River (rare).

Zeacuminia tahuia is distinguished from other New Zealand terebrids by its slender shape, its narrow, sharp-crested axial costae and its very weak spiral sculpture. *Z. tahuia* is the earliest known species of *Zeacuminia*, a genus to which most New Zealand terebrids have been assigned, even though it is not too clear just how it differs from other axially costate members of the family. The genus as a whole seems to have been bathymetrically tolerant, with some species living in very shallow waters and others in outer shelf or upper bathyal habitats.

Figured specimen (Pl. 8y): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 x. *Marshallaria spiralis* (Allan, 1926) [*Verconella spiralis* Allan 1926, p. 340; *Marshallena spiralis*]. Type species of *Marshallaria* Finlay and Marwick, 1937 (Turridae: Pseudotominae).

Size moderate for subfamily (height 20-25 mm), broadly fusiform, spire 0.4-0.5 total height. Protoconch conical, of about 4.5 moderately convex whorls, last 1.25-1.5 whorls with prominent spiral cords, crossed on last 0.25-0.5 whorl by narrow axial costellae, remainder smooth. Teleoconch of up to 4.5 whorls, bluntly shouldered near middle on spire, sutural ramp almost flat or somewhat concave because of subsutural fold; last whorl contracted gradually, broadly excavated. Axial sculpture of rounded or subtriangular costae reaching from near middle of sutural ramp to lower suture on spire whorls, fading out on upper part of base of last whorl; 12-16 on penultimate whorl. Spiral sculpture highly variable, commencing as 6-9 narrow, rather flattened cords, those (4 or 5) on whorl sides stronger than those on ramp. Spirals remaining constant in number during growth on some shells, but typically joined by secondary spirals on ramp and between primaries, some eventually rivalling primaries in strength. Last whorl with 14-16 additional cords, some with interstitial threads, on base and neck. Spirals crossing axial costae with little or no thickening, but finely crenulated by growth lines. Aperture subrectangular, columella smooth with a gentle twist to left at inception of short, unnotched siphonal canal. Outer lip thin, edge weakly crenulate, with a broadly arcuate, shallow anal sinus on ramp.

Kaiatan; Waihao Greensand, McCulloch's Bridge (type) (not uncommon); Kapua Tuff, Waihao River (rare).

Marshallaria senilis (Bortonian, Hampden Beach) is very similar to *M. spiralis* and may be conspecific, but the few specimens that we have seen from Hampden have more rounded teleoconch whorls and more prominently crenulate teleoconch spirals than McCulloch's Bridge shells. *M. serotina* (Bortonian, Waihao Downs) is also similar to *M. spiralis*, but is considerably larger (height about 35 mm) and has more numerous, finer spiral cords.

Marshallaria superficially resembles *Austrotoma* but the latter taxon differs in having a prominent siphonal notch and a ridge-margined fasciole. *Marshallaria* seems to be much closer to the Northern Hemisphere genus *Pseudotoma* Bellardi, 1875, differing from it only in relatively minor characters. All three taxa, as well as *Marshallena*, *Notogenota* and several other Australasian taxa, belong in the subfamily Pseudotominae, which on conchological grounds at least has some claim to being the most primitive subfamily in the Turridae. *Marshallaria* has a recorded range of Wangaloan to Altonian in New Zealand. We are not aware of any undoubted occurrences outside New Zealand. The relatively few records suggest that it favoured moderately deep waters (mid shelf to upper bathyal zones).

Figured specimen (Pl. 8x): GS9480, J40/f8801, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 v. *Marshallena neozelanica* (Suter, 1917) [*Daphnella* (*Raphitoma*) *neozelanica* Suter 1917, p. 60; *Belophos incertus* Marshall 1919, p. 229]. Type species of *Marshallena* Finlay in Allan, 1926 (Turridae: Pseudotominae).

Size moderate for subfamily (height 18-25 mm), fusiform, spire about 0.4 total height. Protoconch conical, of about 5 convex whorls, last 0.25 whorl with distant, narrow axial costellae and very weak spirals, remainder smooth. Teleoconch of up to 4.5 whorls, shouldered a little above middle on spire; last whorl contracted gradually, broadly excavated, with a moderately long, narrow neck. Axial sculpture of narrow, sharp-crested costae reaching from suture to suture on spire and across base onto upper part of neck on last whorl; widely spaced on spire whorls, but more crowded and less distinct on last half-whorl; 20-27 on penultimate whorl. Spiral sculpture of low, narrow cords, the strongest on shoulder angle, those on whorl sides stronger than those on ramp and all less prominent than axial costae. Cord on shoulder angle weakly tuberculate at intersections with costae, other spirals crossing axials unchanged. Well preserved shells with a slightly glazed overall appearance. Aperture pyriform, with a moderately long, slightly curved, narrow, unnotched siphonal canal. Inner lip distinctly impressed; outer lip thin with a shallowly arcuate sinus on ramp.

Bortonian-Kaiatan; Bortonian?, "Teaneraki" (type locality of *D. neozelanica* -probably lower Waihao River); Bortonian, Hampden Formation, Hampden Beach (type locality of *B. incertus*) (rare); Waihao Greensand, McCulloch's Bridge (moderately common).

Marshallena neozelanica is distinguished from other New Zealand turrids by its almost smooth conical protoconch, its moderately long siphonal canal, its fine spiral sculpture and its very shallow anal sinus. Although several other New Zealand turrids have been assigned to *Marshallena*, most belong in other as yet unnamed genera, and only *M. curtata* (Pl. 27r) is considered to be congeneric with *M. neozelanica*. It differs from *M. neozelanica* in being less elongate, having more strongly shouldered teleoconch whorls and having more prominent axial sculpture.

Marshallena seems to be extinct in the New Zealand region, but it is represented in the modern Indo-Pacific fauna by several species from mid-shelf to bathyal habitats (Powell 1969). The few New Zealand records of the genus are from outer-shelf or upper bathyal assemblages.

Figured specimen (Pl. 8v): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 w. *Notogenota finlayi* Powell, 1942 [p. 79] (Turridae: Pseudotominae).

Rather large for subfamily (height 30-50 mm), elongate-biconic, spire 0.4 total height. Protoconch broadly conical, of about 5 smooth whorls. Teleoconch of 5-6 whorls, prominently shouldered at or above middle on spire, sutural ramp concave; last whorl contracted gradually, only weakly excavated. Axial sculpture of numerous, rather irregular, narrow, strongly opisthocline costae reaching from suture to suture on spire and about half the length of the last whorl, becoming more widely spaced and weaker on last whorl. Spiral sculpture on spire whorls very weak, of numerous closely spaced threads, somewhat stronger on whorl sides than on ramp; last whorl with more prominent, but still rather subdued, flat-topped cords, some with interstitial threads, over lower part of base and neck. Aperture elongate, subrectangular, siphonal canal barely differentiated, unnotched. Outer lip thin, anal sinus broadly and shallowly arcuate, occupying sutural ramp.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (uncommon).

Notogenota goniodes (Bortonian ?, Waihao River) is very similar, but has a steeper, less strongly concave sutural ramp and has axial sculpture becoming obsolete at an

earlier stage of growth. The very poorly known species *N. pahiensis* (Bortonian, Pahi) seems to resemble *N. goniodes* in having axial sculpture restricted to early whorls.

Notogenota is known only from the Bortonian and Kaiatan in New Zealand. It is, however, very similar to the Northern Hemisphere Paleogene genus *Surculites* Conrad, 1865 and may not be distinct.

Figured specimen (Pl. 8w): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 1.5.

Pl. 8 q. *Cochlespira* (*Tahusyrinx*) *maora* (Marshall and Murdoch, 1923) [*Columbarium maorum* Marshall and Murdoch 1923a, p. 127; *Vesanula maorum*; *Parasyrinx finlayi* Allan 1926, p. 344; *Tahusyrinx finlayi*]. Type species (as *P. finlayi*) of *Tahusyrinx* Powell, 1942 (Turridae: Turrinae).

Rather small for subfamily (height 15-26 mm), fusiform-pagodiform, spire about half total height. Protoconch conical, of about 4 or 5 whorls, last 2 whorls keeled above middle, last whorl with very small, sharp peripheral tubercles, other whorls smooth. Teleoconch of up to 7 whorls, sharply and prominently keeled near middle on spire; last whorl with much less prominent peribasal keel, contracted gradually below, shallowly excavated, with a long, slender neck. Axial sculpture of small, sharply triangular serrations on peripheral keel, short, narrow ridges bordering upper suture and, particularly evident on last whorl, numerous growth lines. Spiral sculpture commencing on about 2nd whorl as a narrow suprasutural cord, joined on 4th or 5th whorl by a similar though weaker cord between it and peripheral keel; sutural ramp smooth except for occasional weak threads. Suprasutural cord emerging on last whorl as peribasal keel, accompanied by up to 20 somewhat weaker cords, some with interstitial threads, on base and neck. All spirals on last whorl (and to some extent on earlier whorls) gemmulated by growth lines. Aperture narrowly pyriform, with a moderately long, narrow siphonal canal. Outer lip thin, with a deep U-shaped anal sinus, its apex near middle of sutural ramp.

Kaiatan; "Pukeuri" (type locality of *C. maorum* - actually from McCulloch's Bridge (Maxwell 1966, p. 455)); Waihao Greensand, McCulloch's Bridge (type locality of *P. finlayi*) (uncommon).

Cochlespira maora is the only species of *Cochlespira* (sensu lato) to have been described from New Zealand, although other species are known from the upper Waihao River (Mangaorapan), Greymouth (Clifdenian and Waiauan) and Parengarenga Harbour (Altonian). Recent species of *Cochlespira* are recorded only from tropical or subtropical regions and mostly at bathyal depths, although there are a few records from the outer shelf (Powell 1969, p. 396-404).

Figured specimen (Pl. 8q): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 n. *Eoturris complicata* (Suter, 1917) [*Turris complicatus* Suter 1917, p. 45; *T. neglectus* Suter 1917, p. 46; *Surcula mordax* Suter 1917, p. 51; *Turris insensus* Finlay 1924a, p. 103 (invalid name change for *T. neglectus*); *Gemmula complicata*; *Insolentia mordax*; *Eoturris neglectus*]. Type species of *Eoturris* Finlay and Marwick, 1937 (Turridae: Turrinae).

Size moderate for subfamily (height 25-45 mm), fusiform, spire 0.6 total height. Protoconch narrowly conical, of 5 strongly convex whorls, last 0.25-0.5 whorl with distant, arcuate axial costellae, remainder smooth. Teleoconch of up to 10 whorls, obtusely and often weakly shouldered at a position varying from near mid-whorl height to just above suture on spire whorls; last whorl excavated with a moderately long, narrow neck. Sutural ramp steep, concave, most shells with well developed subsutural fold. Axial sculpture rather variable, typically of moderately

strong, rounded nodules largely confined to shoulder but somewhat extended abapically, matched by a row of weaker nodules on subsutural fold; other shells with more numerous and much weaker peripheral nodules but lacking subsutural nodules entirely; extreme range 12-18 nodules on penultimate whorl. Spiral sculpture more variable, some shells lacking it entirely except for a few weak grooves on base and neck, others having 2 or 3 strong cords on sides of spire whorls but none on ramp, and others with 4 or 5 narrow cords on sides and up to 12 on ramp. Sculpture on base and neck tending to match that on spire. Aperture pyriform, columella weakly twisted at inception of moderately long, unnotched siphonal canal. Inner lip smooth, slightly impressed adapically; outer lip thin, with a deep U-shaped anal sinus, its apex slightly but consistently above shoulder.

Bortonian-Kaiatan; Waihao Greensand, McCulloch's Bridge, Kaiatan (type locality of *T. complicatus* and probably of *S. mordax*) (common); Bortonian?, "Teaneraki" (type locality of *T. neglectus* - probably lower Waihao Valley); Hampden Formation, Hampden Beach (rare).

Eoturris complicata differs from *E. uttleyi* (Pl. 15t) in having more distinctly shouldered teleoconch whorls and nodular rather than comma-shaped axial sculpture. *Turris neglectus* has hitherto been regarded as a distinct taxon, but the holotype does not differ significantly from some topotypes of *Eoturris complicata*. As first revisers we choose the name *Eoturris complicata* for the species named *Turris complicatus* and *T. neglectus* by Suter (1917).

Eoturris seems to have been an endemic genus and has a recorded range of Porangan (?) to Waitakian. Although superficially similar to *Comitas*, it differs in having a narrower anal sinus with its apex much closer to the periphery than in *Comitas*.

Figured specimen (Pl. 8n): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 2.

Pl. 8 r. *Gemmula bimarginata* (Suter, 1917) [*Turris bimarginatus* Suter 1917, p. 44-45] (Turridae: Turrinae).

Rather small for subfamily (height 12-18 mm), narrowly fusiform, spire 0.6 total height. Protoconch conical, of about 5 strongly convex whorls, last 2.5 whorls with narrow, opisthocyrt costellae, remainder smooth. Teleoconch of 6-7 whorls, spire whorls with a prominent though not greatly projecting peripheral band at or near middle; sutural ramp strongly concave, with a prominent subsutural fold; last whorl with a prominent peribasal keel, excavated below with a moderately long, narrow neck. Axial sculpture confined to peripheral band, of rounded gemmules of squarish outline, with interspaces of similar width; 13-18 on penultimate whorl. Spiral sculpture consisting of a cord on subsutural fold, 3 narrow threads of variable strength on peripheral band, and an almost submerged suprasutural cord; most shells with a few fine threads on ramp, some with an additional cord about halfway between periphery and lower suture. Suprasutural cord emerging on last whorl as peribasal keel, accompanied by a somewhat weaker one on base, and up to 18 weak cords on base and neck. Aperture elongate-pyriform, with a moderately long, unnotched siphonal canal. Inner lip impressed adapically; outer lip thin, smooth within, anal sinus deep, narrowly U-shaped, apex on peripheral band.

Kaiatan; "Teaneraki" (type - probably lower Waihao Valley); Waihao Greensand, McCulloch's Bridge (not uncommon).

The sympatric species *Gemmula duplex* is similar in size, but has a narrower, less strongly sculptured protoconch, a narrower peripheral band and a row of gemmules rather than a spiral cord bordering the upper suture. *G. bimarginata* differs from *G. waihaoensis* (also McCulloch's Bridge) in its smaller size and more rounded peripheral gemmules, by the absence of subsutural

collabral ridges and in having two prominent basal spiral cords.

Gemmula is first recorded from about Mangaorapan in New Zealand and seems to have become extinct in the North Otago-South Canterbury region during or after the Waitakian, although elsewhere it survived until the Opoitian. Recent species are widely distributed in tropical or subtropical waters, mostly at mid-shelf to bathyal depths, although a few species occur shallower than 20 m (Powell 1964, p. 243-275).

Figured specimen (Pl. 8r): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 l. *Zemacies marginalis* (Marshall, 1919) [*Surcula marginalis* Marshall 1919, p. 231-232; *S. equispiralis* Marshall 1919, p. 232; *S. hampdenensis* Marshall and Murdoch 1920, p. 134] (Turridae: Turrinae).

Moderately large for subfamily (height 40-80 mm), fusiform, spire half total height. Protoconch narrowly conical, of about 4 smooth whorls. Teleoconch of 7 or 8 whorls, obtusely angled somewhat above middle on spire; sutural ramp slightly concave, with a weak subsutural swelling; last whorl weakly excavated, tapering to a moderately long neck. Axial sculpture consisting of narrow, strongly opisthocline costae reaching from shoulder to lower suture on early whorls, but becoming restricted to peripheral nodules on later whorls (12-15 on penultimate whorl), eventually becoming obsolete on largest shells. Spiral sculpture consisting of a single narrow cord on subsutural swelling, a few weak threads between it and shoulder, and rather subdued, low, rounded cords below shoulder. Aperture narrow, with a moderately long, narrow siphonal canal. Inner lip only thinly glazed; outer lip thin with a deep, tongue-shaped anal sinus, its apex near middle of ramp.

Bortonian-Kaiatan; Bortonian, Hampden Formation, Hampden Beach (type locality of all three nominal species); Waihao Greensand, McCulloch's Bridge. Uncommon at both localities.

Zemacies elatior (Pl. 26i) resembles *Z. marginalis* in having a narrow cord near the upper suture, but differs in having finer spiral sculpture, and axial sculpture of short, opisthocline ridges extending a short distance below the periphery (confined to early whorls on many shells).

Zemacies has a recorded range of Wangaloan to Waipipian in New Zealand (although there are no records from the Taranaki Series), and is also present in the mid-Cenozoic of Victoria, Australia. The genus seems to have had a mid-shelf to upper bathyal habitat.

Figured specimen (Pl. 8l): GS9480, J40/f8801, McCulloch's Bridge, Kaiatan (NZGS) x 1.5.

Pl. 8 m. *Cordieria rudis* (Hutton, 1885) [*Clathurella rudis* Hutton 1885b, p. 328; *Mangilia* (*Clathurella*) *rudis*; *Borsonia rudis*; *Cordieria haasti* Finlay 1930b, p. 83; *C. verrucosa* Finlay 1930b, p. 83-84] (Turridae: Mitromorphinae).

Size moderate for subfamily (height 10-17 mm), ovate, spire highly variable, 0.4-0.7 total height. Protoconch mamillate, of about 1.5 smooth whorls. Teleoconch of 5-6 whorls, weakly shouldered at or somewhat above middle on spire; sutural ramp slightly concave, with a low subsutural fold; last whorl shallowly excavated, with a short, in many specimens ill-defined, neck. Axial sculpture of prominent rounded costae with concave interspaces, subobsolete on ramp and usually weakening before reaching lower suture, dying out on upper part of base of last whorl, and in many shells becoming obsolete on last half-whorl; 7-11 costae on penultimate whorl. Spiral sculpture highly variable, in some shells consisting of a few narrow, rather subdued cords on sides of spire whorls, joined by somewhat finer cords on base and neck, in other shells restricted to subobsolete peripheral threads. Aperture elongate-pyriform, with a rather poorly defined, short, unnotched

siphonal canal. Columella gently convex with 2 narrow plaits, one somewhat above middle, other (usually slightly stronger) near adapical end. Inner lip thinly glazed, flush; outer lip thin, weakly lirate well within aperture on some shells, with a shallow, arcuate anal sinus just below suture.

Kaiatan; "Waiho" [sic] (type locality of *C. rudis*—probably McCulloch's Bridge); Waihao Greensand, McCulloch's Bridge (type locality of *C. haasti* and *C. verrucosa*) (very common); Kapua Tuff, Waihao River (moderately common).

This little turrid is one of the most abundant molluscs at McCulloch's Bridge and is also one of the most variable. Finlay (1930b, p. 83-84) segregated *C. haasti* and *C. verrucosa* on the basis of alleged differences in shape, coarseness of spiral sculpture and number of axial costae per whorl, but study of large samples shows that these differences are not constant and that the various morphotypes grade into one another (Maxwell, in prep.). Finlay (1930b, p. 84) also recognised another species of *Cordieria*, *C. huttoni*, from McCulloch's Bridge; this does seem to be a distinct taxon differing from *C. rudis* in its smaller size (maximum height 11 mm), more slender shell, less prominent and less nodular axial sculpture, more prominent spiral sculpture and weaker columellar plaits.

Cordieria occurs widely in the European Cenozoic and is also recorded from the Eocene of North America and Australia (Powell 1966, p. 59, 60; Long 1981, p. 32-34). A Recent species occurs at depths of 140-190 m in the Caribbean (Powell 1966, p. 59). Apart from the two McCulloch's Bridge species, New Zealand records of the genus are from the upper Waihao River (Mangaorapan ?) and Trig M, Totara (Runangan).

Figured specimen (Pl. 8m): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 h. *Fusiaphera marshalli* (Allan, 1926) [*Uxia* (?) *marshalli* Allan 1926, p. 342; *Unitas marshalli*] (Cancellariidae: Cancellariinae).

Size moderate for family (height 10-19 mm), broadly fusiform, spire 0.5-0.6 total height. Protoconch depressed dome-shaped, of 3.5 whorls, apex almost flat, last 0.25 whorl with weak axial costellae and subobsolete spirals, remainder smooth. Teleoconch of 5-6 whorls, markedly convex on spire; last whorl strongly excavated, with a short neck. Sutures impressed at first, narrowly canaliculate on later whorls. Axial sculpture of very prominent rounded prosocline costae reaching from suture to suture on spire, and extending across base but not onto neck of last whorl; 10-12 costae on last whorl; varices at irregular intervals. Spiral sculpture commencing as 3 narrow, rounded subequal cords, a fourth appearing out of lower suture during growth, and 4 or 5 additional cords appearing on last whorl; narrow, flattened threads also appearing between cords and elsewhere on later whorls. Cords crossing axial costae and varices with only slight thickening. Aperture ovate, columella almost straight, twisted to left abapically to form very short, unnotched siphonal canal, bearing 3 oblique plaits, the lowest one reduced to a low tubercle on largest specimen seen. Inner lip moderately thickly callused over columella, thinly in parietal area. Outer lip with a moderately heavy varix externally and 7 narrow lirae within.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (rare).

Fusiaphera naroniformis (Altonian, Oamaru) has a protoconch of only one whorl, distinctly shouldered teleoconch whorls, a less strongly impressed suture, and less prominent spiral sculpture. Both species were originally referred to *Uxia* Jousseaume, 1887 (now known by its replacement name *Unitas* Palmer, 1947) but they have more in common with the widespread warm-water genus *Fusiaphera* Habe, 1951.

Figured specimen (Pl. 8h): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 5.

Pl. 8 k. *Tatara revoluta* (Finlay, 1924) [*Cymatium revolutum* Finlay 1924b, p. 456; *Semitriton revolutum*] (Cancellariidae: Cancellariinae).

Moderately large for family (height 30-45 mm), broadly fusiform, spire 0.4 total height. Protoconch dome-shaped, of 1.5 smooth whorls, apex flattened. Teleoconch whorls convex on spire; last whorl long, broadly excavated, with moderately long, thick neck. Axial sculpture of narrow, low costae reaching from suture to suture on spire and across base of last whorl; low varices present down much or all of spire, but indistinct towards apex. Spiral sculpture of numerous, narrow, rather widely spaced, rounded cords similar in strength to axial costae; interspaces with fine, low threads cancelled by fine growth ridges. Intersections of spiral cords with axial costae nodulose. Aperture narrow, with a short, straight, widely open, unnotched siphonal canal; no obvious fasciole. Inner lip spread as a moderately wide callus pad with a thickened edge, bearing 3 prominent, narrow columellar plaits medially, and many narrow spiral ridges (most of them corresponding to spiral cords on base and neck) over whole callus. Outer lip wide, strongly thickened, inner face almost flat, with 14 prominent, narrow ridges.

Kaiatan (- Whaingaroan?); "Kakanui Beach (tuffs below the limestone)" (type—almost certainly from Waiareka Volcanic Formation, Lorne (Kaiatan), where this species is not uncommon (see comments under *Sassia* (*Haurokoa*) *marwicki*, above); ? Kakanui, top of McDonald Limestone (Whaingaroan).

Tatara pahiensis (Bortonian, Pahi), the type species of *Tatara* Fleming, 1950, is known only by the holotype; it is larger and less slender than *T. revoluta*, has coarsely cancellate teleoconch sculpture lacking the finely reticulate interstitial sculpture of the latter species, has a very wide outer lip bearing 11 transverse ridges, and has four low, wide columellar plaits. *T. flemingi* (Pl. 9k) is similar to *T. revoluta* but is shorter and wider, has weaker axial sculpture but stronger secondary spiral sculpture, has a more laterally sinuous aperture (inclined at 20° to vertical), has a wider outer lip bearing 18-20 low, transverse ridges and has only two prominent (and a weaker third) columellar plaits. *T. transenna* (Suter, 1917) (Waitakian, "Isis" bed, Campbell's Beach, Kakanui) is a rather poorly known, relatively stumpy, low-spined, coarsely cancellate species; it has been interpreted in a very broad sense by Beu and Maxwell (1987) to include all of the younger *Tatara* records, although probably more than one species is involved. These include fragmentary specimens with beautiful reticulate microsculpture from Parengarenga Harbour (Altonian), and poorly preserved moulds from the Stillwater Mudstone at Greymouth (Clifdenian).

Tatara has traditionally been regarded as a member of the Ranellidae, but Beu and Maxwell (1987) have shown that it is a cancellariid closely similar to *Semitriton* Cossmann, 1903. The genus is endemic to New Zealand, and includes both shallow-water species (e.g. *T. pahiensis* and possibly *T. revoluta*) and deeper-water forms (*T. flemingi* and *T. transenna*), mostly from "hard-ground" facies.

Figured specimen (Pl. 8k): GS9481, J41/f8025, Lorne, inland from Oamaru, Kaiatan (TM5145, NZGS) x 1.5.

Pl. 7 q, r. *Wangaloa ngaparaensis* (Suter, 1917) [*Architectonica ngaparaensis* Suter 1917, p. 14] (Architectonicidae).

Size moderate for family (diameter 8-12.5 mm), lenticular, spire very depressed but not flat. Protoconch heterostrophic, initial whorl

immersed. Teleoconch of about 4 whorls that are flat or gently convex dorsally; last whorl sharply keeled, base moderately convex, with a wide, perspective umbilicus. Spiral sculpture consisting primarily of a narrow, finely beaded cord immediately above suture, becoming peripheral keel on last whorl, where it is joined by a narrow, smooth or feebly gemmulate cord a short distance below. A row of small gemmules, without a connecting thread on most specimens, below suture on some shells. Remainder of shell with weak or subobsolete threads. Axial sculpture, apart from gemmules margining suture, of growth lines which weakly gemmulate dorsal spiral threads on some shells. Umbilical border strongly crenulated by 24-30 axial folds. Umbilicus with a crenulated cord within in most specimens, ending somewhat above middle of inner lip, but cord absent from a few specimens. Aperture subquadrate.

Kaiatan; "concretions with fossils overlying coal beds, Ngapara" (type—almost certainly from the Waihao Greensand, McCulloch's Bridge where it is not uncommon (see Maxwell 1966, p. 451)); Kapua Tuff, Waihao River.

Wangaloa plana (Wangaloan, Wangaloa and Boulder Hill), the type species of the genus, has a less acute periphery and has much coarser sculpture (of short ridges rather than gemmules) margining the lower suture. Both species are readily distinguished from other New Zealand architectonicids by the relatively weakly developed spiral sculpture, and by the very depressed spire.

Figured specimen (Pl. 7q, r): GS9508, J40/f8803, McCulloch's Bridge, Kaiatan (NZGS) x 3.

Pl. 8 aa. *Triploca waihaoensis* Marshall and Murdoch, 1923a [p. 128] (Acteonidae).

Size moderate for family (height c.10 mm), ovate, spire a little more than half total height. Protoconch of about 2 smooth whorls, initial whorl depressed. Teleoconch of 5 whorls, those on spire gently convex with a narrow sutural shelf; last whorl large, evenly convex with a small pseudumbilicus. Spiral sculpture of fine grooves with broad, flat interspaces, 6-7 on penultimate whorl, an additional 16 on base of last whorl. Axial sculpture of very fine growth lines restricted to grooves. Aperture ovate, columella short, subvertical with 3 strong, rather sharp plaits, the adapical one the strongest. Inner lip thinly callused; outer lip apparently thin, opisthocline, with shallow spiral grooves within.

Kaiatan, Waihao Greensand, McCulloch's Bridge (type) (rare).

Triploca waihaoensis is distinguished from other New Zealand acteonids by its relatively tall spire and, most importantly, by the presence of three columellar plaits. *T. waihaoensis* is very similar to the type species, *T. ligata* Tate, 1894 (Late Eocene, South Australia) and may be conspecific. The only other New Zealand record of the genus is from the Mangaorapan of White's Creek, North Canterbury.

Figured specimen (Pl. 8aa): McCulloch's Bridge, Kaiatan (Canterbury Museum) x 6.

Pl. 8 z. *Superstes marshalli* Finlay and Marwick, 1937 [*Avellana tertiaria* Marshall 1916b, p.121 (not of Vincent 1884); *Superstes marshalli* Finlay and Marwick 1937, p.109, p.120 (new name for *Avellana tertiaria* Marshall, preoccupied); *Gilbertia tertiaria*] (Ringiculidae).

Moderately large for family (height 7-9 mm), ovate, spire low, dome-shaped, 0.2-0.3 total height. Protoconch depressed dome-shaped of about 2 smooth whorls. Teleoconch of about 3 whorls, moderately convex on spire, with impressed sutures; last whorl large, strongly inflated. Sculpture of narrow spiral grooves with broad, flat interspaces, typically constricted at regular intervals to form punctate sculpture of shallow, oval pits; 20-27 grooves on last whorl. Aperture pyriform, strongly constricted posteriorly; columella concave, bearing 2 strong plaits, a vertical one bordering the shallow siphonal notch and a nearly horizontal one near adapical end. A third strong plait on lower part

of parietal region. Inner lip prominently callused, with a heavy, rounded ridge running along its edge from top of columella almost to adapical end of aperture. Some shells with a very short ridge or tubercle above parietal plait and within aperture. Outer lip slightly prosocline, thickened externally by broad, rather low varix, padded within, bearing 2 strong denticles on abapical half (interspace smooth or with up to 3 weak denticles), and up to 10 weaker ones above.

Bortonian-Kaiatan; Bortonian, Hampden (type); Waihao Greensand, McCulloch's Bridge (rare); Kapua Tuff, Waihao River (common).

Superstes phoenix (Kaiatan, Lorne), the type species of *Superstes* Finlay and Marwick, 1937, is very similar but differs in having a prominent vertical ridge rather than a very short ridge or tubercle in the parietal area.

Superstes is an endemic genus, apparently closely related to *Gilbertina* Morlet, 1888, occurring in the Paleocene to Miocene of the Northern Hemisphere, but differing in having a much less strongly prosocline outer lip, and a distinct siphonal notch. Both genera differ from *Ringicula* (Pl. 56i,j) in their larger size and more globose, lower-spined shell and in having a prosocline rather than an opisthocline outer lip. Their closest relationship seems to be with Late Cretaceous taxa such as *Avellana* Orbigny, 1843 and *Eriptycha* Meek, 1876.

Figured specimen (Pl. 8z): GS11,200, J40/f8853, Kapua Tuff, Waihao River, Kaiatan (NZGS) x 5.

Pl. 8 u. *Hyalocyclus annulata* (Tate, 1887) [*Styliola annulata* Tate 1887b, p.195; *Clio annulata*; *Clio rangiana* (Tate, 1887) (not of Tate)] (Cavoliniidae: Creseinae).

Rather large for family (length 15-35 mm), thin-shelled, tubular, of circular cross-section, slowly tapering, straight or gently curved. Apical details not known. Teleoconch sculpture of narrow, low ridges with wider interspaces, not quite perpendicular to axis of tube.

Bortonian-Runangan; Middle-Late Eocene, Aldinga, South Australia (type); Waihao Greensand, Black Point, Bortons; Waiareka Volcanic Formation, Lorne; Kapua Tuff, Waihao River; Trig M, Totara; Bridge Point, Kakanui.

Although this rather nondescript fossil superficially resembles some scaphopods (e.g. species of *Fustiaria*) it differs radically in having a very thin shell and except for its much larger size, it is very similar to the extant thecosome pteropod *Hyalocyclus striata* (Rang, 1828). At most of the localities listed above it is associated with undoubted pteropods, particularly species of *Spiratella*, and there can be little doubt that it too is a thecosome. *H. striata* sheds the early part of the shell, leaving a curved septum in the remaining portion, and it seems very likely that *H. annulata* had a similar habit, although none of the available specimens are sufficiently well preserved to be certain.

H. annulata is very similar to certain pteropods of Late Eocene and Oligocene age from Europe, Syria and USSR (e.g. *H. maxima* (Ludwig, 1864), *H. cretacea* (Blanckenhorn, 1890) and *Praehyalocyclus chivensis* Korobkov and Makarova, 1962), and in view of the wide distribution of most modern thecosomes it is not unlikely that all of these names apply to a single widespread species. Although the genus-group name *Praehyalocyclus* Korobkov and Marakova, 1962 is available for these outsize species, there are no convincing criteria by which it can be differentiated from *Hyalocyclus*.

Figured specimen (Pl. 8u): GS3869, J41/f8539, Lorne, inland from Oamaru, Kaiatan (NZGS) x 3.

CHAPTER 9. EARLY–MIDDLE OLIGOCENE FAUNA (WHAINGAROAN STAGE): PLATE 9

INTRODUCTION (Figure 14)

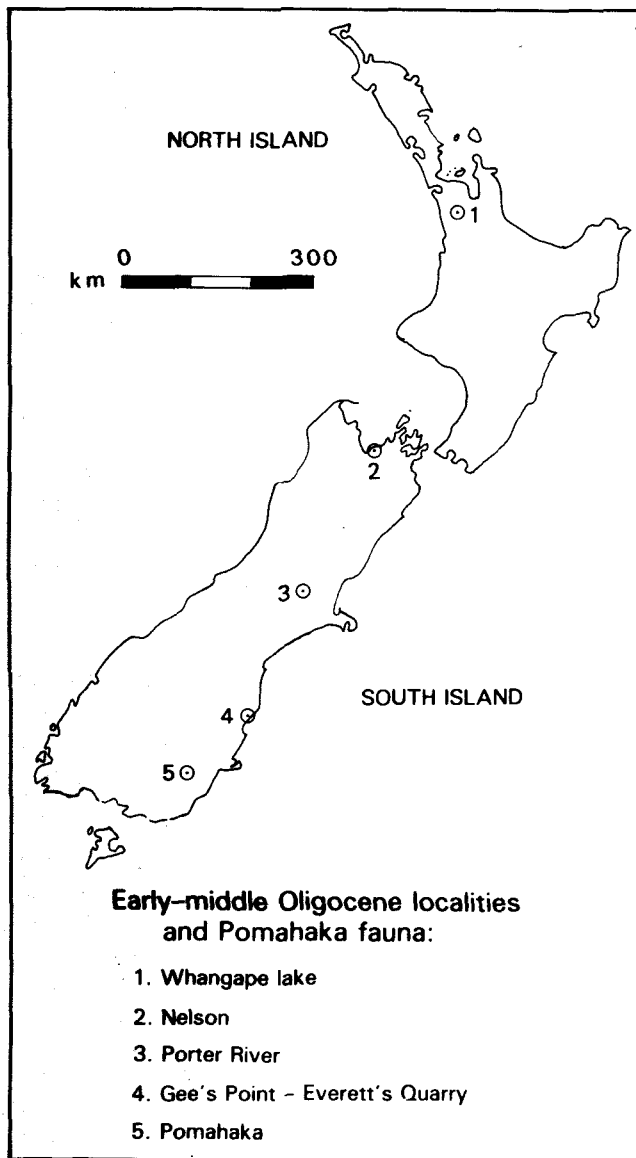


Figure 14 The main molluscan fossil localities of Whaingaroan (Early-mid Oligocene) age, and location of the Pomahaka faunule (Pl. 9; described in the following chapter).

By the mid-Oligocene much of present-day New Zealand was submerged, and what land remained (mostly central North and South Islands) was low-lying and supplying relatively little terrigenous material to the surrounding seas. Over much of the country Early and middle Oligocene (Whaingaroan) rocks are marl or limestone, typically containing few, if any molluscs. Those that do occur are calcitic species, e.g. *Janupecten polemicus*, *J. uttleyi*, *Acesta* spp. and *Cirsotrema lyratum*. Most of what we know about Whaingaroan molluscs, however, is based on collections from rocks with a higher terrigenous content (particularly from south-west Auckland and Nelson) or from volcano-genic sediments (mostly from North Otago). These faunules are rather restricted and give only a limited picture of the Whaingaroan molluscan fauna.

Another factor that makes it difficult to make generalisations about the Whaingaroan is the exceptional length of the stage - about nine million years, i.e., two to three times the length of most other local Cenozoic stages. Micropaleontologists subdivide the stage into lower and upper (or early and late) Whaingaroan, but molluscan faunas are too poorly known to tell if a similar subdivision is warranted for them. Whaingaroan faunules from North Otago are from the lower Whaingaroan, and are mostly from a hard-ground habitat, but the faunule from The Cliffs, Nelson, which is from high in the stage, is from a shallow-water, sandy bottom facies, so the faunules are not directly comparable. However, in view of the considerable length of time involved it seems probable that early and late Whaingaroan faunas differed significantly at the species level, if not in generic composition.

South-west Auckland

The name-bearer of the Whaingaroan Stage is at Waitetuna Estuary, Raglan (= Whaingaroa) Harbour; here and elsewhere in south-west Auckland and in North Taranaki Whaingaroan sediments are relatively thick, and constitute the middle part of the Te Kuiti Group (Kear and Schofield 1959, 1978). They include sandstone (in places directly overlying Eocene coal-measures), siltstone and limestone, but despite their apparently suitable lithology and shallow-water nature they contain relatively few molluscs, possibly because some of the lower units accumulated under anoxic conditions (Kear and Schofield 1978, p. 66). Hutton (1873b, p. 1, 18, 32) described a scaphopod and two bivalves (including the widespread species *Propeamussium zitteli*) from Whaingaroa Siltstone at Lake Whangape, and Marwick (1924d, p. 562; 1927, p. 628) described *Polinices waipaensis* and the distinctive thick-shelled venerid *Eumarcia* (*Atamarcia*) *crassa* from the same unit near Karamu. Other molluscs recorded from Whaingaroan beds in the Kawhia-Te Kuiti area include species of shallow-water genera such as *Cucullaea*, *Chlamys*, *Janupecten*, *Spissatella*, "*Cyclocardia*", *Dosinia*, *Panopea*, *Zefallacia*, *Sigapatella*, *Crepidula* and *Austrofusus*, but specimens are typically poorly preserved and rarely identifiable to species level.

Nelson

The locality known as "The Cliffs" on the foreshore near Port Nelson has some claim to fame as being the source of several of the first fossil molluscs to be formally described from New Zealand. Material collected by F. Manse in the early 19th century was given to the famous shell-collector Hugh Cuming and was briefly discussed by Forbes (in Mantell 1850, p. 343). Zittel (1864) recorded seven species (three of them described as new) in a collection made by Ferdinand von Hochstetter in 1859, and subsequent workers described an additional three species from this locality.

Molluscs from The Cliffs are poorly preserved and occur in lenticular conglomeratic bodies in a sequence of alternating sandstone and mudstone (Magazine Point Formation). According to Lewis (1980) the conglomerates

are debris-flow deposits (possibly storm-generated) emplaced in a relatively shallow-water (shelf) environment, although there is some evidence that at least part of the unit accumulated in significantly deeper (i.e. bathyal) conditions. The molluscan faunule itself has a distinctly shallow-water (inner shelf) aspect, and was listed by Vella (1962), although his identifications are rather more precise than the material warrants. Besides the six species described from The Cliffs (i.e. *Limopsis zitteli*, *Neilo funiculata*, *Austrofusus* (*Neocola*) *zitteli*, *Zelandiella robinsoni*, *Austrotoma gracilicostata* and *Dentalium mantelli*) the faunule includes species of *Glycymerita*, *Cucullaea* (*Latiarca*), *Spondylus*, "*Cyclocardia*", *Megacardita*, *Dosinia*, *Haliotis*, *Polinices*, *Magnatica* (*Spelaenacca*), *Tanea*, *Sigapatella*, *Crepidula*, *Echinophoria*, *Falsicolus*, *Austrofusus* (*Austrofusus*), *Ficus*, *Amalda* (*Baryspira*), *Austrotoma* and *Zeacuminia*.

North Otago

The best-preserved Whaingaroan molluscan faunules are from the Deborah Volcanic Formation and McDonald Limestone (particularly the former unit) near Kakanui, North Otago. The two most important localities are at Gee's Point where the dominant lithology is fine conglomerate/breccia, and a tuff bed in the cliff below Everett's Quarry (long disused). The faunule from the former locality includes *Quadrilatera januaria*, *Tucetona lornensis*, *Glyptoactis benhami*, "*Cyclocardia*" n.sp., *Spissatella* n.sp., *Diplodonta* (*Zemysina*) n.sp., *Caryocorbula* n.sp., *Spectamen* n.sp., *Astraea* n.sp., *Spirocolpus tophinus* and *Tatara flemingi*. The Everett's Quarry faunule apparently lived in quieter and deeper conditions and includes *Serripecten* n.spp, *Notochlamys* n.sp., *Glyptoactis benhami*, "*Verticordia*" n.sp., *Conominolia sulcatina*, *Calliotropis* aff. *fenestratus*, *Bolma marshalli*, *Zeacolpus wharekuriensis*, *Cypraea* sp. and *Austrofusus* n.sp.

Faunules from the McDonald Limestone are much sparser than those from the volcanics—the best is from the right bank of the Kakanui River near its mouth, where occur *Notochlamys* n.sp., *Serripecten* n.sp. (distinct from either of the Everett's Quarry species), *Cirsotrema lyratum* and *C. gagei*. Also noteworthy are rare specimens of a giant nautiloid (*Aturia* sp.) from the McDonald Limestone, probably from McDonald's Quarry. The huge nautiloid, more than 50 cm in diameter, recorded from "Wharekuri" in the Waitaki valley (Hamilton 1903; now in Otago Museum) is probably of similar age.

Composition of the Early Oligocene molluscan fauna

No molluscan genera are known to be restricted to the Whaingaroan, and only one (*Quadrilatera*) is last recorded from the stage, although it is possible that some taxa last reported from the Late Eocene survived into the Early Oligocene. Genus-group taxa that are first recorded from the Whaingaroan (mostly from the later part of the stage) include *Glycymeris*, *Propeamusium*, *Megacardita*, *Notocallista* (*Fossacallista*), *Eumarcia* (*Atamarcia*), *Tugali*, *Zefallacia*, *Crepidula*, *Struthiolaria*, *Echinophoria*, *Zelandiella* (doubtfully in Wangaloan), *Austrofusus* (*Neocola*) and *Austrotoma*. It seems likely that many molluscan genera that are first known from the Duntroonian (see next chapter) were already present

during the Whaingaroan, but this must remain conjectural until such time as Whaingaroan faunules become much better known.

There is ample evidence from oxygen isotope studies for a relatively rapid decrease in bottom-water temperatures at the Eocene-Oligocene boundary, followed by a more gradual increase thereafter (Shackelton and Kennett 1975; Keigwin 1980). This change is thought to signal the development of the psychrosphere, the oceanic system existing at the present day in which there is a clear distinction between cool bottom waters and significantly warmer surface waters. Before this time bottom and surface waters were at much the same temperature. In his pioneering study on New Zealand Cenozoic paleotemperatures, Devereaux (1967) postulated a fall in temperature of about 9°C across the Runangan-Whaingaroan boundary, but his conclusions have been criticised by Burns and Nelson (1981). Their work on sequences at Point Elizabeth and Cape Foulwind on the West Coast indicates a gradual decrease of about 3°C through the Runangan, a slight warming at the Runangan—Whaingaroan boundary, and a relatively rapid drop of about 2°C in the basal Whaingaroan. They advocate a change from warm temperate to cool temperate conditions during this period, followed by a rise back to warm temperate conditions later in the Whaingaroan.

The molluscan evidence unfortunately does not provide any clear-cut evidence for such temperature changes, although Beu and Maxwell (1968, fig. 2) showed that there was a significant decrease in the proportion of "Indo-Pacific" molluscs (expressed as a percentage of the total recorded fauna) from Runangan to Whaingaroan. However, the early Whaingaroan faunules from North Otago include such warm-water taxa as *Arca*, *Quadrilatera*, *Bolma*, *Cypraea* (sensu lato) and *Conus* (sensu lato) and do not seem to be of obviously cooler-water aspect than Runangan faunules from the same area. Of course these faunules may pre-date or post-date the short-lived temperature minimum, or they may have lived in anomalously warm conditions, perhaps caused by locally enhanced insolation on the crest or flanks of a volcanic sea-mount. The presence of *Spondylus*, *Polinices* and *Ficus* in The Cliffs faunule suggests that warm conditions also prevailed during the late Whaingaroan.

REPRESENTATIVE EARLY AND MID-OLIGOCENE MOLLUSCA

Pl. 10 f. *Janupecten uttleyi* (Marwick, 1924) [*Pecten uttleyi* Marwick 1924e, p. 325; *Serripecten* (*Janupecten*) *uttleyi*]. Type species of *Janupecten* Marwick, 1928 (Pectinidae).

Size moderate for family (height 55–60 mm), left valve more inflated than right. Ears subequal, separated from disc by narrow channels, these much more marked in right than in left valve, and more prominent posteriorly than anteriorly. Byssal notch deep, fasciole narrow; ctenolium apparently absent. Dorsal margins of left valve ears colinear, smooth, those of right valve divergent, serrate. Radial sculpture on right valve appearing at about 20 mm from umbo, of about 50–60 low, flattened or convex costae, scaly in some specimens but almost smooth in most shells; interspaces typically somewhat wider than costae. Ears with 4 or 5 similar costae. Other sculpture of growth lines and "Camptonectes" microsculpture. Radial sculpture in left valve highly variable, almost obsolete in some shells, in others consisting of subdued costae similar to those on right valve but appearing distally. Other sculpture of very fine radial striae and fine growth lines.

Runangan?, Whaingaroan; Whaingaroan, lower part of Wharekuri Greensand, "Fishing Rock", Waitaki River near Wharekuri (type) (common); ?Woodpecker Bay, North Westland (some specimens with radial costellae between costae on right valve, but otherwise similar to topotypes).

The discrepant sculpture and the presence of aural channels in both valves effectively distinguish *Janupecten uttleyi* from nearly all other New Zealand pectens. *J. polemicus* (Whaingaroan, south-west Auckland) is most similar, but has less well developed channels (particularly in the left valve) and has radial rays with little or no surface expression in the right valve. *J. subteres* (Duntroonian, North Otago) resembles *J. polemicus* in aural channel development but has right valve radial costae present only distally (only near the dorsal margins in some shells). *Duplipecten waihaoensis* (Pl. 5d) and *D. parki* have aural channels in the right valve only, and have the right valve more inflated than the left, the opposite situation to that in *Janupecten*.

Figured specimen (Pl. 10f): GS486, I40/f6467, Fishing Rock, Wharekuri, Waitaki Valley, Whaingaroan (NZGS) x 1. [Please note: this illustration is out of sequence.]

Pl. 9 a. *Serripecten* n. sp. (Pectinidae).

Rather small for genus (height 35-40 mm), right valve somewhat more inflated than left. Dorsal margins of left valve colinear, those of right valve divergent, slightly serrate; byssal notch deep. Proximal 10-12 mm of both valves smooth except for commarginal striae and "Camptonectes" sculpture, remainder with 41-44 narrow, rounded to squarish primary costae which become scaly distally. Scaly secondary costellae appearing between costae and near dorsal margins, about halfway across disc. Ears with fine scaly costellae. Hinge with broad resilifer, prominent cardinal crurae and well developed provinculum.

Whaingaroan, Deborah Volcanic Formation, Everett's Quarry, Kakanui (common).

The new species resembles *S. tiorioriensis* (Pl. 4b) in its small size and relatively simple sculpture, but has more numerous radial costae and has secondary costellae appearing at a much earlier stage of growth. *S. enfieldensis* (Kaiatan-Runangan, North Otago) has less numerous costae (26-29), which commence much closer to the beaks (c. 5 mm).

Figured specimen (Pl. 9a): GS9535, J42/f6031, beach below Everett's Quarry, Kakanui, Whaingaroan (NZGS) x 1.5.

Pl. 9 g. *Notochlamys* n. sp. (Pectinidae)

Small for family (height 17-24 mm), left valve weakly inflated, right valve slightly more inflated. Some specimens bent in towards commissure distally, producing a humped profile. Ears unequal, particularly in right valve; byssal notch well developed, moderately wide, ctenolium present. Radial sculpture in both valves commencing near beaks as 11 or 12 narrow, well spaced costae that quickly become broad plicae (i.e. involve whole thickness of shell), those on left valve developing 2 (or rarely 3) longitudinal grooves so that distally they consist of 3 (or 4) narrow, subequal, scaly costae and are typically of reduced relief. Secondary costae, also scaly, developing by intercalation at 6-11 mm from beak, and tertiary costellae at a later stage, either by intercalation or by branching off sides of plicae. Plicae on right valve developing 1 (or less commonly 2) deep longitudinal grooves, the resulting costae remaining rounded and smooth apart from weak growth lines. Secondary and tertiary radials similar in character to plicae. Ears with 4 or 5 narrow radial costae. Both valves with "Camptonectes" microsculpture on disc and ears, in most specimens much better developed on left than on right valve, and in places (particularly on lateral margins) producing microcellular ("shagreen") sculpture where intersected by fine growth ridges.

Whaingaroan, McDonald Limestone, Kakanui River, near mouth (uncommon); Deborah Volcanic Formation, Everett's Quarry, Kakanui (moderately common); tuffs below limestone, All Day Bay, Kakanui (rare).

Although this distinctive little pecten superficially resembles some species of *Mesopeplum* it differs in having distinct "Camptonectes" (and locally shagreen) microsculpture and a relatively broad byssal notch. *Mesopeplum* lacks "Camptonectes" or shagreen microsculpture but has numerous fine, closely spaced commarginal ridges extending over the whole disc and ears, and has a very narrow byssal notch (apparently becoming obsolete in the adult of the Australian Recent type species, *M. caroli* Iredale, 1929). The Kakanui species is here referred to *Notochlamys*, proposed by Cotton in 1930 for Australian *Mesopeplum*-like shells with shagreen sculpture, and although *Notochlamys* is usually regarded as a synonym of *Mesopeplum* we contend that these taxa are worth separating. *Mesopeplum* is represented by several species in New Zealand, but the only other local record of *Notochlamys* we are aware of is from the Mohakatino Formation (Lillburnian) near Mokau, North Taranaki.

Figured specimen (Pl. 9g): GS14431, J42/f6573A, right bank, Kakanui River near mouth, Whaingaroan (NZGS) x 2.

Pl. 9 b, f. *Pycnodonte* (*Notostrea*) *subdentata* (Hutton, 1873) [*Ostrea subdentata* Hutton 1873b, p. 48; *O. (Eostrea) subdentata*; *Notostrea subdentata*; *Ostrea (Notostrea) subdentata*]. Type species of *Notostrea* Finlay, 1928 (Gryphaeidae: Pycnodonteinae).

Small for genus (height 25 mm), ovate-trigonal, known definitely only by the moderately inflated lower (left) valve. Attachment area small, no sculpture apart from irregular growth ridges and welts. Ligamental area rather small, with a relatively large, shallow resilifer. Commissural shelf narrow, bearing distinct chomata. Adductor muscle scar small, subcircular, much closer to hinge than to ventral margin.

Whaingaroan, "Broken River (Lower beds)" (type—probably from marls below limestone (Coleridge Formation), lower gorge of Porter River, Castle Hill Basin). Not definitely recorded elsewhere, but possibly present in Cobden Limestone, Greymouth (Whaingaroan?) and in marls of similar age in Te Kuiti district.

Pycnodonte subdentata differs from *P. (Notostrea) tarda* (Pl. 3b, c) in its smaller size, its less inflated left valve, and its much stronger chomata. Although no unequivocal evidence for vesicular shell layers—the diagnostic character of the Pycnodonteinae, and present in *P. tarda*—could be discerned in the available material, the similarity of *P. subdentata* to *P. tarda* in shell shape and in the shape and position of the adductor muscle scar indicates that these species are closely related.

Figured specimen (Pl. 9b, f): holotype, probably from lower gorge, Porter River, Castle Hill Basin, Canterbury, Whaingaroan (TM2856, NZGS) x 1.5.

Pl. 9 c, d. *Glyptoactis* (*Fasciculicardia*) *benhami* (Thomson, 1908) [*Cardita benhami* Thomson 1908, p. 102-103; *Venericardia benhami*; *V. (Fasciculicardia) benhami*] (Carditidae: Venericardiinae).

Small for genus (length 25-30 mm), subquadrate, beaks situated at about 0.2 anterior-posterior distance; strongly inflated; posterior area

slightly concave. Lunule small, pouting. Radial sculpture of 28-31 prominent, narrow, strongly nodulose costae that are noticeably weaker in middle of posterior area than elsewhere. Some costae, particularly on posterior part of flanks and on posterior area, with a low ridge on each side. Commarginal sculpture of nodules and scales on costal crests, and numerous very fine ridges and wrinkles in between. Left hinge with a small, tubercular anterior lateral tooth at end of lunular groove, a broadly triangular anterior cardinal and a long, narrow, slightly curved posterior cardinal tooth. Right hinge with small anterior lateral socket and a curved, excavated median cardinal tooth. Ligament groove narrow, bounded by a thin ridge along margin of sunken escutcheon.

Whaingaroan; Deborah Volcanic Formation, Everett's Quarry, Kakanui (type) (common); Gee's Point, Kakanui (rare).

Glyptoactis benhami is distinguished from *G. acanthodes* (Pl. 5g, h) and *G. subintermedia* (Pl. 23g) by its relatively small size, its less rounded outline and its more closely spaced, less obviously tripartite radial costae. The number of costae is similar to that in *G. subintermedia*; *G. acanthodes*, by contrast, has only 21-24 costae.

Figured specimen (Pl. 9c, d): GS9535, J42/f6031, beach below Everett's Quarry, Kakanui, Whaingaroan (NZGS) x 2.

Pl. 9 h, i. *Procardia dolicha* (Suter, 1917) [*Cardium (Fragum) dolichum* Suter 1917, p. 76; *C. (Fragum) maorinum* Suter 1917, p. 77] (Parilimyidae).

Size moderate for family (length 35-55 mm), thin-shelled, inner layer nacreous; broadly trigonal, anterior area very well defined by umbonal ridge, somewhat concave. Lunule prominent, strongly impressed; escutcheon long, narrow, slightly concave. Radial sculpture confined to flanks, of 25-28 narrow, subequal, rather wavy costae. Commarginal sculpture of growth lines and ridges, noticeably stronger on anterior area than elsewhere. Nymphs short, slightly projecting above dorsal margins; internal characters not known.

Runangan-Altonian; Whaingaroan or Duntroonian, Cobden Limestone, Cobden or Greymouth (type locality of *C. dolichum*); Whaingaroan, Magazine Point

Formation, The Cliffs, Nelson (type locality of *C. maorinum*); Waiareka Volcanic Formation, Maheno; Tarakohe Marl, Tarakohe Quarry; Otekaike Limestone, Frenchman's Gully, Pareora; Maramarua Opencast Mine.

This is the most widespread and hence best-known New Zealand pholadomyacean, and is readily distinguished from other members of the superfamily by its trigonal shape, its strongly differentiated anterior area and its fine radial sculpture. Most records are of deformed, articulated specimens from moderately deep-water (upper bathyal) sediments.

Procardia is very similar to *Panacca* Dall, 1903 (syn. *Aporema* Dall, 1903), but differs in having a distinct lunule. The genus is otherwise known only from Late Jurassic to Late Cretaceous (Cox in Moore 1969, p. N830), so its presence in the mid-Cenozoic of New Zealand suggests that it persisted here longer than elsewhere.

Figured specimen (Pl. 9h, i): GS1286, N25/f8498, Tarakohe Quarry, Takaka, Altonian (hypotype of Marwick 1944, pl. 37, fig. 31) (TM4785, NZGS) x 1.

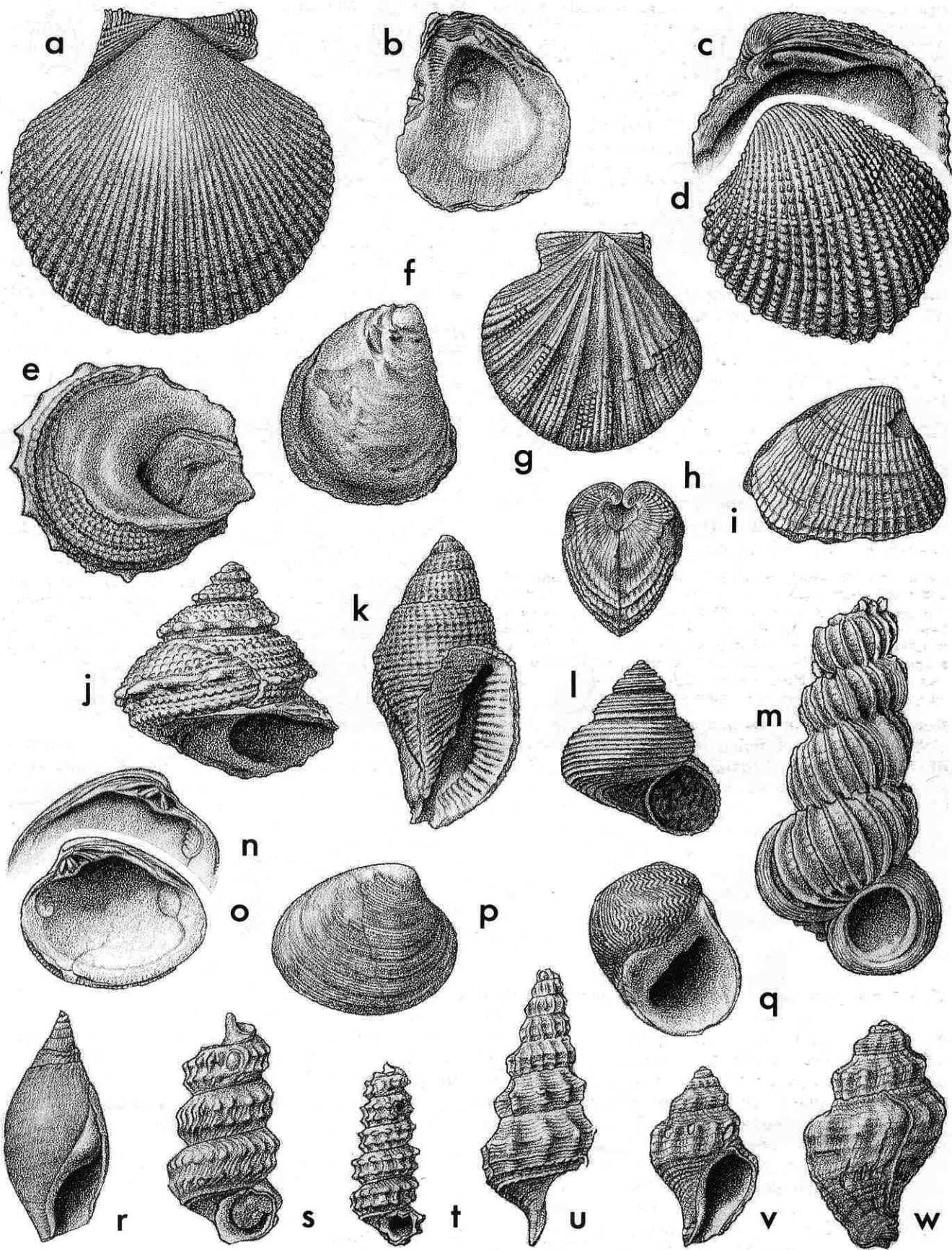
Pl. 9 l. *Conominolia sulcatina* (Suter, 1917) [*Solariella sulcatina* Suter 1917, p. 5] (Trochidae: Solariellinae).

Size moderate for family (height 10-12 mm), turbiniform, spire 0.6 total height. Protoconch small, of slightly more than 1 smooth whorl. Teleoconch whorls 6, strongly convex except for a narrow, well-defined sutural shelf; last whorl widely umbilicate. Axial sculpture of weak costellae on sutural shelf of early whorls, obsolete on last 2 or 3 whorls. Spiral sculpture of thin, rather crisp, subequal cords, some with interstitial threads, 1 marking edge of shelf finely beaded by axial costellae on early whorls; 7-9 cords on penultimate whorl. Base of last whorl with 7 or 8 additional cords similar in strength to those above, one on edge of umbilicus somewhat stronger than others. Umbilicus with about 7 cords within, slightly weaker than those on base, and finely beaded in some shells. Aperture circular.

Whaingaroan, Deborah Volcanic Formation, Everett's Quarry, Kakanui (type) (moderately common).

Plate 9 Early-middle Oligocene (Whaingaroan) Mollusca and Pomahaka faunule.

- a. *Serripecten* n.sp., x 1.5.
- b,f. *Pycnodonte (Notostrea) subdentata* (Hutton), x 1.5.
- c,d. *Glyptoactis (Fasciculicardia) benhami* (Thomson), x 2.
- e,j. *Bolma (Ormastraliium) marshalli* (Thomson), x 1.5.
- g. *Notochlamys* n.sp., x 2.
- h,i. *Procardia dolicha* (Suter), x 1.
- k. *Tatara flemingi* Beu and Maxwell, x 1.5.
- l. *Conominolia sulcatina* (Suter), x 3.
- m. *Cirsotrema (Cirsotrema) gagei* Maxwell, x 1.5.
- n,o,p. *Hinemioana acuminata* (Hutton), x 1.5.
- q. *Neritoplica(?) pomahakaensis* (Finlay), x 3.
- r. *Melanopsis (Stilospirula?) pomahaka* (Hutton), x 3.
- s,t. *Batillona amara* Finlay, x 8.
- u. *Batillaria(?) pomahakensis* Harris, x 1.5.
- v,w. *Pomahakia aberrans* Finlay, x 2.



Conominolia sulcatina differs from *C. conica* (Pl. 2a) in having a narrower sutural shelf, crisper spiral sculpture but much weaker axial sculpture, and stronger basal spiral sculpture.

Figured specimen (Pl. 9l): GS9535, J42/f6031, beach below Everett's Quarry, Kakanui, Whaingaroan (NZGS) x 3.

Pl. 9 e, j. *Bolma (Ormastraliium) marshalli* (Thomson, 1908) [*Turbo marshalli* Thomson 1908, p. 103; *Incilaster marshalli*]. Type species of *Incilaster* Finlay, 1926, here synonymised with *Ormastraliium* Sacco, 1896 (Turbinidae: Turbininae).

Size moderate for genus (height up to 30 mm), trochiform, spire conic, stepped, 0.6 total height. Protoconch not clearly differentiated in available material; teleoconch of about 5 or 6 whorls, apex flat, later whorls with a well marked sutural shelf at or somewhat below suture and a prominent keel close to lower suture (fused to succeeding whorl in some shells). Last whorl with a prominent peribasal keel and an almost flat base with a large, central, flat callus pad extending more than half diameter of shell. Sculpture of short triangular spines on peripheral keel (about 12 per whorl) and several closely spaced rows of small rounded or rather sharp nodules, largest on edge of sutural shelf, alternating in strength on whorl sides, but nodules more even on base. Aperture strongly prosocline, outer lip lightly flared on large specimens. Operculum thick, weakly convex, with weakly pustulose sculpture.

Whaingaroan, Deborah Volcanic Formation, Everett's Quarry, Kakanui (type) (moderately common).

Specimens from the Waiareka Volcanic Formation at Lorne (Kaiatan) have a more marked sutural channel, flatter whorl sides, a slightly taller spire, more evenly granulose sculpture and shorter peripheral spines than Kakanui specimens of *Bolma marshalli*, and probably represent an unnamed but closely related species. Other poorly known, unnamed species of the subgenus are recorded from the Kauru Formation, North Otago (Teurian ?), the Greymouth area (Clifdenian) and the shore platform east of Te Araroa, East Cape (Kapitean). Beu and Ponder (1979) referred *Bolma* species to two informal "species groups", but previous authors had regarded these as different subgenera (or genera), and in our opinion they are worth recognising at the subgeneric level. Typical *Bolma* (= *Oobolma* Sacco, 1896 and *Galeoastraea* Habe, 1958) reaches a markedly larger size and has more rugose sculpture and, in many species, much larger peripheral spines than the smaller, more or less evenly granulose species of *B. (Ormastraliium)*. Beu and Ponder (1979) pointed out that *B. marshalli* is closely similar to the species group of *B. guttata* (A. Adams, 1863), which is now widely distributed in the Indo-West Pacific province, from South Africa to the Kermadec Islands and Japan. One member of this group, *B. (Ormastraliium) recens* (Dell, 1967), is recorded from depths of about 350-700 m between New Zealand and the Kermadec Islands and on the Norfolk Ridge.

Figured specimen (Pl. 9e, j): GS9535, J42/f6031, beach below Everett's Quarry, Kakanui, Whaingaroan (TM5421, NZGS—specimen figured by Beu and Ponder 1979, fig. 11a-c) x 1.5.

Pl. 9 m. *Cirsotrema (Cirsotrema) gagei* Maxwell, 1978 [p. 36-37] (Epitoniidae).

Size moderate for genus (height probably about 65 mm), high-spired. Apical whorls missing from only known specimen, 5.5 strongly convex whorls remaining; last whorl with a well defined basal disc. Sutures obscured by fusion of axial costae with suprasutural cord and costae on previous whorl. Axial sculpture of slightly prosocline, blade-like costae, each composed of several (typically about 6) thin lamellae fused together, reaching from suture to suture on spire, and extending across base of last whorl to aperture. Very prominent, rounded varices, narrowing posteriorly and composed of very numerous fused lamellae, at irregular intervals; 16 costae and varices on penultimate whorl. Spiral sculpture, apart from a suprasutural cord that emerges on last whorl as peribasal keel, consisting of very fine, weakly impressed grooves and occasional low, broad, subdued cords between axial costae; about 5 on last whorl. Aperture oval, peristome complete, varix prominent; fasciole, if present, hidden by inner lip.

Whaingaroan, McDonald Limestone, Kakanui River, near mouth (type).

This highly distinctive species differs from "typical" New Zealand members of *Cirsotrema*, e.g. *C. lyratum* (Pl. 14l) and *C. kuriense* (Pl. 6c), in having very thin axial costae and very feeble spiral sculpture. *C. (Tioria) youngi* (Pl. 4n) also has thin costae and weak spiral sculpture, but it lacks definite varices, and has a distinct fasciolar ridge. *C. gagei* occurs with *C. lyratum* at Kakanui River.

Figured specimen (Pl. 9m): holotype, GS3892, J42/f6573, right bank, Kakanui River near mouth, Whaingaroan (TM5472, NZGS) x 1.5.

Pl. 9 k. *Tatara flemingi* Beu and Maxwell, 1987 [p.53] (Cancellariidae: Cancellariinae).

Size moderate for family (height 35 mm), very similar to *T. revoluta* (Pl. 8k) but smaller, a little wider, with a shorter spire, finer sculpture caused by weaker axial costae and the presence of a prominent secondary spiral cord in each interspace, a similar but slightly flatter, laterally sinuous outer lip inclined at 20° to the coiling axis, and with more numerous transverse ridges on outer lip (18-20 compared with 14 in *T. revoluta*), only 2 rather than 3 prominent columellar plaits, and weaker varices than *T. revoluta*.

Runangan-Whaingaroan; Whaingaroan, Deborah volcanic Formation, Gee's Point, Kakanui (type); tuffs below limestone, Everett's Quarry, Kakanui; Totara Limestone, Trig M, Totara. Rare at all localities.

Except for a doubtful Whaingaroan occurrence, the similar but more coarsely sculptured species *Tatara revoluta* is recorded only from late Kaiatan tuffs at Lorne. Other taxa are distinguished and the family relationship discussed under *T. revoluta*, above.

Figured specimen (Pl. 9k): holotype, GS1982, J42/f6493, Gee's Point, Kakanui, Whaingaroan (TM5149, NZGS) x 1.5.

CHAPTER 10. LATE OLIGOCENE AND EARLIEST MIOCENE FAUNAS (DUNTROONIAN AND WAITAKIAN STAGES): PLATES 9-15.

INTRODUCTION (Figure 15)

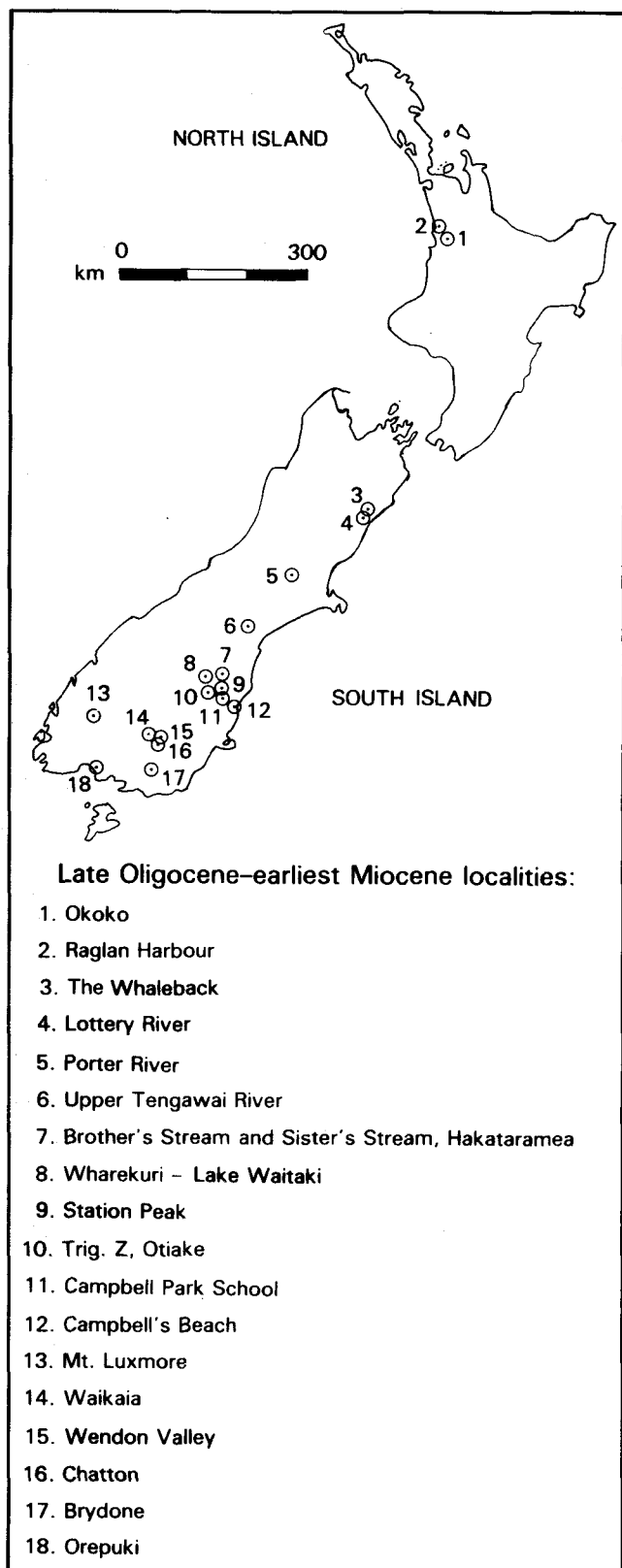


Figure 15 The main molluscan fossil localities of Duntroonian and Waitakian (Late Oligocene and earliest Miocene) age.

The greatest *recorded* increase in molluscan diversity during the Cenozoic period in New Zealand commenced during Duntroonian time and continued through the succeeding Waitakian, Otaian, Altonian and Clifdenian stages. This increase may well have started earlier and possibly merely results from our much greater knowledge of Duntroonian faunules compared with those of Whaingaroan age (see Chapter 9), but the fact remains that from this time onward the New Zealand molluscan fauna assumed an increasingly "modern" aspect. From the point of view of a molluscan worker the Paleogene-Neogene boundary in New Zealand would be more appropriately placed at the base of the Duntroonian Stage rather than at the base of the Waitakian (where the Oligocene-Miocene boundary is currently placed).

Our knowledge of the stratigraphic distributions of Late Oligocene and Early Miocene Mollusca is too imprecise at present to decide whether the diversity increase during this period is gradual or punctuated, so any subdivision of the time involved must be rather arbitrary. However, the Duntroonian and Waitakian faunas are sufficiently similar to each other to justify considering them together, particularly as the best-known localities occur in much the same geographic areas (i.e. Southland, and North Otago—South Canterbury).

The Late Cretaceous-Paleogene marine transgression seems to have reached its acme during Duntroonian or Waitakian times and, as a result, sedimentary rocks of this age are widespread, particularly in the South Island and central North Island. Most of the west coast of the South Island is thought to have been submerged (Nathan et al. 1986, p.38), and in Central Otago marine Duntroonian or Waitakian sandstone occurs as far west as Naseby and St. Bathans, indicating that seas spread further inland in this area than at any other time during the Cenozoic. In Southland, seas penetrated at least as far north as Lake Wakatipu (and probably across what is now the Alpine Fault into Westland and Nelson), westwards to an area west of Lake Te Anau, and eastwards to the Gore district. In most areas Duntroonian-Waitakian rocks comprise calcareous sandstone (locally very glauconitic) and limestone, and in most places are of limited thickness (100 m or less), but in parts of Southland they include siltstone and sandstone with a total thickness of the order of 1000 m. In the upper Tengawai River, South Canterbury, the Waitakian Stage is represented by not only limestone, but also an overlying massive siltstone closely resembling the Mt. Harris Formation at Bluecliffs, in turn overlain by cross-bedded sand. The depositional pattern is also complicated in parts of North Canterbury by the accumulation at this time of large piles of volcanogenic rocks (e.g. Cookson Volcanics).

The "Marshall Paraconformity"

Hutton (1877a, p.43-44) drew attention to what he thought was an unconformable contact between the Weka Pass Limestone (now known to be of Duntroonian and Waitakian age) and the underlying Amuri Limestone (Whaingaroan) in the Waipara district, North

Canterbury. He noted that the base of the Weka Pass Limestone in this area is a greensand containing pebbles of Amuri Limestone, which penetrates fissures at the top of the Amuri Limestone. He concluded that the Amuri Limestone had become lithified and "water-worn" before the Weka Pass Limestone was deposited. Because of the importance of the Cretaceous-Cenozoic sequence in the Waipara district to the development of ideas on New Zealand stratigraphy, most of the leading local geologists felt obliged to comment on the nature of this contact (see summary in Thomson 1920, p.328-334). Except for Morgan (1915, 1916) and Park (1912), all discounted Hutton's views. Marshall (1916a, p.95; 1916b, p.104), in particular, claimed that the two units are petrographically rather similar, and that the differences that do exist could be attributed to shallowing and an increase in bottom-current activity. (Such processes might be reasonably expected to produce an unconformity, but Marshall was adamant that none exists).

Interest in the problem died away almost completely for about 40 years following the publication of Thomson's (1920) study of the geology of the Waipara district, in which he reaffirmed the prevailing view that the contact between the limestone beds is conformable. (Thomson unfortunately confused matters by concluding that the contact represents the Cretaceous-Cenozoic boundary!). In the meantime, however, Allan (1938a) had proposed the Duntroonian Stage on the basis of a distinctive brachiopod assemblage (the "*Liothyrella landonensis* fauna"), which was first described from localities in North Otago and South Canterbury (Thomson 1926), and later recognised in the Mt. Somers area and Rakaia River in Mid Canterbury and in the Waipara district, North Canterbury. Allan proposed as the Duntroonian stratotype a thin bed of glauconitic limestone with a "rubby" basal layer, exposed in the north branch of Landon Creek, North Otago. Here, as in many other parts of North Otago and South Canterbury, this unit (Kokoamu Greensand) rests on an irregular, well burrowed and locally phosphatised surface at the top of a bryozoan limestone (McDonald Limestone) or marl (Earthquakes Marl).

Foraminiferal studies by H. J. Finlay and later by N. de B. Hornibrook proved of great value in dating the relevant rock units when the north-east Otago (Gage 1957) and Waipara districts (Wilson 1963) were mapped during the 1940s and 50s. They confirmed that the Kokoamu Greensand and Weka Pass Limestone are Duntroonian at the base in most sections, and that the top of the underlying unit is Whaingaroan in most sections. Gage (1957, table 2, p.18) concluded that there had been a "short halt in sedimentation" with corrosion, burrowing and, in places, phosphatisation of the substrate prior to deposition of the Kokoamu Greensand. (Hornibrook (1966) later described relevant sections in Landon Creek in some detail). Wilson (1963, p.35-38) redescribed the contact between the Weka Pass and Amuri limestone in the Waipara district, and concluded that although there is clear evidence for a break in deposition, the time missing is short, and the break was possibly caused by "sudden" regression brought about "by earth movements in the Alpine region". Andrews (1963) included the Weka Pass Limestone in his Omihi Formation, proposed for glauconitic sandstone,

glauconitic limestone and calcareous tuff of Duntroonian and Waitakian age in North Canterbury. He considered the formation to be a regressive unit, at most places disconformably overlying Amuri Limestone (which he thought accumulated at the time of maximum marine transgression) or older units. Maxwell (1964) pointed out that in the Kaiwara district, North Canterbury, the Amuri Limestone is very discontinuous laterally (as it is in some other parts of North Canterbury) and that the Omihi Formation varies considerably in thickness and lithology. He noted that the Omihi Formation is similar in age and lithology to the Kokoamu Greensand (and its South Canterbury correlative, the Squires Greensand) and that there is evidence for a hiatus between these and their underlying units, and suggested that their deposition had been preceded by a period of gentle folding and erosion.

By the late 1960s it was clear to some geologists, at least, that there is evidence for a widespread mid-Oligocene unconformity, not necessarily of great time significance, over much of the east coast of the South Island. Carter and Landis (1972) pointed out that an unconformity of similar age had been identified in deep-sea cores from the southwest Pacific, and accordingly proposed the name "Marshall Paraconformity" for this and its correlative in land-based sections. Their paper has engendered a considerable amount of discussion, and although it is now generally accepted that there is evidence for a regionally significant mid-Oligocene unconformity representing a hiatus of at least one million years duration (Jenkins 1987, p.178)—at least in the South Island—its cause is uncertain. Carter and Landis (1972) suggested that it resulted from an increase in bottom-current velocity caused by the final separation of Australia from Antarctica; Loutit and Kennett (1981), however, ascribed it to a major (400 m) fall in sea-level at about 29.0 Ma, postulated by Vail and Hardenbol (1979) (see also Haq et al. 1987). Even if it is accepted that the sea-level fall has been greatly over-estimated, the latter explanation (which was favoured by Nathan et al. 1986, p.44) is difficult to reconcile with the observation that beds *above* the unconformity seem to have accumulated during the period of maximum marine transgression in New Zealand (Carter 1985, p.364). Furthermore, there is a serious problem in matching the unconformity with the drop in sea-level in the light of the refined biostratigraphy now available (Hornibrook 1987, p.184).

The relevance of the mid-Oligocene unconformity to the present discussion is that it immediately pre-dates the dramatic increase in recorded molluscan diversity mentioned above. This may be fortuitous, but it is certainly plausible to relate an apparent "invasion" of the New Zealand region by a host of molluscs (many of them of warm-water affinities) to either a profound rearrangement of oceanic current patterns in the southwest Pacific, or a major fall in sea-level followed by a renewed transgression (possibly reflecting an increase in sea temperature). The similarity of the mid-Oligocene to the mid-Eocene unconformity has already been mentioned above—in both instances the hiatus was followed by a significant increase in recorded molluscan diversity. Of course, the evidence for gentle folding in North Canterbury and for Oligocene volcanism in parts of the east coast of the South Island (Schofield 1951) suggests that matters were more complicated than either

explanation would indicate. However, although we accept the existence of a regionally important mid-Oligocene unconformity or hiatus, we must agree with Gage (1988) that the name chosen for it by Carter and Landis (1972) is singularly inapt in view of Marshall's clear opposition to the idea that any kind of unconformity is present.

Duntroonian Faunas

North Otago-South Canterbury

Over much of North Otago and South Canterbury the Duntroonian Stage is represented by a thin calcareous greensand (Kokoamu Greensand) and the lower part of the overlying Otekaike Limestone. Although brachiopods are locally very common in the Kokoamu Greensand, molluscs are much rarer and consist solely of calcitic species such as *Lentipecten hochstetteri*, *Janupecten subteres*, *Chlamys* spp., teredinid tubes, and *Cirsotrema lyratum*, suggesting that aragonitic shells have been removed during diagenesis. However, much richer assemblages occur in a thicker, less calcareous, glauconitic sandstone (Wharekuri Greensand) in the Waitaki River between the Aviemore and Waitaki hydroelectric dams. The lower part of the Wharekuri Greensand (with *Janupecten uttlei*) is Whaingaroan, but the upper (and most richly fossiliferous) part is Duntroonian (possibly Waitakian at the top). The locality on the north (Canterbury) side of the river long known to geologists as "Wharekuri" is now submerged beneath Lake Waitaki, but good collections can still be made from the low cliffs at the head of the lake. The richest faunule, from near the middle of the section, has a deeper-water aspect than those from the Chatton Formation (see below) and probably lived at mid-shelf depths. Characteristic species include *Neilo sinangula*, *Cucullaea attenuata*, *Glycymeris waitakiensis*, *Limopsis catenata*, *Notolimopsis caelata*, *Chlamys chathamensis*, *Parvamussium paradoxum*, *Pododesmus maxwelli*, *Spissatella subobesa*, "*Cyclocardia*" aff. *awamoensis*, *Megacardita ponderosa*, *Hedecardium waitakiense*, *Tapes parki*, *Notocallista tecta*, *Panopea worthingtoni*, *Zeacolpus wharekuriensis*, *Gazameda grindleyi*, *Xenophora prognata* (giant specimens up to 120 mm in diameter), *Struthiolaria* n.sp., *Magnatica planispira*, *Sassia minima*, *Typhis adventus*, *Morum* (*Oniscidia*) n.sp., *Penion* n.sp., *Austrofusus praecursor*, *Cominella* (*Procominula*) *propinqua*, *Falsicolus allani*, *Amalda* (*Baryspira*) *pristina*, *Waihaia nodulifera*, *Spinomelon* sp., *Comitas fusiformis*, *Borsonia mitromorphoides*, and *Fissidentalium* n.sp. aff. *solidum*.

Molluscs are generally uncommon in the lower (Duntroonian) part of the Otekaike Limestone, but a rich assemblage has been collected from this horizon from the matrix of a mysticete whale skeleton at Sister's Creek, Hakataramea Valley. One of the most characteristic species in this faunule is the distinctive turbinid *Guildfordia* n.sp., which is far less common at other Otekaike Limestone localities. The presence of the pleurotomariid *Perotrochus masoni*, as well as of many other genera, indicates a moderately deep-water (outer shelf or upper bathyal) depositional environment.

Southland

Sedimentary rocks of Landon Series age are widespread

in Southland and western Otago, and locally attain great thicknesses. Rich molluscan faunules, mostly of Duntroonian age, are recorded from sandstone (Chatton Formation) associated with Gore Lignite Measures in the eastern part of the province ("platform area" of Wood, in Suggate et al. 1978, p.521), and a deeper-water faunule occurs further to the west, near Orepuki. The best-known shallow-water assemblage is from Shell Gully, Chatton (Marwick 1929) and includes *Nucula vestigia*, *Saccella probellula*, *Glycymerita thomsoni*, *Limopsis parma*, *Crenostrea wuellerstorfi*, *Flemingostrea wollastoni*, *Dosinia* (*Austrodosinia*) *sodalis*, *Turia chattonensis*, *Hedecardium olssoni*, *Maoricardium strangi*, "*Cyclocardia*" *christiei*, *Megacardita ponderosa*, *Myrtea staminifera*, *Gonimyrtea bucculenta*, *Spissatella porolea*, *Salaputium animula*, *Myadora delta*, *Conominolia vixincisa*, *Spirocolpus tophinus*, *Tropicolpus chattonensis*, *Pyrasus sutherlandi*, *Magnatica* (*Spelaenacca*) *sutherlandi*, *Austrofusus praecursor*, *Cominella* (*Josepha*) *chattonensis*, *Austrotoma inaequabilis*, *Scalptia*(?) *christiei*, *Ringicula castigata* and *Acanthochitona ashbyi*.

Many of these species are present also in somewhat deeper-water assemblages at Waikaia and Wendon Valley, northwest of Chatton.

A small faunule from the coast near Orepuki represents a much deeper-water facies than those from eastern Southland, and includes *Myrtea* aff. *staminifera*, *Uberella* aff. *cicatrix*, *Gemmula longwoodensis*, *Cryptodaphne semilirata* and *Waipaoa*(?) aff. *grata*. By contrast, the faunule from Mt. Luxmore, eastern Fiordland, recorded by Lee et al. (1983) is from a rocky shore environment, a habitat rarely preserved fossil before the late Pleistocene—it includes species of *Barbatia*, *Trichomya*(?), *Codakia*, *Haliotis*, *Cookia*, and *Trochus* (*Thorista*) and is probably Duntroonian, although a Waitakian age is possible.

The Pomahaka faunule

The vast majority of the molluscs recorded from New Zealand Cenozoic rocks are marine, and only a few named species (most from the late Cenozoic) are from terrestrial or freshwater habitats. The most important non-marine faunules recorded are from the Pomahaka Formation (formerly Pomahaka Estuarine Bed; Wood 1956), a sequence of interbedded mudstone, lignite and sandstone exposed in Pomahaka River and its tributary Waikoikoi Stream. Although not precisely dated, the Pomahaka Formation is generally thought a correlative of the Chatton Formation (Wood 1956, p.86; Pocknall 1982, p.282) and therefore probably of Duntroonian age, but a late Whaingaroan age cannot be ruled out. The unusual molluscan faunules from this formation have been known for well over a century, and most of the more obvious species were described by Hutton (1873b). Recent recollections include several hitherto unrecorded species and underscore the importance of the provision by the Pomahaka Formation of a "window" on the otherwise almost entirely unknown pre-Pleistocene non-marine fauna of New Zealand.

Assemblages from the Pomahaka Formation vary considerably in composition, with certain species (e.g. *Batillona amara*) occurring in great profusion—often to the almost complete exclusion of other taxa—in some thin

beds, but quite absent from other parts of the formation. Some species inhabited fresh water, others probably brackish water or estuaries. The combined fauna includes *Barbatia* n.sp. (a very distinctive, modioliform species), *Crassostrea*(?) sp., *Hinemoana acuminata*, *Neritoplica* (?) *pomahakaensis*, *Potamopyrgus*(?) n.sp., *Batillona amara*, *Batillaria pomahakensis*, *Melanopsis* (*Stilospirula*) *pomahaka*, *Melanoides* n.sp., *Pomahakia aberrans*, and *Planorbis* n.sp. One species, the neritid *Neritoplica*(?) *pomahakaensis*, was deleted from the New Zealand fauna by Finlay (1926c, p. 374) because it was considered to be a foreign shell introduced into the original collection by accident, but many additional specimens (some with colour pattern preserved) have been collected recently.

North Canterbury

In parts of North Canterbury, particularly in the Castle Hill (= Treliwick) Basin and in the Lottery River—Mason River area, the upper Landon Series is represented by extensive marine volcanogenic sediments, which locally contain diverse hard-bottom molluscan faunules. Those from Castle Hill Basin (Thomas Formation) are reasonably well known (Boreham, in Gage 1970) and are of Duntroonian age, whereas the others (from the Cookson Volcanics) are less well known and not precisely dated.

The most important localities in the Thomas Formation are Broken River Gorge, Coleridge Creek, Whitewater Creek and the "Fan coral bed" at the junction of Porter and Thomas Rivers. The last is the source of several species described by Hutton (1873b) and Suter (1917); among the molluscs occurring here are *Glycymeris treliwickensis*, *Serripecten* n.sp., *Chlamys chathamensis*, *Lima paleata*, *Limatula arcis*, *Musculus elongatus*, *Septifer* n.sp., *Hedecardium subcordatum*, *Nemocardium* (*Varicardium*) *serum*, *Oxyperas* (*Pseudoxyperas*) *leda*, *Placamen morgani*, *Caryocorbula* n.sp., *Calliostoma* n.sp., *Micrelenchus* n.sp., *Zetela praetextilis* (and a variety of other Trochidae and Turbinidae), and *Willungia fracta*.

A faunule from the top of the Cookson Volcanics near "The Whaleback", Mason River, may serve as an example of a molluscan assemblage from this unit. It includes the following species, indicating a shallow water, firm or rocky substrate: *Limopsis* sp., *Mesopeplum* sp., "Hinnites" sp., *Modiolus* sp., *Spissatella* cf. *poroleda*, *Placamen* cf. *morgani*, *Irus* (*Notopaphia*?) n.sp., *Haliotis* (*Notohaliotis*) n.sp., *Xenophora* sp., and *Haustrum*(?) n.sp. This faunule has not been precisely dated and could be Waitakian rather than Duntroonian.

South-West Auckland

The upper part of the Te Kuiti Group, which consists of limestone and calcareous sandstone and siltstone, is of Duntroonian to Waitakian age. Molluscan assemblages are generally of low diversity, but those from Okoko (on the Kawhia-Pirongia Road) and from near Otorohanga are richer (although poorly preserved) and include *Limopsis* sp., *Cucullaea* sp., *Lentipecten hochstetteri*, *Divaricella* sp., *Hedecardium* cf. *waitakiense*, *Marama*(?) sp., *Tapes parki*, *Panopea* cf. *worthingtoni*, *Cirsotrema lyratum*, *Magnatica* sp., *Struthiolaria* cf. *calcar*, and *Echinophoria* sp. These shallow-water faunules are similar to—although less diverse than—those from the Wharekuri Greensand in Waitaki Valley.

A locality on the coast north of Raglan Harbour, probably in the Duntroonian sandstone that has been mapped here as Aotea Sandstone (not the lower Whaingaroan Aotea Sandstone of the type locality at Whaingaroa Harbour), is notable as being the type locality of the widely recorded bivalves *Crenostrea wuellerstorfi* and *Lentipecten hochstetteri*.

Composition of the Duntroonian molluscan fauna

Except for a few non-marine taxa present in the Pomahaka faunules (e.g., *Hinemoana*, *Neritoplica*(?), *Batillona* and *Pomahakia*), the only genus-group taxa apparently restricted to the Duntroonian Stage are *Musculus*, *Zirlona* and *Gazameda*. Three others, *Athlopecten*, *Proxichione* and *Guildfordia* (sensu stricto) are known only from the Duntroonian and Waitakian Stages. In contrast, the taxa first recorded from the Duntroonian are numerous, and include *Linucula*, *Myrtea*, *Genaxinus*, *Neolepton*, *Benthocardiella*, *Salaputium*, *Maoricardium*, *Hedecardium* (*Titanocardium*), *Tellinota*, *Solecurtus*, *Dosina*, *Bassina*, *Dosinia* (*Asa*), *D.* (*Raina*), *Tapes*, *Notocorbula*, *Myadora*, *Hunkydora*, *Clavagella*, *Puncturella*, *Micrelenchus*, *Thoristella*, *Pterolabrella*, *Pyrazus*, *Oniscidia*, *Cominella* (*Josepha*), *C.* (*Procominula*), *Zemitrella*, *Murexsul*, *Spinomelon*, *Metamelon*, *Comitas*, *Parasyrinx* (sensu stricto), *Mauidrillia*, *Etrempsopsis*, *Neoguraleus* (*Fusiguraleus*), and *Oamaruia* (sensu lato). Many of these taxa are endemic to New Zealand or occur also in southern Australia—some of the latter (e.g., *Dosina*, *Salaputium*, *Comitas*, *Mauidrillia*, and *Oamaruia* sensu lato) are recorded earlier (Late Eocene) in Australia than in New Zealand. Other taxa (e.g., *Solecurtus*, *Tapes*, *Myadora*, *Clavagella* and *Oniscidia*) have warm-water (presumably Tethyan) affinities.

This dramatic increase in molluscan diversity during the Duntroonian may signal a massive and relatively rapid influx of molluscs into the New Zealand region at this time, but it is equally likely that it reflects the much greater variety of molluscan faunules recorded from this stage compared with the preceding Whaingaroan. The shallow-water assemblage from The Cliffs, Nelson, of upper Whaingaroan age (see previous chapter) closely resembles Duntroonian faunules of similar facies, suggesting that many of the taxa first recorded from Duntroonian rocks could eventually be discovered in late Whaingaroan rocks. Although it is tempting to invoke large-scale dispersal of Mollusca to New Zealand during the Duntroonian, possibly caused by important changes in oceanic circulation (e.g. initiation of the circum-Antarctic current), the available evidence is far from conclusive.

Waitakian Faunas

North Otago—South Canterbury

The type locality of the Waitakian Stage is at Trig. Z, Otiake, in the Waitaki Valley, where about 60 m of Otekaike Limestone is exposed. The lower part of the limestone (Maerewhenua Member) is Duntroonian, and is almost devoid of molluscs, but rich Waitakian assemblages occur in a glauconitic shellbed at the base of the overlying Miller Member and, more importantly, in the Waitoura Marl at the top of the formation. The

latter faunule includes *Varinucula* aff. *sagittata*, *Cucullaea worthingtoni*, *Limopsis* aff. *zealandica*, *Notolimopsis pulchra*, *Lentipecten hochstetteri*, *Flemingostrea wollastoni*, *Spissatella* n.sp. aff. *trailli*, *Divaricella* (*Divalucina*) *huttoniana*, *Kuia vellicata*, *Dosina uttlei*, *Notocallista wattii*, *Zenatia* n.sp. aff. *acinaces*, *Notocorbula* n.sp. aff. *humerosa*, *Zeacolpus flemingi*, *Tropicolpus* (*Amplicolpus*) *gittosinus*, *Cirsotrema lyratum*, *Magnatica planispira*, *Friginatica vaughani*, "*Uberella*" aff. *acerva*, *Globisium crassiliratum*, *Poirieria primigena*, *Austrofusus affiliatus*, *A. (Neocola) apudalpha*, *Cominella* (*Procominula*) *denselirata*, *Exilia dalli*, *Amalda* (*Alocospira*) *cuppedia*, *Parasyrinx subalta*, *Eoturris uttlei*, *Austrotoma finlayi*, *Rugobela semilaevigata*, and *Fissidentalium* n.sp. aff. *solidum*. A very similar assemblage is present in the upper part of the limestone at Campbell Park (formerly Otekaike Special) School, Otekaike Valley. Faunules from Brother's Stream and Sister's Creek, Hakataramea Valley, are also similar but have more common turrids and smaller specimens of *Cucullaea*, and probably lived at greater depths than those in Waitaki Valley.

A deeper-water assemblage (outer shelf or upper bathyal) is present in blue-grey siltstone (Mount Harris Formation) in the upper Tengawai River near Trap Creek. This faunule has greater similarity to Otaian assemblages from Bluecliffs and Pareora River (see succeeding Early Miocene chapter) than do other Waitakian assemblages, and includes *Limopsis* aff. *zealandica* (most smaller than Trig. Z specimens), *Spissatella* n.sp., *Notocorbula* n.sp. aff. *humerosa*, *Zeacolpus greggi*, *Z.* aff. *woodhouseae*, *Maoricolpus doni*, *Xymene* n.sp., *Austrofusus affiliatus*, *Cominella* (*Procominula*) n.sp., *Exilia dalli*, *Eumitra* aff. *nitens*, *Proximitra* aff. *partinoda*, *Spinomelon* sp., *Comitas fusiformis*, *Bathytoma* aff. *hokianga*, *Zeacuminia* aff. *biplex*, and *Turehua lividorupis*. The Tengawai River sequence shallows upwards, and the topmost marine unit is a Waitakian cross-bedded shelly sandstone containing *Glycymeris* sp., *Anomia trigonopsis*, *Mesopeplum burnetti*, *Oxyperas* (*Pseudoxyperas*) *exensis*, *Magnatica planispira*, and *Parasyrinx subalta*.

Southland

Most faunules from the Chatton Formation are Duntroonian (see above), but a very diverse one from the Maitara River near Brydone is Waitakian in age. Chitons, rissoacean gastropods and limpets are common, and indicate a very shallow-water environment, although probably not close to a rocky shore. Characteristic species are "*Isognomon*" n.sp.? aff. *zealandicus*, *Athlopecten athleta*, "*Hinnites*" sp., *Cosa* n.sp., *Miltha neozelanica*, *Gonimyrtea* aff. *bucculenta*, *Divaricella huttoniana*, *Eucrassatella ampla*, *Hedecardium* (*Titanocardium*) aff. *greyi*, *Maoricardium* aff. *strangi*, *Bassina speighti*, *Austrovenus* n.sp., *Notocorbula* n.sp. aff. *humerosa*, *Cleidotherus albidus*, *Emarginula* n.sp., *Rimula* n.sp., *Cosmetalepas* (?) n.sp., *Puncturella* n.sp., *Notoacmea* n.sp., *Atalacmea*(?) n.sp., *Cantharidus* n.sp., *Thoristella* n.sp., *Sarmaturbo* n.sp., *Rissoina* n.sp., *Merelina* spp., *Pisinna* spp., *Eatoniella* (*Dardanula*) n.sp., *Tropicolpus* (*Tropicolpus*) *mackellari*, *T. (Amplicolpus)* *gittosinus*, *Cabestana tetleyi*, *Paracomina* n.sp., *Austrofusus affiliatus*, *Penion* n.sp., and *Austrotoma* cf. *finlayi*.

Composition of the Waitakian molluscan fauna

Duntroonian and Waitakian molluscan faunules are generally very similar to one another, but there are several species that seem to be useful for distinguishing between them. In the following list, the first-named species in each pair is not known after Duntroonian time, whereas the second is not recorded before Waitakian time (it should be noted, however, that these species pairs do not necessarily have an ancestor-descendant relationship): *Cucullaea attenuata*, *C. worthingtoni*; *Notolimopsis caelata*, *N. pulchra*; *Pododesmus maxwelli*, *P. incisurus*; "*Cyclocardia*" *christiei*, "*C.*" *marama*; *Spissatella subobesa*, *S. n.sp.*; *Dosina* n.sp., *D. uttlei*; *Notocallista tecta*, *N. wattii*; *Tropicolpus chattonensis*, *T. mackellari*; *Zeacolpus wharekuriensis*, *Z. flemingi*; *Austrofusus praecursor*, *A. affiliatus*; *Cominella* (*Procominula*) *propinqua*, *C. denselirata*; *Amalda* (*Alocospira*) *electa*, *A. cuppedia*; *Austrotoma inaequabilis*, *A. finlayi*; *Scrinium callimorphum*, *S. blandiatum*.

With the possible exception of *Rimula*, *Cosmetalepas* (?) and other "limpets" at Brydone, Maitara River, none of the numerous genus-group taxa recorded from the Waitakian Stage seem to be restricted to the stage, but a considerable number are first known from assemblages of this age, i.e. *Philobrya*, *Cosa*, *Trichomya*, *Melliteryx*, *Myllita* (*Zemylita*), *Austrovenus*, *Euchelus* (*Herpetopoma*), *Sarmaturbo*, *Merelina*, *Onoba* (*Ovirissoa*), *Pusillina* (*Haurakia*), *Amphithalamus* (*Notoscrops*), *Pisinna*, *Eatoniella* (*Dardanula*), *Bembicium*, *Orbitestella*, *Naricava*, *Maoricolpus*, *Cabestana*, *Buccinulum*, *Cominella* (*Eucominia*), *Egotistica*, *Paracomina*, *Mitrella*, *Typhis* (*Hirtotyphis*), *Eumitra*, *Alcithoe* (*Leporemax*), *Austroclavus*, *Bathytoma*, *Mitrolumna*, *Neoguraleus* (sensu stricto), *Maoridaphne*, and *Brooksena*. Genera last recorded in the Waitakian are *Athlopecten*, *Proxichione*, *Guildfordia* (sensu stricto), *Spirocolpus*, and *Eoturris*.

Climate

The presence of such genera as *Arca*, *Solecortus*, *Tapes*, *Clavagella*, *Perotrochus*, *Guildfordia* (sensu stricto), *Pyrasus*, *Ficus*, *Oniscidia* and *Gemmula* in Duntroonian and/or Waitakian faunules in the central and southern South Island indicates that conditions were significantly warmer (warm-temperate or subtropical) than those prevailing at the present day.

REPRESENTATIVE LATE OLIGOCENE AND EARLIEST MIOCENE MOLLUSCA

Pomahaka faunule: Plate 9

Pl. 9 n.o.p. *Hinemoana acuminata* (Hutton, 1873) [*Chione accuminata* Hutton 1873b, p. 21; *C. (Hinemoana) acuminata*]. Type species of *Hinemoana* Marwick, 1927 (Veneridae: Chioninae).

Rather small for family (length 20-30 mm), ovate-trigonal, moderately inflated. Lunule not strongly differentiated, bounded by weak groove; escutcheon broad and flattened in left valve, scarcely defined on right. Commarginal sculpture of very fine, crowded, low, weakly frilled ridges; no definite radial sculpture, but subsurface radial elements revealed by weathering on some shells. Left hinge with short, narrowly triangular anterior cardinal tooth, a subrectangular, grooved median cardinal tooth, and a moderately long posterior cardinal tooth that is largely fused to nymph. Right hinge with a very short, thin anterior cardinal

tooth, a stout, grooved median cardinal tooth and a rather short, grooved posterior cardinal tooth; posterior lateral tooth distant, well developed, bounded above by groove to take projecting margin of left escutcheon. Pallial sinus very short, angular. Inner margins finely crenulate.

Duntroonian(?), Pomahaka Formation, Pomahaka River (type); Waikoikoi Stream. Locally abundant.

Hinemoana acuminata resembles *Austrovenus stutchburyi* and other *Austrovenus* species in cardinal dentition and in the very short, angular pallial sinus, but differs in lacking definite radial sculpture and in having a distinct right posterior lateral tooth. This is the only known species of the genus. *Austrovenus* is first recorded from the Waitakian (Mataura River, near Brydone) and may have ecologically replaced *Hinemoana*.

Figured specimens: (Pl. 9o, p), lectotype (TM2889, NZGS); (Pl. 9n), possible syntype, GS329, G45/f8491, both from Pomahaka River, Duntroonian? (NZGS) x 1.5.

Pl. 9 q. *Neritoplica* (?) *pomahakaensis* (Finlay, 1924) [*Neritella nitida* Hutton 1873b, p. 15; *Nerita nitida*; *Nerita pomahakaensis* Finlay 1924a, p. 100 (new name for *Nerita nitida* (Hutton), a secondary homonym of *N. nitida* Donovan, 1804); "*Theodoxus* sp." (rejected as not a New Zealand species; Finlay 1926c, p. 374)] (Neritidae: Neritinae).

Rather small for family (height 8-10 mm), globose, spire depressed, corroded on most specimens. Protoconch smooth, cap-shaped. Teleoconch of 2-2.5 whorls, slightly flattened or weakly concave adapically, convex below; last whorl very capacious. No sculpture apart from growth lines and weak spiral striae. Some shells with well developed colour pattern of narrow dark brown or grey zig-zag stripes on paler background; other shells unicoloured. Aperture large, ovate; inner lip oblique, almost straight, produced laterally to form a moderately wide, thin septum, bearing a single low fold near adapical end, otherwise smooth. Septum callus not particularly thick, strongly depressed abapically. Outer lip thin, prosocline, inclined at about 20° from vertical. Operculum ovate; outer face smooth, paucispiral, with subterminal nucleus; inner face with curved apophysis emerging opposite nucleus.

Duntroonian(?), Pomahaka Formation, Pomahaka (type). Absent from most collections from the unit, but not uncommon at one locality.

This species was expunged from the New Zealand fauna by Finlay (1926c, p. 374) who considered the type specimen—which is badly damaged—to be a Recent Pacific *Theodoxus*. Finlay was particularly impressed by the retention of a colour pattern, even though such patterns are preserved on a number of European fossil neritids. Until recently only the holotype was known, but in 1978, Dr M.J. Isaac (New Zealand Geological Survey) collected a considerable number of specimens from submerged outcrops in the Pomahaka River, downstream from Oyster Creek. *N. pomahakaensis* is therefore reinstated as a *bona fide* New Zealand species.

Because of its rather "generalised" neritid shell characters, *N. pomahakaensis* is of uncertain affinities, but assignment to "*Neritella* Gray, 1848" (= *Neritina* Lamarck, 1816) or *Nerita* Linné, 1758 can be ruled out. *Theodoxus* Montfort, 1810 (sensu stricto) also seems an unlikely location, but there is some similarity to certain extant Pacific species usually assigned to subgenera of *Theodoxus* or of *Clithon* Montfort, 1810, although all seem to differ from *N. pomahakaensis* in columellar or

opercular characters. It is here referred tentatively to *Neritoplica* Oppenheim, 1892 because of its great similarity (including colour pattern) to the French Paleocene fresh-water species *N. subornata* (Orbigny, 1850), which was placed in *Neritoplica* by Wenz (1929, p.2895). Suter (1914, p. 13) referred this species to *Nerita*, and Finlay (1924a, p. 100) provided the replacement name *Nerita pomahakaensis* because of the prior *Nerita nitida* Donovan, 1804. We are obliged to retain Finlay's replacement name under ICZN Article 59(b).

Neritids have a very poor fossil record in New Zealand, one that is far worse than the haliotids. The only other records we are aware of are *N. (Melanerita) melanotragus* from Kaawa Creek (Opoitian) (Laws 1936b, p. 105) and two undescribed species from Parengarenga Harbour (Otaian) (Wakefield 1976).

Figured specimen (Pl. 9q): GS13416, G45/f61, Pomahaka River, 500 m downstream from Oyster Creek, Duntroonian? (NZGS) x 3.

Pl. 9 u. *Batillaria* (?) *pomahakensis* Harris, 1897 [*Cerithium rugatum* Hutton, 1873b, p. 11 (not of Carpenter, 1865, nor of Deshayes, 1864); *Batillaria pomahakensis* Harris 1897, p.229 (new name for *Cerithium rugatum* Hutton, preoccupied); *Batillona pomahakensis*] (Potamididae).

Size moderate for family (height 30-65 mm), cerithiiform, spire elevated. Protoconch not known; teleoconch of up to at least 12 whorls, larger specimens often severely corroded. Early whorls biangulate, one angulation at or slightly above middle on spire, the other less prominent, about halfway between upper angle and lower suture; on later whorls lower angulation decreasing in prominence, whorls becoming strongly medially angled. Last whorl with weak peribasal angulation and another of similar strength on upper part of strongly convex base. Axial sculpture of narrow, well spaced costae reaching from suture to suture and slightly tubercular at intersections with whorl angulations on early whorls, but tending to become restricted to peripheral tubercles on later whorls; 9-11 axials on penultimate whorl. Spiral sculpture consisting of narrow cords marking whorl angulations, those on base slightly nodulose, and fine threads on ramp and base and between cords. Aperture ovate; columella twisted to left anteriorly to form very short siphonal canal, concave above. Inner lip callused; outer lip thin, broadly concave from suture to lower basal angulation, straight below.

Duntroonian(?), Pomahaka Formation, Pomahaka River (type); Waikoikoi Stream.

Batillaria (?) *pomahakensis* differs from most New Zealand cerithiaceans in its relatively large size, its strongly medially angled teleoconch whorls and its prominent axial sculpture. *B. hectori* (Altonian, Porter River, Castle Hill Basin) is similar but has more prominent axial nodules and stronger basal cords. Both species were assigned to *Batillona* Finlay, 1927 by Finlay (1927b, p. 496) but they are not congeneric (or even confamilial) with the type species *B. amara* (see below). Their affinities are uncertain, but they are here provisionally placed in *Batillaria*.

Figured specimen (Pl. 9u): GS329, G45/f8491, Pomahaka River, Duntroonian? (NZGS) x 1.5.

Pl. 9 s,t. *Batillona amara* Finlay, 1927 [*Turritella ornata* Hutton 1873b, p.13 (not of d'Orbigny, 1843, nor of Michelotti, 1847); *Batillona amara* Finlay 1927b, p.496 (new name for *Turritella ornata* Hutton, preoccupied); *Epitonium (Acirsa) ornatum*]. Type species of *Batillona* Finlay, 1927 (Pareoridae?).

Rather small for family (height c. 10 mm), turriculate, protoconch not known, early teleoconch whorls missing from most shells. Teleoconch whorls strongly biangulate at about 0.3 and 0.7 whorl height; last whorl with well defined peribasal keel, base almost flat. Axial sculpture, apart from opisthocyrt growth lines, of weak opisthocline costae connecting prominent nodules on the whorl angles, costae becoming obsolete and nodules becoming more crowded and comma-shaped on the last whorl of some shells. Spiral sculpture of narrow, low cords on shoulder angles, becoming obsolete on later whorls of large shells; a thin ridge marking the peribasal angle. Aperture incompletely preserved on all specimens examined, but apparently subcircular, without a definite siphonal canal; columella concave, inner lip bounded by a narrow ridge that enters aperture. Outer lip apparently thin with a deep rounded sinus posteriorly, its apex slightly above posterior keel, strongly opisthocline below to peribasal keel, and prosocyrt (convex) on base.

Duntroonian(?), Pomahaka Formation, Pomahaka River (type), locally very abundant.

The affinities of this little gastropod are uncertain; although long included in the Potamididae, the absence of a definite siphonal canal and the shape of the outer lip rule out assignment to that family. The apertural characters, particularly the deep anal sinus and prosocyrt basal lip, and the thin columellar ridge suggest a provisional location in the Pareoridae near *Pareora* (see Pl. 55c,f,g), although the strongly biangulate whorls and the presence of axial sculpture sets it apart from other members of the family. Hutton's original description of this species as a *Turritella* was probably not too far off the mark.

Figured specimens (Pl. 9s, t): GS329, G45/f8491, Pomahaka River, Duntroonian? (NZGS) x 8.

Pl. 9 r. *Melanopsis (Stilospirula?) pomahaka* (Hutton, 1873) [*Ancillaria (Amalda?) pomahaka* Hutton 1873b, p. 6-7; *Zemelanopsis pomahaka*] (Thiaridae).

Size moderate for family (height 15-40 mm), elongate-ovate, spire about 0.3-0.4 total height. Protoconch not clearly marked off from teleoconch, apparently mamillate, of about 1.5 whorls with a bulbous initial whorl. Teleoconch of 10-13, possibly more, whorls, first 9 or so increasing only slowly in diameter and flat-sided or feebly convex, so that apical whorls (where preserved) are narrowly conical; later whorls increasing quickly in size and becoming distinctly concave posteriorly and strongly convex below. No sculpture apart from weak growth lines and feeble spiral striae, shell somewhat polished. Aperture ovate, constricted posteriorly by heavy, triangular parietal callus pad alongside which runs a narrow groove. Columella short, strongly concave except for leftward twist at anterior end, defining a short, unnotched siphonal spout; young shells with narrow, oblique plait near posterior end, but absent from adult shells. Inner lip narrowly but quite thickly callused below parietal pad. Outer lip thin, straight and vertical from suture to near base of parietal pad, strongly convex below to base where it bends back to siphonal spout.

Duntroonian(?), Pomahaka Formation, Pomahaka River (type); Waikoikoi Stream. Locally very common.

Melanopsis pomahaka is superficially very similar to *M. trifasciata* (Opoitian-Recent) but differing in having a very slender rather than a broadly conic, blunt apex, and in having the outer lip strongly convex below the parietal pad rather than prosocline and straight or weakly concave. In these respects *M. pomahaka* is very similar to *M. proboscidea* Deshayes, 1862 (Eocene, France), the type species of *Stilospirula* Rovereto, 1899, and is here tentatively considered to be consubgeneric. *Stilospirula* is otherwise known only from the Eocene and Oligocene of Europe.

Figured specimen (Pl. 9r): GS13416, G45/f61, Pomahaka River, 500 m downstream from Oyster Creek, Duntroonian? (NZGS) x 3.

Pl. 9 v,w. *Pomahakia aberrans* Finlay, 1927 [*Fusus plicatilis* Hutton, 1873b, p. 3 (not *Fusus plicatilis* Bean MS, in synonymy of *Clavatula turricula* (Montfort) in Wood 1848, p.62); *Pomahakia aberrans* Finlay 1927b, p.507 (new name for *Fusus plicatilis* Hutton, preoccupied)]. Type species of *Pomahakia* Finlay, 1927 (Buccinidae?).

Rather small for family (height 18-25 mm), bucciniform, spire 0.4 total height. Protoconch mamillate, of 1.5 strongly convex, smooth whorls with bulbous initial whorl. Teleoconch of 5-6 whorls shouldered somewhat above middle on spire, shoulder becoming rounded on last whorl of some shells but remaining angled on others; last whorl with evenly rounded periphery or weak basal subangulation. Axial sculpture, apart from growth lines, commencing as narrow, opisthocyrt costae reaching from suture to suture, but becoming obsolete on ramp and more widely spaced during growth, reduced to peripheral nodules on last whorl, or becoming obsolete on last few whorls; 11-12 per whorl. Spiral sculpture on spire of very subdued, narrow, rounded cords and threads, last whorl with much more prominent but nonetheless subdued, rounded or flattened cords. Shell with distinctly glazed appearance. Aperture ovate with a short, shallowly notched siphonal canal; fasciole rounded, not prominent. Inner lip moderately callused, outer lip thin with a broad, shallow sinus with its apex on shoulder angulation.

Duntroonian(?), Pomahaka Formation, Pomahaka River (type); Waikoikoi Stream. Uncommon.

Pomahakia is a monotypic genus of uncertain affinity but probably referable to the Buccinidae. *P. aberrans* is superficially similar to some species of *Austrofusus*, but differs in having a mamillate rather than a conical protoconch, and in having a shallow but distinct sinus in the outer lip. It may represent an offshoot from *Austrofusus* or a related group which became adapted to a brackish-water habitat. The glazed exterior suggests that *Pomahakia aberrans* had a reasonably thick periostracum when alive. A few species of tropical Pacific fresh-water shells with heavy brown periostraca (in the genera *Clea* A. Adams, 1855 and *Anentome* Cossmann, 1901) have siphonal canals and are now referred to the Buccinidae, although they were previously referred to the Thiaridae, and this suggests an alternative position for *Pomahakia*.

Finlay (1927b, p. 507) considered that *Fusus plicatilis* Hutton is preoccupied by "*Fusus plicatilis* Bean MS", published as a synonym of *Clavatula turricula* (Montfort) by Wood (1848, p. 62). Contrary to common sense, we are unfortunately obliged to use Finlay's replacement name as the relevant article (11e) of the International Code of Zoological Nomenclature (1985 ed.) states that a name published in synonymy is to be regarded as available if prior to 1961 it has been treated as a senior homonym.

Figured specimens (Pl. 9v, w): GS13416, G45/f61, Pomahaka River, 500 m downstream from Oyster Creek, Duntroonian? (NZGS) x 2.

Other Duntroonian-Waitakian Mollusca: Plates 10-15

Pl. 10 b. *Acanthochitona (Notoplax) ashbyi* (Laws, 1932) [*Loboplax ashbyi* Laws 1932, p. 184; *Notoplax ashbyi*] (Acanthochitonidae).

Shell small (holotype, a median valve, 3.5 mm long x 5.5 mm wide; anterior valve 3.3 x 4.7 mm; posterior valve (figured) 2.2 x 3.7 mm), similar to *A. (Notoplax) mariae* (Pl. 44a, d, h) and the large living *A. (Notoplax) violacea* (Quoy and Gaimard, 1835), but differing in its more steeply arched back (Laws (1932, p. 184) recorded that the holotype has a jugal angle of 90°) and in having very large, flattened granules on the tegmentum. Laws' description and figure of median valve are

of one much like that of *A. mariae*, with roughly triangular tegmentum and without a ridge between lateral and pleural areas. Anterior valve incomplete in the only known specimen (missing tegmentum), with 5 slits, 5 prominent radial ridges, and a deeply lobate tegmental margin. Posterior valve with 7 deep slits and several shorter ones, a short, wide, oval tegmentum (as in many modern *A. mariae*), jugum not well differentiated from latero-pleural areas, and a low mucro at posterior 0.6 of tegmentum length.

Duntroonian, Chatton Formation, Shell Gully, Chatton (type), uncommon in washings.

Acanthochitona ashbyi evidently lived in a similar environment to that of *A. mariae* today, i.e. in the intertidal zone, or more commonly, in the shallow subtidal zone, on hard substrates or on boulders and shells in soft substrates.

Figured specimen (Pl. 10b): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 16.5.

Pl. 10, e, j. *Cucullaea (Latiarca) worthingtoni* Hutton, 1873b [p. 27] (Cucullaeidae).

Large for genus (length 80-110 mm), thick-shelled, oblong or somewhat oblique, strongly inflated, left valve larger than right, overlapping along ventral margin. Umbones prominent, situated near middle of dorsal margin. Posterior area flattened, with an indistinct sulcus near middle. Sculpture discrepant, left valve with broad, low, flattened costae with linear interspaces over middle of shell, becoming much narrower and more crowded towards anterior end, and very subdued on posterior part of flank and towards ventral margin. Numerous fine threads but no costae on posterior area. Right valve with similar but more prominent costae than on left valve, also becoming weaker and more crowded anteriorly but extending further posteriorly, onto anterior part of posterior area, and remaining strong right to ventral margin; interspaces wider than on left valve, particularly anteriorly. On both valves some costae bear a narrow median groove, and all are crossed by numerous, fine growth lines, those on right valve interrupted by intercostal grooves. Hinge very prominent, ends with 3-6 subhorizontal, straight or slightly curved, transversely striate teeth, remainder with numerous small, irregular vertical or sloping striate teeth. Cardinal area large, triangular, with 6-8 incised, rather irregular chevron-shaped grooves; some well preserved shells with ligament material partly retained. Adductor muscle scars large, typically differently preserved from rest of shell, posterior scar with pronounced myophoric ridge. Ventral margin strongly denticulate except on some very large shells where the margins become thick and grow in towards each other; denticulations also absent from posterior margin and dorsal part of anterior margin.

Waitakian; "Waitaki" (type—probably from Otekaike Limestone, Waitaki Valley); Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike.

Hutton (1873b, p. 27-28) described two other large mid-

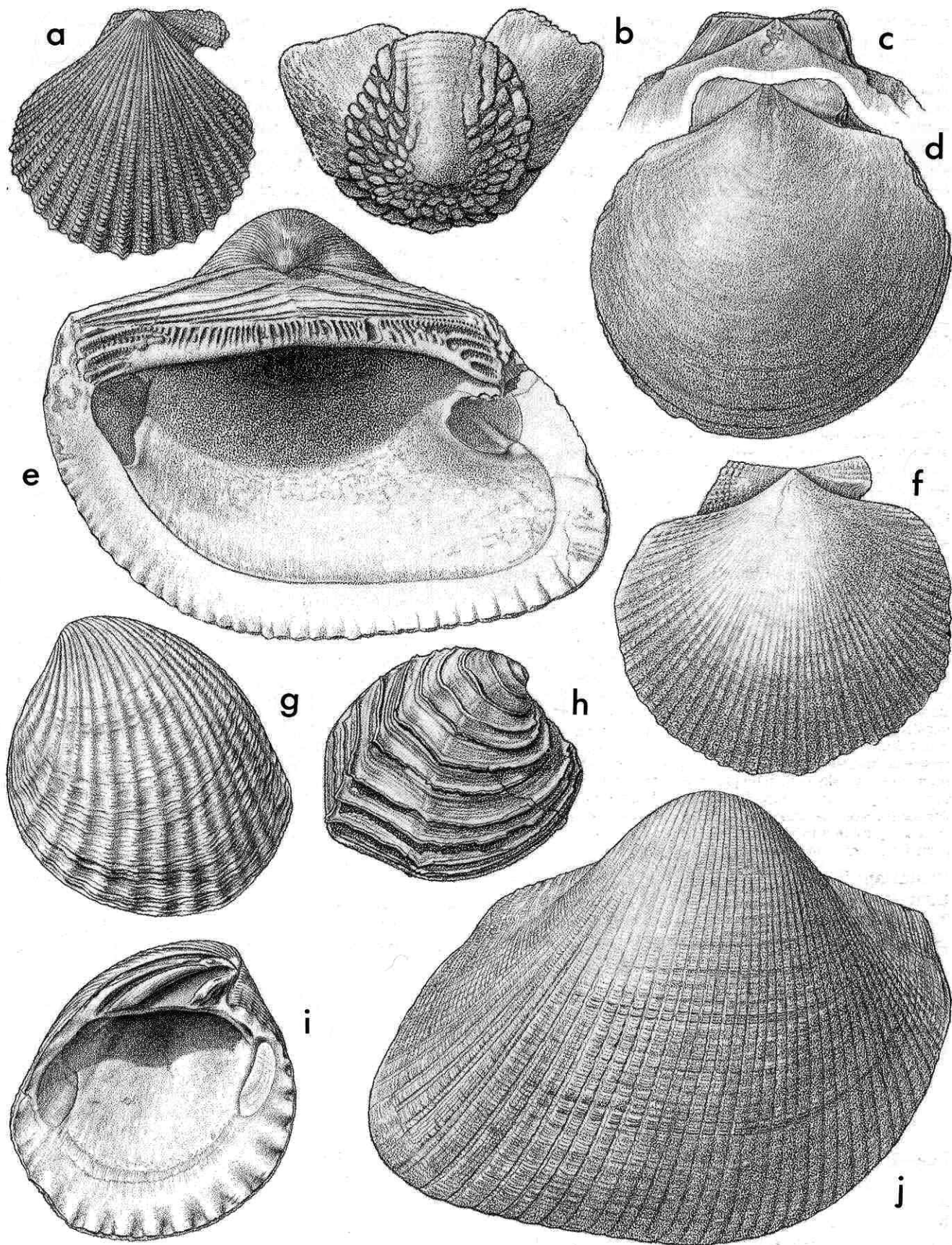
Tertiary species of *Cucullaea*, *C. attenuata* (Duntroonian?, Lake Wakatipu) and *C. ponderosa* (Lillburnian?, Korakonui, East Wellington), which were distinguished from *C. worthingtoni* on the basis of shape differences. Boreham (1965, p. 8-13) carried out a biometric study of *Cucullaea* from Wharekuri (Duntroonian) (assigned to *C. attenuata*), Trig Z, Otiake (*C. worthingtoni*) and Cucullaea Point, Clifden (Lillburnian) (*C. ponderosa*) and found that although there is considerable overlap between the three samples, scatter diagrams of hinge length vs shell height could be used to discriminate between them. Specimens assigned to *C. attenuata* are relatively elongate (and oblique) and have a long hinge-line, whereas those included in *C. ponderosa* are considerably higher relative to length and have a relatively short hinge. *C. worthingtoni* falls between these two species in shape and in hinge development. It should be emphasised, however, that the differences between these taxa are statistical in nature and as a consequence, individuals may not always be readily assignable to species (see Boreham 1965, p. 8-13, for a detailed discussion).

The status of other New Zealand species of *Cucullaea (Latiarca)* is more doubtful. *C. australis* (Altonian, White Rock River) was based on a juvenile shell, but according to Boreham (1965, p. 11) some specimens of *Cucullaea* from Altonian localities in North Otago and South Canterbury fall within the range of variation of *C. worthingtoni*, others within that of *C. ponderosa*, so *C. australis* should probably be synonymised with one or the other of these species. *C. waihaoensis* (? Porangan, Bortonian-Kaiatan) seems to be similar in shape to *C. attenuata* (Boreham 1965, p. 11) but the largest known specimens (length 70-80 mm) do not begin to approach the latter species in size, so it is probably best regarded as a distinct species. *C. hamptoni* (Tongaporutuan-Kapitean) is similar in shape to *C. ponderosa* and although most specimens are smaller than typical adult *C. ponderosa* and it allegedly differs in sculptural details, it is probably not distinct.

The subgenus *Cucullaea (Latiarca)*, which is based on an Eocene species from Maryland, USA, was present in New Zealand from at least late Dannevirke Series until the end of "lower" Kapitean time (end of the *Globorotalia conomiozea* zone), and was a characteristic member of

Plate 10 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (1).

- a. *Chlamys* (sensu lato) *chathamensis* (Hutton), x 1.5.
- b. *Acanthochitona (Notoplax) ashbyi* (Laws), x 16.5.
- c,d. *Lentipecten hochstetteri* (Zittel), x 1.
- e,j. *Cucullaea (Latiarca) worthingtoni* Hutton, x 1.
- f. *Janupecten uttlei* (Marwick), x 1. [Note: out of sequence; described in chapter on Early-mid Oligocene (Whaingaroan) Mollusca].
- g,i. "*Cyclocardia*" *christiei* (Marwick), x 1.
- h. *Bassina speighti* (Suter), x 1.



most shallow-water (shelf) assemblages during this period. Rarer (and considerably smaller) specimens occur in deeper-water (upper bathyal) faunules. The subgenus *C. (Cucullastis)* Finlay and Marwick, 1937 is superficially similar to *C. (Latiarca)*, but the type species, *C. (Cucullastis) barbara* (Pl. 1a, c), has a broad, shallow median sulcus, which forms a shallow sinus in the middle of the ventral margin, and has more markedly discrepant radial sculpture. This consists of broad, flat-topped costae in the right valve (i.e. like *C. (Latiarca)* species) and narrow, rounded costae and fine threads on the anterior and middle portions of the left valve.

Figured specimen (Pl. 10e, j): GS1473, I40/f9519, Trig Z, Otiake, Waitakian (TM2850, NZGS, specimen illustrated by Boreham 1965, pl.2, fig. 1,4) x 1.

Janupecten uttleyi (Marwick) (Pl. 10 f) is described in the preceding chapter.

Pl. 11 b. *Athlopecten athleta* (Zittel, 1864) [*Pecten athleta* Zittel 1864, p. 49; *Pecten (Patinopekten) marshalli* Suter 1913b, p.295; *Athlopecten marshalli*]. Type species of *Athlopecten* Marwick, 1928 (Pectinidae).

Large for family (height 100-180 mm), robust, moderately to strongly inflated, apparently equivalve. Ears large, the anterior ones somewhat the larger, those on left valve separated from disc by deep channels; posterior ear on right valve with similar channel, anterior ear with deep, broad byssal notch in young shells, notch apparently shallower and less prominent in adults; ctenolium prominent in young shells, absent from adults. Radial sculpture on disc of 10 or 11 prominent costae, those on left valve remaining simple and convex throughout growth, though joined by secondary costae in some shells; those on right valve more flattened and subdivided by a longitudinal groove, which may arise near the beak or at some distance from it, and may divide the costae subequally or very unequally; secondary costae arising in interspaces during growth. Ears with prominent radial costae. Commarginal sculpture of imbricate, lamellar growth ridges, locally prominent, particularly on ears. Well preserved shells with "shagreen" microsculpture on disc and ears. Resilifer large, distinctly oblique, directed postero-ventrally, bounded by narrow ridges.

Duntroonian-Waitakian; Takaka Limestone, Motupipi, Northwest Nelson, Waitakian (type locality of *P. athleta*); Muddy Terrace, Waikaia, Southland, Duntroonian (type locality of *P. marshalli*); and from numerous localities in North and South Islands, mostly from limestone, greensand and calcareous sandstone.

This distinctive and spectacular pecten has no known close relatives in the New Zealand fauna nor, as far as can be judged from available literature, elsewhere. Apart from its large size (greater than any other New Zealand Cenozoic pecten), it is distinguished by its deep subaural channels, by having relatively few primary radial costae, by its rather coarsely lamellar commarginal sculpture and by the shagreen microsculpture, and in having an oblique resilifer bordered by tooth-like ridges. *Pecten marshalli* was not compared with *A. athleta* by its author, but apart from the relatively small size of the holotype (height 115 mm), it does not differ significantly from younger (Waitakian rather than Duntroonian) specimens, and is here regarded as a synonym of *Athlopecten athleta*.

Figured specimen (Pl. 11b): GS990, R14/f6012, coastal section between Gibson and Carter's beaches, near Whaingaroa Harbour, South-west Auckland, Waitakian (NZGS) x 0.67.

Pl. 10 a. *Chlamys* (sensu lato) *chathamensis* (Hutton,

1873) [*Pecten chathamensis* Hutton 1873b, p. 29; *Cyclopecten compitum* Marwick 1929, p. 909; *Chlamys compitum*] (Pectinidae).

Size moderate for genus (height 25-40 mm), considerably higher than long, only moderately inflated. Ears very unequal, anterior ears much the larger, dorsal margins colinear but markedly oblique to axis of symmetry of disc. Byssal notch deep and wide, fasciole very prominent, sunken; ctenolium present. Radial sculpture on disc similar in both valves, of 20-27 (mean 22) prominent, simple, rather wide, scaly costae or plicae of rounded or subtriangular cross-section. Interspaces without secondary costellae, sculptured by growth lines and "Camptonectes" striae, more prominent towards ends than in middle of disc. Ears with about 4 narrow, scaly costellae.

Duntroonian; "Broken River" (type locality of *P. chathamensis* probably from the "Fan coral bed", Thomas Formation, junction of Porter and Thomas Rivers, Castle Hill Basin); Chatton Formation, Shell Gully, Chatton (type locality of *C. compitum*); Wharekuri Greensand, Waitaki River, opposite Wharekuri. Common only at the last locality. Despite the name this species is not known from the Chatham Islands, although it is a reasonable assumption that Hutton probably intended the type to be from there (Boreham 1965, p. 21).

Chlamys williamsoni (Whaingaroan, south-west Auckland) is similar to *C. chathamensis* but has more numerous radial costae (24-27, mean 26) (Boreham 1965, p. 22).

Figured specimen (Pl. 10a): GS1341, I40/f6492, Waitaki River, opposite Wharekuri, Duntroonian (NZGS) x 1.5.

Pl. 10 c,d. *Lentipekten hochstetteri* (Zittel, 1864) [*Pecten hochstetteri* Zittel 1864, p. 50; *Pseudamussium (Pecten) huttoni* Park 1905, p. 485; *Pecten (Camptonectes) huttoni*]. Type species of *Lentipekten* Marwick, 1928 (Pectinidae).

Moderately large for family (height 55-75 mm), left valve more inflated than right, articulated specimens with well marked gape at each end, at and below ears. Ears subequal, separated from disc by shallow grooves; dorsal margins of left ears smooth, colinear, those of right valve slightly divergent, weakly serrate in some shells. Byssal notch shallow, fasciole flat or slightly convex. Both valves smooth except for weak growth lines and exceedingly fine radial striae. Cardinal crura well developed; auricular crura strongly tubercular distally. Adductor muscle scar much larger and situated in a more ventral position in left valve than in right.

Duntroonian-Kapitean; "Aotea Sandstone" (not the lower Whaingaroan Aotea Sandstone of the type locality), coast north of Whaingaroa (Raglan) Harbour, Duntroonian (type locality of both *P. hochstetteri* and *P. huttoni*) and from numerous localities in a wide range of lithofacies.

Lentipekten hochstetteri is one of the most widely recorded of all New Zealand Cenozoic molluscs and is readily distinguished from nearly all other local pectens by having both valves smooth (except for very weak growth lines and radial striae). *Duplipecten parki* (late Bortonian-Kaiaian) also has both valves smooth, but differs in having the right valve more inflated than the left (i.e. the opposite of *L. hochstetteri*) and in having deep channels separating the right valve ears from the disc.

The description given above is based on a broad, traditional concept of *Lentipekten hochstetteri*, i.e. one that includes all post-Whaingaroan pectens with both valves smooth, but there is some evidence to suggest that two species, possibly with quite different antecedents, are involved. The type locality of *L. hochstetteri* unfortunately has not been relocated (Fleming in

Hochstetter 1959, p. 78, footnote 3) but as far as can be judged from the original illustration (Zittel 1864, pl. 11, fig. 5a) and a plaster replica in the Geological Survey, the type specimen is relatively broad (about as long as it is high) and has an ill-defined, presumably flat byssal fasciole. In these respects it closely resembles pectens from the Kokoamu Greensand in the vicinity of Dunroon, North Otago (Dunroonian). The right valve ears on Kokoamu Greensand specimens have finely serrate dorsal margins and some retain very faint traces of radial sculpture, but the type of *L. hochstetteri* does not seem to be well enough preserved to show if these characters are present. Olson and Fleming (in Gage 1957, p. 49) noted the similarity of Kokoamu specimens to *L. hochstetteri*, but because of the serrate and radially sculptured ears referred them to *Janupecten subteres*, even though they lack the weak radial sculpture on the disc characteristic of the latter species.

Pectens from the "Curiosity Shop", Rakaia River (Waitakian)—including the specimen figured here—closely resemble the Kokoamu shells but have much weaker serrations on the ears. Post-Waitakian *Lentipecten*-like shells, however, are noticeably higher than they are long, have almost smooth dorsal margins to the ears, and have a distinctly convex byssal fasciole. Very similar shells, apparently differing only in minor details, occur in a Bortonian shellbed in the upper Waihao River, South Canterbury, which suggests that the smooth Neogene pecten is not descended from *L. hochstetteri* but has a quite independent origin in the upper Waihao River species or a related Eocene species. However, because of uncertainties about the age and characters of the type specimen, *L. hochstetteri* is here interpreted in a broad sense.

Figured specimen (Pl. 10c, d): GS311, K36/f7499, "Curiosity Shop", Rakaia River, Canterbury, Waitakian (NZGS) x 1.

Pl. 12 a,b. *Crenostrea wuellerstorfi* (Zittel, 1864) [*Ostrea wuellerstorfi* Zittel 1864, p. 54; *O. (Crenostrea) wuellerstorfi*; *Gigantostrea wuellerstorfi*; *Pycnodonte (Crenostrea) wuellerstorfi*]. Type species of *Crenostrea* Marwick, 1931 (Gryphaeidae: Pycnodontinae).

Moderately large for genus (height 100-160 mm), subequilateral to strongly oblique, left valve only moderately inflated, right valve considerably flatter. Shell composed of lamellar and vesicular layers. Sculpture mostly of irregular puckers and welts but also some more or less regular radial costae. Ligamental area rather small, not strongly projecting, with a broad, oblique resilifer. Chomata well developed, long and prominent, extending well down anterior and posterior margins, and all around margin on some specimens. Adductor muscle scar large, subcircular, behind middle of shell.

Dunroonian-Waitakian; "Aotea Sandstone" (not the lower Whaingaroan Aotea Sandstone of the type locality), coast north of Whaingaroa (Raglan) Harbour, Southwest Auckland, Dunroonian (type); Chatton Formation, Shell Gully, Chatton.

Although this species has been recorded from numerous localities in the past, many of the records probably pertain to other species, not all of them assignable to the Pycnodontinae, let alone to *Crenostrea*. Some at least of the "giant" oysters in the Landon Series belong in the Ostreidae rather than the Gryphaeidae, probably in *Flemingostrea* (see below). As with most other oysters the

distinctions between taxa are not always well defined, and as a consequence the group as a whole has been shunned by most paleontologists. *C. wuellerstorfi* is here restricted to species with a relatively small ligamental area that does not project strongly above the dorsal margin, with prominent chomata and with a large adductor muscle scar. The Paleocene species *C. cannoni* (Pl. 3a, f) is more equilateral in shape, has a much larger and more strongly projecting ligamental area, much weaker chomata and a smaller adductor muscle scar than *C. wuellerstorfi*. *C. gittosina* (Otaian, Waiheke Island) seems to be very similar to *C. wuellerstorfi* and may not be distinct.

Figured specimen (Pl. 12a, b): GS9806, F45/f9668, Shell Gully, Chatton, Dunroonian (NZGS) x 0.67.

Pl. 11 g,i. *Flemingostrea wollastoni* (Finlay, 1927) [*Ostrea incurva* Hutton 1873b, p.35 (not of Nilsson, 1827); *Ostrea wollastoni* Finlay 1927b, p.528 (new name for *O. incurva* Hutton, preoccupied); *O. (Gigantostrea) wollastoni*] (Ostreidae: Ostreinae).

Large for family (height 140-160 mm), thick-shelled, ovate, subequilateral. No vesicular shell-layers. Left valve more inflated than right but shell-cavity not deep and not extending under umbo. Ventral margin broadly and deeply folded, some shells with shallow sulcus on left valve running from umbo to posterior end of fold. Attachment area rather small. Sculpture on left valve of imbricated growth ridges, some shells with irregular radial corrugations as well; right valve with more regular and more numerous growth ridges. Ligamental area moderately large with a very broad resilifer. Chomata absent. Adductor muscle scar large, reniform, dorsal margin concave, strongly inclined to interior of shell on left valve, less so on right valve, situated posterior to middle of shell.

Dunroonian-Waitakian; "Oamaru" (type—probably from Kokoamu Greensand or Gee Greensand, North Otago); Otekaike Limestone, Campbell Park School, Otekaike Valley; Trig Z, Otiake; Chatton Formation, Shell Gully, Chatton; Waikaia, Southland. Many of the records of "giant" oysters from the Landon Series are probably of this or a related species, but most specimens are articulated or poorly preserved or both and are not confidently assignable to genera.

This species has long been included in *Gigantostrea* (= *Pycnodonte*), but the reniform (rather than circular or subcircular) adductor muscle scar, and the absence of vesicular shell material indicate assignment to the Ostreidae. It is particularly similar to *Ostrea hemiglobosa* Romanovskiy, 1884 (Eocene; USSR and Afghanistan), the type species of *Solidostrea* Vyalov, 1948, which has been somewhat doubtfully synonymised with *Flemingostrea* Vredenburg, 1916 by Stenzel (in Moore 1971, p. N1150, 1153).

Ostrea suteri Ihering (1907, p.94) may be an earlier name for this oyster. The type material of *O. suteri* is allegedly from "Westport", but the sole specimen we are aware of in New Zealand collections that has been identified as *O. suteri* (in NZGS, from H. Suter's collection, labelled "*O. suteri* Ihering" in Suter's handwriting) bears the locality "Kahurangi, southwest Nelson" (Dunroonian or Waitakian). As we are not aware of any possible locality for such an oyster near Westport, the type locality seems likely to be Kahurangi Point. The specimen in Suter's collection is articulated and partly enclosed in matrix, and we cannot be sure it is conspecific with *F. wollastoni*. The question can be resolved only by comparison of good material from the two type localities.

Figured specimen (Pl. 11g, i): holotype, "Oamaru" (age uncertain, probably Duntroonian or Waitakian) (TM2854, NZGS) x 0.67.

Pl. 11 a. *Spissatella subobesa* (Marshall and Murdoch, 1919) [*Crassatellites subobesus* Marshall and Murdoch 1919, p. 257] (Crassatellidae).

Rather large for genus (length 43-65 mm), relatively elongate (length/height ratio 1.48-1.70), moderately inflated; posterior area concave, differentiated by well-defined umbonal ridge. Lunule well developed on each valve, deeply impressed; escutcheon prominent and deeply impressed on right valve, much narrower and more subdued on left valve. Commarginal sculpture on flanks of low, narrowly rounded ridges, 21-24 per cm at 1 cm from apex, in some specimens weakening distally; ridges much finer and more numerous and tending to be subobsolete on posterior area. Left hinge with narrow anterior lateral tooth formed by end of lunule, thin anterior and median cardinals, and a posterior cardinal tooth which is scarcely distinguishable from escutcheon margin; posterior lateral socket well defined. Resilifer deeply impressed, reaching almost to hinge margin. Right anterior cardinal tooth coalescent with edge of lunule, median cardinal narrowly triangular. Posterior lateral tooth finely transversely striate, coalescent with escutcheon. Adductor muscle scars oval, subequal. Internal margins smooth.

Duntroonian; Wharekuri Greensand, Waitaki River, opposite Wharekuri (type); head of Lake Waitaki (common).

Spissatella subobesa is distinguished from *S. trailli* (Pl. 18 i,k) by its larger size, its typically more elongate shell and its considerably finer commarginal sculpture. Some individuals approach topotypes of *S. trailli* in shape but may be distinguished by the finer sculpture, particularly on the umbones. *S. acculta* (Duntroonian, Wharekuri) is much less elongate and less strongly inflated than *S. subobesa*, has a less well defined umbonal ridge and a slightly convex rather than a straight or slightly concave posterodorsal margin. The two Wharekuri species apparently do not occur together in the Wharekuri Greensand and presumably were ecologically segregated. Yet another Duntroonian species, *S. poroleda* (Shell Gully, Chatton), is more like *S. subobesa* in overall shape, but is less strongly inflated, has a more strongly convex ventral margin, and has a sharp rather than a rounded umbonal ridge.

Figured specimen (Pl. 11a): GS10837, I40/f001, head of Lake Waitaki, Duntroonian (NZGS) x 1.25.

Pl. 12 d,e. *Eucrassatella ampla* (Zittel, 1864) [*Crassatella*

ampla Zittel 1864, p. 46; *C. attenuata* Hutton 1873b, p. 24; *Crassatellites attenuatus*; *Eucrassatella attenuata*] (Crassatellidae).

Large for genus (length 80-150 mm), thick-shelled, subtrigonal to oblong, length/height ratio 1.1-1.5, some shells almost equilateral, others strongly inequilateral. Posterior end truncate, posterior area flattened or slightly concave; umbonal ridge not well defined. Lunule large, strongly impressed; escutcheon well defined in right valve, transversely striate in well preserved shells, narrower and more obscure in left valve. Well preserved shells with rounded commarginal ridges on proximal few mm of umbones, remainder smooth except for growth lines. Hinge heavy, varying considerably in width, dominated by a deeply impressed triangular resilifer extending almost to ventral edge. Left valve with a low, finely rugose anterior lateral tooth, a thick anterior cardinal, a narrower median cardinal, and a prominent posterior lateral with a finely rugose socket above. Right valve with a shallow anterior lateral socket, a short anterior cardinal tooth, which is largely fused to lunule, and a heavy, triangular median cardinal; posterior lateral tooth formed by inner edge of escutcheon. Adductor muscle scars large, strongly impressed. Inner margins smooth.

Duntroonian-Tongaporutuan; Cape Rodney, Auckland, Otaian (type locality of *C. ampla*); "Broken River" (type locality of *C. attenuata*, i.e. probably basal shellbed, Enys Formation, junction of Porter and Thomas River, Castle Hill Basin, Altonian), and numerous localities in North and South Islands.

Eucrassatella ampla differs from *E. australis* (Pl. 5f, i) in its much larger size, its more weakly defined left escutcheon and in invariably having smooth internal margins. *E. marshalli* (Kapitean-Waipipian) is much smaller and has a less strongly impressed left escutcheon than *E. ampla*.

Eucrassatella apparently became extinct in New Zealand during the late Pliocene, but the extant Australian species are primarily inner-shelf dwellers that only rarely extend into deeper waters. *E. ampla* seems to have had a similar habitat.

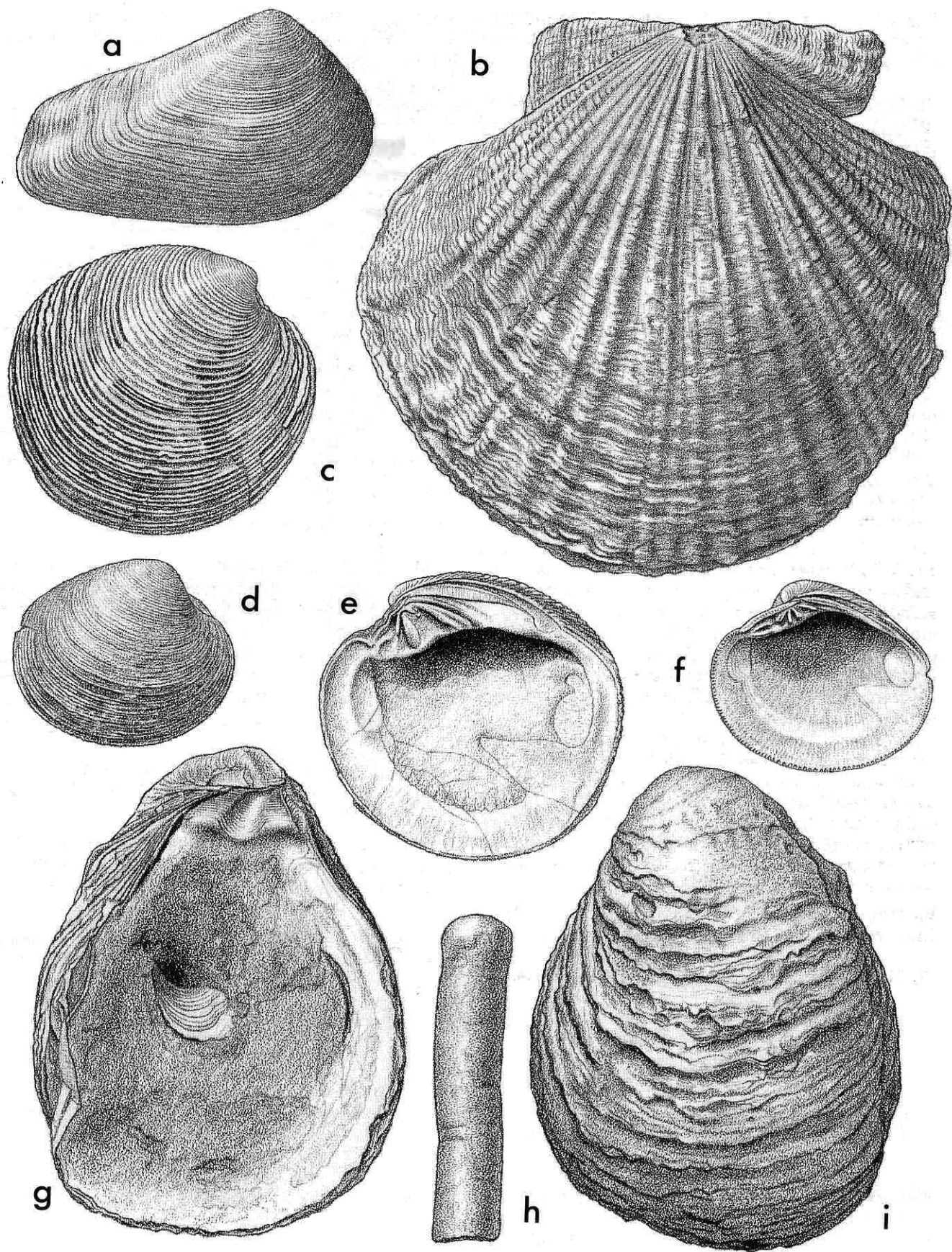
Figured specimen (Pl. 12d, e): GS3600, F46/f8492, Maitara River, near Brydone, Southland, Waitakian (NZGS) x 0.67.

Pl. 10 g,i. "*Cyclocardia*" *christiei* (Marwick, 1929) [*Venericardia christiei* Marwick 1929, p. 910; *V. (Megacardita) christiei*; *V. (Cyclocardia) christiei*] (Carditidae: Venericardiinae).

Moderately large for family (height 45-65 mm), robust, ovate, generally higher than long, with beaks close to anterior end. Posterior end only weakly truncate. Lunule very narrow, strongly impressed, sloping

Plate 11 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (2).

- a. *Spissatella subobesa* (Marshall and Murdoch), x 1.25.
- b. *Athlopecten athleta* (Zittel), x 0.67.
- c,e *Dosinia (Austrodosinia) sodalis* Marwick, x 1.
- d,f *Kuia vellicata* (Hutton), x 1.5.
- g,i *Flemingostrea wollastoni* (Finlay), x 0.67.
- h. Terebratulidae, unidentified tube, x 1.



backwards under beak; escutcheon narrow, almost vertical. Radial sculpture of 22-24 prominent costae, typically sharply defined and somewhat flattened on top on proximal half, but lower, less distinct and more rounded distally. Costae on umbones bearing small tubercles on their crests, but soon becoming smooth or bearing only fine growth lines. Left hinge with a narrow, backward-directed anterior cardinal tooth and a long, arched posterior cardinal. Right valve with a low anterior cardinal tooth confluent with lunular margin, a broadly triangular, arched median cardinal, and a thin, grooved posterior cardinal joined to nymph.

Duntroonian; Chatton Formation, Shell Gully, Chatton (type) (abundant); Wendon Valley, Southland (abundant);? Waiwiri Beach, Southwest Auckland (very large shells up to 85 mm in height, with sculpture becoming obsolete distally).

"*Cyclocardia*" *christiei* is similar to "*Cyclocardia*" *awamoensis* (Pl. 17h, i) but is much larger, thicker-shelled and more oblique, and has more prominent radial costae. "*Cyclocardia*" *marama* (Waitakian, North Otago and South Canterbury) is smaller and more circular than "*C.*" *christiei*, and has weaker radial sculpture and a nearly vertical lunular margin. Although these species were referred to *Cyclocardia* Conrad, 1867 by Maxwell (1969, p. 172) their resemblance to the type species of that genus is almost certainly fortuitous, and they are probably derived from a New Zealand Eocene species of *Glyptoactis* (*Fasciculicardia*).

Figured specimen (Pl. 10g, i): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.

Pl. 12 i,j. *Megacardita ponderosa* (Suter, 1913) [*Venericardia ponderosa* Suter 1913b, p. 296; *V. (Megacardita) ponderosa*; *V. caelebs* Marwick 1929, p. 911; *V. (Megacardita) caelebs*] (Carditidae: Venericardiinae).

Large for family (length 65-85 mm), subelliptical, beaks close to anterior end. Posterior area rather narrow, shallowly concave. Lunule relatively small, smooth, strongly pouting. Radial sculpture of 26-29 prominent costae of variable shape and spacing, in some specimens squarish-sectioned with relatively broad interspaces (as wide as costae in some shells), on others rounded or broadly triangular with narrow interspaces. Anterior ribs finely scabrous (particularly proximally), others smooth or with fine growth lines. Costae on middle part of posterior area considerably weaker than elsewhere. Hinge heavy, left valve with prominent triangular anterior cardinal tooth, widely separated from a long, narrow, slightly curved posterior cardinal. Right hinge with anterior cardinal fused to lunule, and a very broad, somewhat excavated median cardinal.

Duntroonian; Chatton Formation, Muddy Terrace, Waikaia, Southland (type locality of *V. ponderosa*); Shell Gully, Chatton (type locality of *V. caelebs*) (rare); Wendon Valley, moderately common; Wharekuri Greensand, Wharekuri (rare). *V. caelebs* was based on an immature specimen only 30 mm long. Adult topotypes are considered to fall within the limits of variation of *M. ponderosa*.

Megacardita includes relatively large, elongate venericardiines with anteriorly placed beaks. The only other New Zealand species of the genus—which also occurs in the mid-Cenozoic of Europe and Africa—is *M. squadronensis* (Otaian, Waiheke and Kawau Islands); this differs from *M. ponderosa* in having flattened ribs with narrow interspaces.

Figured specimen (Pl. 12i, j): Shell Gully, Chatton, Duntroonian (NZGS, ex C.R. Laws Colln) x 1.

Pl. 13 d,e. *Hedecardium (Hedecardium) waitakiense*

(Suter, 1907) [*Cardium (Trachycardium) waitakiense* Suter 1907a, p. 209]. Type species of *Hedecardium* Marwick, 1944 (Cardiidae: Protocardiinae).

Size moderate for family (height 60-70 mm), rather thin-shelled, subquadrate, strongly inflated. Posterior area well defined; junction of posterior and posterodorsal margins sharply angled in right valve, more rounded in left. Lunule only weakly differentiated. Radial sculpture on "main" part of shell (i.e. other than posterior area) of 40-48 flat-topped or narrowly rounded costae, interspaces wider than costae on adult. Commarginal sculpture of fine growth ridges in intercostal spaces. Posterior area glossy, with 14-16 subdued, rounded costae that become obsolete towards dorsal margin. Hinge narrow, almost straight, both valves with prominent, pointed anterior and posterior lateral teeth. Left cardinal teeth separate, anterior tooth peg-like, posterior one much smaller. Right cardinals fused dorsally, anterior one the smaller. Adductor muscle scars oval, subequal. Ventral margin crenulate, posterior margin less prominently than elsewhere.

Duntroonian; Wharekuri Greensand, Waitaki River, opposite Wharekuri (type); head of Lake Waitaki; Wendon Valley; Otorohanga; Okoko.

Hedecardium olssoni (Duntroonian, Shell Gully, Chatton) is probably conspecific with *H. waitakiense*—it differs only in having fewer (37) radial costae on the main part of the shell, and in having costae of triangular rather than rounded or flattened cross-section.

Hedecardium is an endemic genus first recorded from beds of probable Porangan age (*H. collinsi*; Otaio Gorge, Pareora Gorge) and is probably derived from a Paleocene or Early Eocene species of *Nemocardium* (sensu lato). The Eocene species are similar in shape and sculpture to *H. waitakiense*, but are much smaller; *H. collinsi* is only 21 mm long and *H. brunneri* (Bortonian-Kaiatan, widespread) is 35-50 mm in length.

Hedecardium (sensu stricto) is not known after the Waitakian, but the subgenus *H. (Titanocardium)* persisted until the Waiauian or Tongaporutuan (see Pl. 19d, e). The genus seems to have been confined to shallow waters (inner or middle shelf).

Figured specimen (Pl. 13d, e): GS10837, I40/f001, head of Lake Waitaki, Duntroonian (NZGS) x 1.

Pl. 11 c,e. *Dosinia (Austrodosinia) sodalis* Marwick, 1929 [*D. (Raina) sodalis* Marwick 1929, p.913] (Veneridae: Dosiniinae).

Size moderate for genus (length 50-60 mm), subcircular, moderately inflated, posterior area slightly concave, posterior end weakly truncate. Lunule small, pouting; escutcheon very well defined, particularly in left valve. Commarginal sculpture of thin, well spaced, erect ridges elevated into prominent lamellae posteriorly and near anterodorsal margin, extending across right escutcheon but stopping abruptly at edge of left escutcheon. Left hinge with a small anterior lateral tooth, a thin anterior cardinal, a narrowly triangular median cardinal, and a thin, grooved posterior cardinal. Right hinge with a shallow anterior lateral socket, a very short anterior cardinal tooth, a narrowly triangular median cardinal and a narrow, bifid posterior cardinal. Pallial sinus moderately deep, triangular, horizontal.

Duntroonian, Chatton Formation, Shell Gully, Chatton (type) (not uncommon).

Although *Dosinia sodalis* was originally assigned to the subgenus *Dosinia (Raina)*, the nature of the sculpture (raised into lamellae near the escutcheon), the narrow right posterior cardinal tooth and the horizontal pallial

sinus indicate a location in *Austrodosinia*. It differs from *D. (Austrodosinia) anus* (Nukumaruan-Recent) in being more strongly inflated and in having coarser sculpture, a more sharply defined escutcheon (particularly in the right valve) and a much smaller left anterior lateral tooth.

Figured specimen (pl. 11c, e): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.

Pl. 10 h. *Bassina speighti* (Suter, 1913) [*Chione (Liprophora) speighti* Suter, 1913b, p. 296] (Veneridae: Chioninae).

Size moderate for family (length 40-60 mm), broadly ovate, posteriorly truncate, moderately inflated, strongly inequilateral. Two well marked umbonal ridges, one running to posteroventral angle, thus defining a posterior area, the other ending posterior to middle of ventral margin. Anterodorsal margin short, almost straight; posterodorsal margin long, convex; ventral margin obtusely angled. Lunule narrow, but strongly differentiated, broader in right valve than in left. Escutcheon broader and more sharply defined in left than in right valve. Commarginal sculpture of distant, thin lamellae, well preserved shells with crests turned over towards umbones and produced into short triangular spines where they cross the umbonal ridges; interspaces with fine growth lines. Left hinge with a narrow anterior cardinal tooth, a triangular, bifid median cardinal and a narrow, almost horizontal posterior cardinal. Right hinge with a narrow interior cardinal tooth, a narrowly triangular, bifid median cardinal and an equally narrow, weakly bifid posterior cardinal. Pallial sinus moderately deep, triangular. Internal margins finely and weakly crenulate, appearing smooth in many specimens.

Duntroonian-Tongaporutuan; Double Corner Shellbeds, Lower Waipara Gorge, Waiauian (type) and numerous localities in both North and South Islands (Fleming 1962, p. 238).

Bassina yatei (Opoitian-Recent) is similar in size to *B. speighti* but lacks the submedian umbonal ridge and consequently has an evenly convex rather than an obtusely angled ventral margin, although a faint ridge does occur in a few individuals. *B. southlandica* (Opoitian, Te Waewae Bay, Southland) and *B. lawsi* (Opoitian, Kaawa Creek) also lack the submedian ridge and differ from *B. yatei* in their smaller size and in outline. *B. parva* (Mangapanian-Nukumaruan; Pl. 39e, h) and *B. katherinae* (Waipipian, Otahuhu) retain the submedian ridge (presumably a primitive character for the genus) but differ from *B. speighti* in their much smaller size and in having more closely spaced commarginal lamellae. *B. macchurugi* (Nukumaruan, Chatham Island) differs little from *B. yatei*; a recently collected left valve lacks the anterior lateral tooth by which Marwick (1928) differentiated the genus *Bassinaria* for *B. macchurugi*, and we regard *Bassinaria* as a synonym of *Bassina*.

Bassina speighti seems to be a good example of "morphological stasis"; during its relatively long period of existence (c. 20 million years) it does not seem to have undergone any significant change in such external features as shape or structure, although it must be admitted that internal characters, particularly those of the hinge and pallial sinus, are known for only a few specimens. No other species of *Bassina* are known from New Zealand during this period, but no fewer than three taxa, *B. yatei*, *B. lawsi* and *B. southlandica*, are recorded from the Opoitian and a fourth, *B. katherinae* is present in the Waipipian. As with many other New Zealand molluscan genera, speciation seems to have taken place during the Kapitean or earliest Opoitian, probably in response to the marked climatic and eustatic changes during this terminal Miocene to early Pliocene period (see Fleming 1962a).

The extant *B. yatei* inhabits sandy substrates in shallow waters (less than about 40 m), mostly off sandy ocean beaches. *B. speighti* probably had a similar habitat.

Figures specimen (pl. 10h): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 1.

Pl. 13 a,b. *Tapes (sensu lato) parki* (Marshall and Murdoch, 1921) [*Miltha parki* Marshall and Murdoch 1921a, p. 79] (Veneridae: Tapetinae).

Moderately large for family (length 65-90 mm), ovate, moderately inflated; posterior area well defined. Lunule small, impressed; escutcheon broad, strongly differentiated. Sculpture of closely spaced, thin, low commarginal ridges crossed by numerous radial costellae similar in strength to, or slightly coarser than ridges, producing a finely reticulate effect. Left hinge with a narrow anterior cardinal tooth, a bifid, triangular median cardinal and a thin posterior cardinal. Right hinge unknown. Pallial sinus moderately deep, horizontal, apex rounded. Internal margins smooth.

Duntroonian; "Aotea" Sandstone?, Okoko-Kawhia Road, Southwest Auckland (type); Wharekuri Greensand, head of Lake Waitaki; Chatton Formation, Wendon Valley, Southland; ? Shell Gully, Chatton. Moderately common at type locality, uncommon at other localities.

The type material and available topotypes of *Tapes parki* are poorly preserved steinkerns retaining traces of external sculpture and may not be conspecific with the South Island specimens. *Tapes parki* differs from typical species of the genus in having relatively prominent radial sculpture. Another, related species occurs in the Gee Greensand (Altonian) at Target Gully, Oamaru, differing from *T. parki* in its smaller and more elongate shell.

Figured specimen (pl. 13a, b): GS9514, I40/f6678, head of Lake Waitaki, Duntroonian (NZGS) x 1.

Pl. 13 h,k. *Notocallista (Fossacallista) watti* Marwick, 1938 [p. 75] (Veneridae: Pitarinae).

Size moderate for genus (length 20-32 mm) suboval, moderately inflated. Lunule scarcely impressed, bounded by narrow groove; escutcheon not differentiated. Sculpture of numerous closely spaced very fine commarginal grooves, surface shining. Left hinge with a prominent, high anterior lateral tooth, a lamellar anterior cardinal, a short, triangular median cardinal and a very thin posterior cardinal. Right valve with a deep anterior lateral socket bounded above and below by a short, thick tooth; anterior and median cardinals short, narrow, closely spaced, subparallel; posterior cardinal narrow, grooved. Ligament deeply sunken. Pedal retractor muscle scar confluent with anterior adductor scar. Pallial sinus rather short, rounded, ascending. Internal margins smooth.

Waitakian; Otekaike Limestone, Trig Z, Otiake, Waitaki Valley (type); Campbell Park School, Otekaike, Waitaki Valley; Sister's Creek, Hakataramea Valley; Brother's Stream, Hakataramea Valley. Moderately to very common at these localities.

Notocallista (Fossacallista) parki (Otaian-Lillburnian) — the type species of *Fossacallista* Marwick, 1938 — is very similar, but is considerably smaller (length 18-23 mm) and somewhat more coarsely sculptured than *N. watti*. *Fossacallista* differs from *Notocallista* (sensu stricto) and from *N. (Striacallista)* in having a rounded rather than a truncate pallial sinus, a deeply sunken ligament, and the pedal retractor scar muscle scar confluent with the anterior adductor scar rather than separate.

N. (Fossacallista) ranges from Duntroonian to Lillburnian

in New Zealand, and is also recorded from the Late Eocene to Middle Miocene of southern Australia and Tasmania (Marwick 1938, p. 74-78).

Figured specimen (Pl. 13h, k): holotype, Trig Z, Otiake, Waitakian (TM4578, NZGS) x 1.5.

Pl. 11 d,f. *Kuia vellicata* (Hutton, 1873) [*Chione vellicata* Hutton 1873b, p. 21; *C. meridionalis* ("Sowerby") (not of Sowerby, 1846); *Cytherea (Circomphalus) chariessa* Suter 1917, p. 74]. Type species of *Kuia* Marwick, 1927 (Veneridae: Venerinae).

Size moderate for subfamily (length 25-40 mm), suboval, moderately inflated. Lunule prominent, bounded by groove; escutcheon broad, more clearly differentiated in left than in right valve. Commarginal sculpture of thin lamellae of variable spacing, not persisting onto lunule or escutcheon. No radial sculpture, but subsurface radial elements visible on worn shells. Left hinge with a prominent anterior lateral tooth, a triangular anterior cardinal and a thin, slightly curved posterior cardinal partly fused to nymph. Right hinge with a deep anterior socket, a short, lamellar anterior cardinal tooth, a narrow median cardinal, and a very broad, deeply divided posterior cardinal. Pallial sinus moderately deep, acutely triangular, horizontal or somewhat ascending. Internal margins finely crenulate.

Waitakian-Altonian; Mount Harris Formation, Awamoa, South Oamaru, Altonian (type locality of *C. vellicata*); Otekaike Limestone, Trig Z, Otiake, Waitakian (type locality of *C. chariessa*), and numerous localities in North Otago and South Canterbury. A juvenile shell from McCulloch's Bridge, Waihao River differs in only minor details from typical specimens, so the range may extend back to the Kaiatan.

Kuia vellicata is the most widely recorded venerid in mid-Cenozoic beds in the North Otago-South Canterbury area, and occurs in a wide range of lithofacies. It is particularly common at some localities (e.g. Trig Z and Target Gully Shellbed). The only other species of the genus so far described, *K. maddowelli* (Pl. 29f) is larger and has commarginal lamellae restricted to the early part of the shell, the remainder having grooves with broad, smooth interspaces.

Figured specimen (Pl. 11d, f): GS9516, I40/f6675, Trig Z, Otiake, Waitakian (NZGS) x 1.5.

Pl. 12 g,h. *Oxyperas (Pseudoxyperas) leda* (Finlay, 1924) [*Macra attenuata* Hutton 1873b, p. 18 (not of Deshayes in Reeve, 1854); *Macra leda* Finlay 1924a, p. 106 (new name for *M. attenuata* Hutton, preoccupied); *Longimacra leda*] (Mactridae: Mactrinae).

Rather large for family (length 60-95 mm), elongate-ovate, beaks

subcentral, anterior end narrowly rounded, posterior end broader. Posterior weakly differentiated. No sculpture apart from subdued commarginal ridges and grooves. Right hinge with a prominent, lateral socket at each end, bounded below by a prominent, finely transversely grooved tooth and above by a much weaker tooth scarcely differentiated from shell margin; cardinal portion with 2 divergent lamellar teeth anterior to an oblique, triangular resilifer. Left hinge imperfectly known, but having a prominent lateral tooth at each end, and a short, narrow anterior cardinal; median cardinals missing in available shells. Other internal features not known, but pallial sinus presumably moderately deep, tongue-shaped.

Duntroonian; "Broken River (lower beds)" (type) i.e. probably the "Fan coral bed", Thomas Formation, junction of Porter and Thomas Rivers, Castle Hill Basin, the only locality where this species is known definitely to occur.

Oxyperas leda differs from *O. elongata* (Nukumaruan-Recent) in its more elongate and more equilateral shell, and in having a more strongly convex ventral margin and longer, more prominently striate lateral teeth. *O. (Pseudoxyperas) exensis* (Waitakian, Tengawai River) is less elongate than *O. leda*, and has a more strongly concave anterodorsal margin and a broader hinge. *O. (Pseudoxyperas) komakoensis* (Waipipian ?; Mangapanian-Nukumaruan) is similar to *O. elongata*, but has much more prominent commarginal sculpture.

The subgenus *O. (Pseudoxyperas)* has a sporadic record in New Zealand from about Porangan (Otaio Gorge) to Recent. The extant species *O. elongata* occurs in shallow waters down to about 75 m.

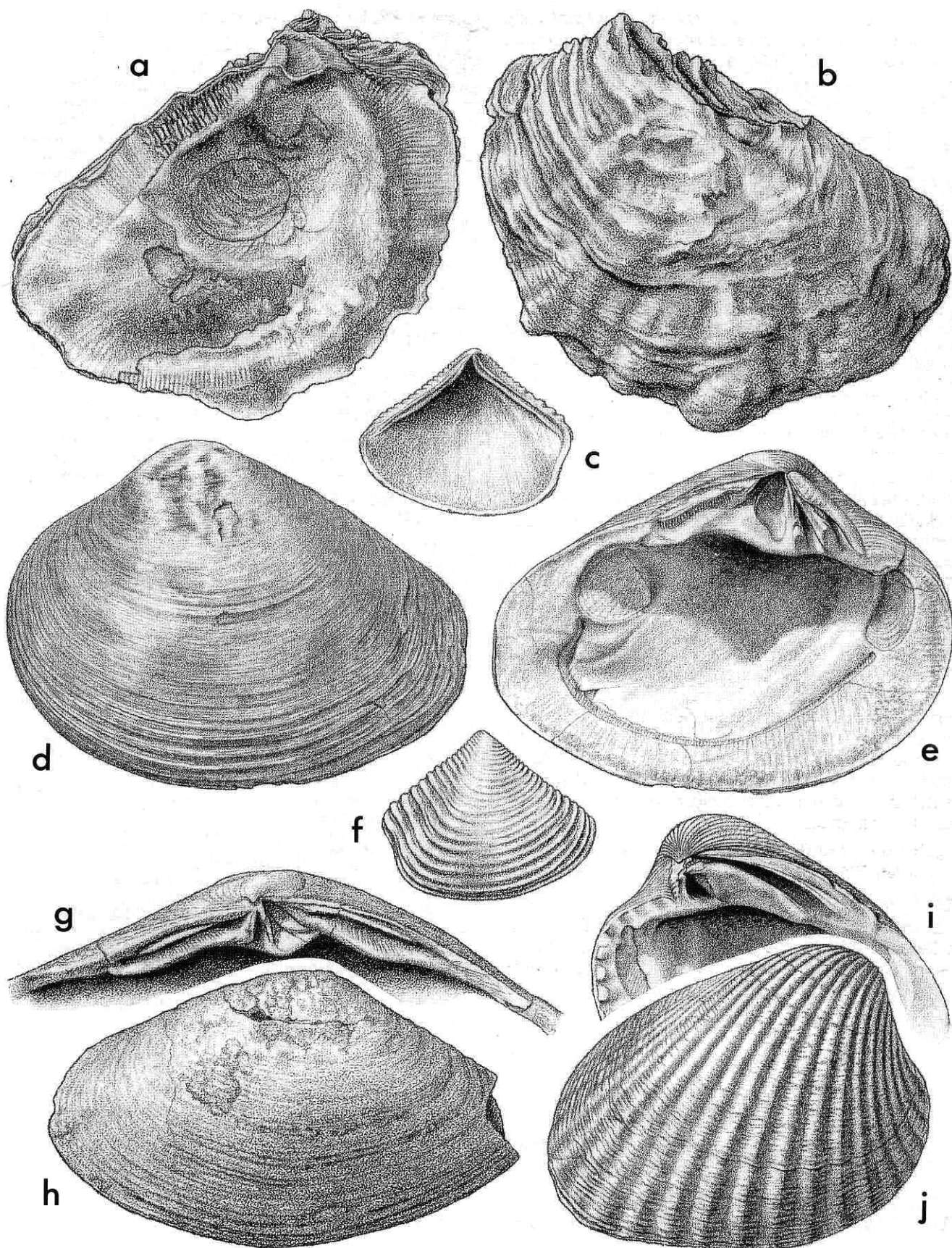
Figured specimens (Pl. 12g): hypotype of Maxwell (1978, fig. 3) (TM 5464, NZGS); (Pl. 12h) lectotype (TM2897, NZGS), both from junction of Porter and Thomas Rivers, Castle Hill Basin, Duntroonian, x 1.5 and x 1 respectively.

Pl. 13 c. *Notocorbula* n. sp. (?) (Corbulidae).

Large for genus (height 12-18 mm), trigonal, strongly inflated, strongly inequivalve, right valve much the larger. Escutcheon on right valve only, large and deeply impressed. Posterior area on right valve narrow with a shallow median furrow. Sculpture on right valve of prominent, rounded commarginal costae of variable spacing, weakly sinuous on flanks on some shells; considerably weaker and more numerous (mainly as a result of bifurcation) on posterior area. Commarginal sculpture on left valve, apart from growth lines, absent or confined to small area on umbo; radial sculpture of a few feeble ridges. Right hinge with a large peg-like anterior cardinal tooth and a deeply impressed resilifer behind. Left hinge with a prominent, narrowly triangular chondrophore divided in 2 by a longitudinal ridge, and a deep socket behind chondrophore to take the right cardinal tooth. Adductor muscle scars large, subequal, anterior scar ovate, posterior one circular, pallial sinus very shallow.

Plate 12 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (3).

- | | |
|-----|---|
| a,b | <i>Crenostrea wuellerstorfi</i> (Zittel), x 0.67. |
| c,f | <i>Myadora delta</i> Marwick, x 4. |
| d,e | <i>Eucrassatella ampla</i> (Zittel), x 0.67. |
| g,h | <i>Oxyperas (Pseudoxyperas) leda</i> (Finlay), x 1.5(g) and x 1(h). |
| i,j | <i>Megacardita ponderosa</i> (Suter), x 1. |



Waitakian; Chatton Formation, Brydone, Mataura River; Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike; Brother's Stream and Sister's Creek, Hakataramea; Mount Harris Formation, upper Tengawai River.

The new (?) species is very similar to the widespread *Notocorbula humerosa* (Duntroonian-Kapitean) but is much larger, has a more prominent radial furrow on the posterior area, and has a larger and more strongly impressed escutcheon. *N. humerosa* is characteristically only 7-8 mm in height. It is unclear, however, if the Waitakian form is really a distinct species or merely an unusually large variant of *N. humerosa*, which for some reason is restricted to this stage. *Caestocorbula* n. sp. (Pl. 7j, k) is also similar, but is smaller and more elongate, and has a siphonal plate.

Figured specimen (Pl. 13c): GS3600, F46/f8492, Mataura River, near Brydone, Southland, Waitakian (NZGS) x 2.

Pl. 11 h. Teredinidae gen. et sp. indeterminate

Featureless thin-shelled tubes of roughly circular or elliptical section and of irregular shape with one end (if preserved) closed by a convex septum are not uncommon in Cenozoic sediments. They may occur singly or, more commonly, in clumps, sometimes in pieces of wood, and are the tubes of wood-boring, or perhaps of soft-sediment-burrowing, bivalves of the family Teredinidae. (Thicker-shelled tubes of similar or larger dimensions but lacking a septum are probably of the polychaete genus *Protula*). Although the names *Teredo heaphyi* and *T. directa* have been proposed for similar tubes, they are taxonomically worthless, for in neither case were the type specimens reported to be associated with the pallets, the only preservable feature of use in classification. Isolated valves of teredinids occasionally turn up in washings of fossiliferous sediments, but these too "are almost useless in classification as they are extremely variable, depending on the age of the specimen and the ecologic conditions affecting it" (Turner in Moore 1969, p. N723). Only one fossil New Zealand teredinid has been based on both the valves and the pallets, *Bankia turneri* (Otaian, Waiheke Island), although it was not until 1978 that the latter were illustrated and the generic assignment confirmed (McKoy 1978, p. 352-353, fig. 1D). Since so little is known about the fossil history of the family, teredinid tubes should be carefully examined to see if they still retain the pallets.

Teredinid tubes may be locally very common, e.g. in the "upper Teredo Limestone" (Waipawan) at Haumuri Bluff,

southern Marlborough (Warren and Speden 1977, fig. 22). Warren and Speden (1977, p. 42) maintained that because of the absence of associated valves or wood, the tubes in this unit are not those of teredinids but probably of some other bivalve group, possibly Clavagellidae. However, the tubes have the characters of teredinid tubes (i.e. thin shell and terminal septum) and are quite unlike those of typical clavagellids, a group with a very sparse record in New Zealand (see Pl. 19f). The absence of valves and pallets and of wood could result from diagenesis, or alternatively the tubes may be those of a sediment-burrowing member of the Teredinidae (i.e. of the genus *Kuphus*).

Figured specimen (Pl. 11h): GS179, I41/f7445, "Maerewhenua Limestone, Waitaki Valley", probably from Kokoamu Greensand near Duntroon, Duntroonian (NZGS) x 1.

Pl. 12 c,f. *Myadora delta* Marwick, 1929 [p. 914-915] (Myochamidae).

Rather small for genus (length 7-10 mm), triangular, subequilateral; strongly inequivalve, right valve inflated, left valve almost flat or concave and twisted. Both valves with long, sharply defined lunule and escutcheon almost perpendicular to remainder of valve exterior; right valve with slightly concave posterior area. Sculpture on left valve of short, prominent commarginal ridges along anterodorsal margin, rest of shell with weak growth ridges or almost smooth. Right valve with similar ridges along both dorsal margins, central area smooth except for a few growth ridges in some shells, but others with ridges continuous across central area. Both valves with squamous microsculpture of minute tesserae. Interior nacreous. Both valves with dorsal margins prominently grooved along most of their length; resilifer narrowly triangular. Pallial sinus very shallow.

Duntroonian-Altonian; Chatton Formation, Shell Gully, Chatton, Duntroonian (type) (common); Wendon Valley; Wharekuri Greensand, Wharekuri; Brother's Stream, Hakataramea Valley; Mount Harris Formation, foot of Mt Horrible, Pareora River; Awamoa Creek; Ardgowan Shellbed, Oamaru.

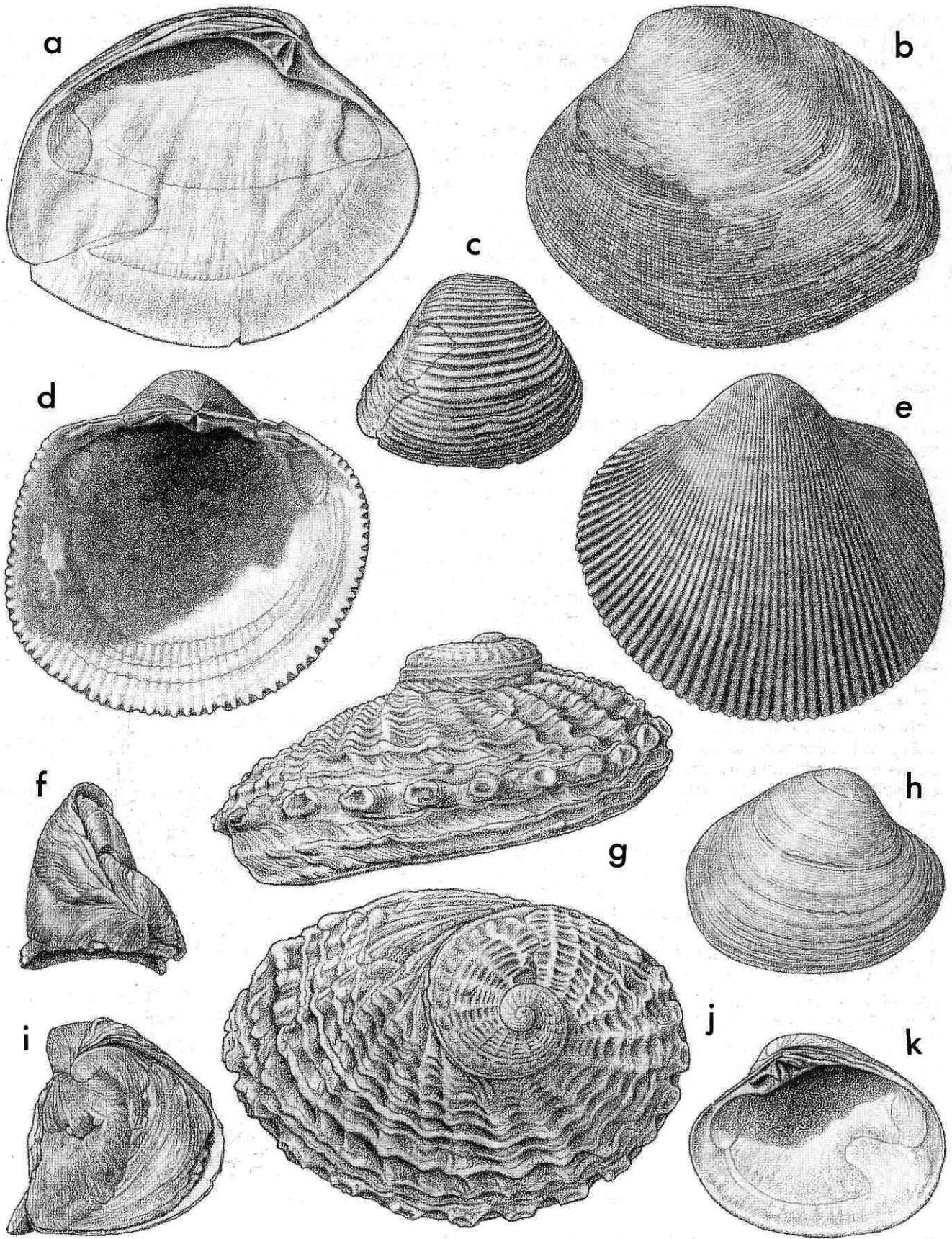
The right valve from Burnt Hill, North Canterbury (Waiauian) recorded by Marwick (1932, p. 499) as this species is more elongate and has more prominent commarginal sculpture than topotypes. *Myadora delta* is the oldest known member of the genus, differing from younger species in its relatively small size, near-equilateral shape and rather weak commarginal sculpture.

Figured specimen (Pl. 12c, f): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 4.

Pl. 13 f,i. *Cleidothaerus albidus* (Lamarck, 1819) [*Chama albidus* Lamarck 1819, p.96; *Chama* ("Camostree")

Plate 13 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (4).

- a,b. *Tapes* (sensu lato) *parki* (Marshall and Murdoch), x 1.
- c. *Notocorbula* n.sp.(?), x 2.
- d,e. *Hedecardium* (*Hedecardium*) *waitakiense* (Suter), x 1.
- f,i. *Cleidothaerus albidus* (Lamarck), x 1.
- g,j. *Haliotis* (*Notohaliotis*?) n.sp., x 1.
- h,k. *Notocallista* (*Fossacallista*) *watti* Marwick, x 1.5.



hemicardium de Roissy in Blainville 1825 (in 1825-27), p.632; *Cleidothaerus chamoides* Stutchbury 1830, p.98; *Chamostrea crassa* Tate 1885, p.228; *Cleidothaerus maorianus* Finlay 1926c, p.474; *Chamostrea albidula*. Type species (as *C. chamoides*) of *Cleidothaerus* Stutchbury, 1830 (Cleidothaeridae).

Rather large for superfamily (height 40-70 mm), robust, trigonal, both valves distinctly coiled; strongly inequivalve, right valve deep, markedly inequilateral with a large, strongly defined anterior area by which it is attached to rock or shells; left valve flat or weakly convex, more equilateral than right valve, with a curved sulcus running from apex to ventral margin. Prodissoconch triangular, closely resembling that of *Myochama* (Odhner 1917, p.36). Sculpture on unattached part of right valve and on left valve posterior to median sulcus of growth lines and ridges, but typically much more irregular anterior to sulcus. Interior nacreous. Hinge of left valve with a single tubercular tooth in front of a deep resilial pit that extends under the umbo; right hinge with a shallow socket projecting somewhat into shell cavity, resilial pit larger than in left valve. Lithodesma weakly coiled. Anterior adductor muscle scar more elongate than posterior scar. Pallial sinus very shallow or obsolete.

Waitakian-Recent; Chatton Formation, Mataura River, near Brydone, Waitakian (rare); Target Gully Shellbed, Oamaru; Castlecliff, Wanganui; Hauriri Terrace cover, Waipipi, Waverley Beach, oxygen isotope stage 5a (common); living in the North Island (type of *C. maorianus* from Kawhia Harbour) to northernmost South Island and the Chatham Islands. The type of *Chama albidula* is a Recent specimen from Tasmania, and *C. hemicardium* and *C. chamoides* are based on Recent shells from southern Australia. *C. crassa* was described from Table Cape, Tasmania (Early Miocene), but Tate himself (Tate 1887a, p.149) quickly realised it is part of the variation of *C. albidus*.

No significant differences can be discerned between the Australian and New Zealand shells or between the fossil and modern specimens. The occurrence of a clearly distinct, internally ridged species of *Cleidothaerus* in northern Western Australia (*C. pliciferus* Odhner 1917, p.34) provides circumstantial evidence that the morphologically identical New Zealand and southern Australian shells are conspecific, but this is one of several examples of apparently conspecific taxa on the two sides of the Tasman Sea where diagnostic characters are simply lacking in the shells, and the taxonomy will remain uncertain until the anatomy is examined and the genetic composition is studied by electrophoresis or other biochemical techniques (others include *Scutus antipodes*, *Anomia trigonopsis*, and *Pododesmus (Monia) zelandicus*).

The priority of the generic names proposed for the single genus in this family has long been debated. The most complete synonymy published is that of Lamy (1936, p.322-323), but the data in the major nomenclators (Neave 1939; Sherborn 1925) and the note by Iredale (1939) show that Lamy's usage of *Chamostrea* is invalid. Roissy (1805) did not include either *Chamostrea* or the vernacular "camostrée" in his section on Mollusca in Buffon's natural history, despite the inclusion of this reference by Hermannsen (1846) and several later authors. The name was first published by Blainville (1825, in 1825-1827, p.632), still as the vernacular "Camostrée", attributed to de Roissy. The latinised name *Camostrea* appears to have been published first by Deshayes (1830, p.178) where, however, it is a genus without species, merely a Latinisation of the vernacular name in Blainville (1825); Deshayes stated that he did not know the genus and could not see why Roissy separated it from *Chama*. [We have been unable to check on the reference to *Chamostrea* in Férussac, "Bull. sc. nat. tom. 24, p.370" (presumably also published about 1830) listed by Hermannsen (1846, p.221), and this is possibly a valid earlier Latinisation of the name].

The name *Cleidothaerus* Stutchbury had, in the meantime, been

proposed in February 1830 (Sherborn 1925, p.1357) and has been accepted as the valid name for the genus by most workers after it was adopted by Iredale (1915). Only the year of publication is known for Deshayes (1830) (Sherborn and Woodward 1906, p.579) and it should, therefore, be dated as 31 December 1830, and so *Cleidothaerus* is undoubtedly the earlier name, and we continue its usage. Two different references to the publication of *Chamostrea* by Gray in 1840 have been published: (1) Sherborn (1925, p. 1210) cited "Syn. Cont. Brit. Mus., ed. 42, 1840, 136 & 150", but noted that the name is a *nomen nudum* in this publication; (2) Neave (1939, p.668) and Vokes (1980, p.207) both cited "1840, Ann. Mag. Nat. Hist., 4, 306," but careful checking of this volume (actually "The Magazine of Natural History", vol. 4, 1840) showed that it does not contain any papers by Gray, and this is yet another fictitious reference in the *Cleidothaerus* saga. The first valid publication of *Chamostrea* appears to have been by Hermannsen (1846, p.221), as was also concluded by Keen (in Moore 1969, p.N844).

The family name Chamostreidae Fischer (1887, in 1880-1887, p.1160) has priority over Cleidothaeridae Hedley, 1918, but as Cleidothaeridae had "won general acceptance" long before 1961, it is here conserved under ICZN (1985 ed.) Article 40(b).

This unusual bivalve has a similar habit and functional morphology to those of *Chama* (Pl. 18d, g) (Odhner 1917; Morton 1974) but belongs in a different subclass. Runnegar (1974, p. 934) suggested that *Cleidothaerus* was derived from "an unspecialised verticordiid" but most workers include it in the Pandoracea near the Pandoridae or Myochamidae. Living *Cleidothaerus albidus* are attached to rocks, shells or algal holdfasts from high tide level down to a few metres. In New Zealand they are most common attached to rocks, on a very exposed coast near Kawhia Harbour and on a sheltered shore in the outer part of Manukau Harbour.

Figured specimen (Pl. 13f, i): GS3600, F46/f8492, Mataura River, near Brydone, Southland, Waitakian (NZGS) x 1.

Pl. 13 g, j. *Haliotis (Notohaliotis?)* n. sp. (Haliotidae).

Size moderate for family (greatest diameter 90 mm), spire relatively elevated, subcentral. Protoconch not preserved, teleoconch of about 2 whorls, obtusely angled somewhat below middle on spire, ramp slightly convex, sides subvertical with a prominent, narrow medial keel. Last whorl with a strong peribasal angulation, basal flange moderately wide. Axial sculpture of well spaced, rather irregular, prosocline plicae that become less distinct near outer lip, extending from upper suture to whorl angulation, about 19 on last whorl. Spiral sculpture of a prominent cord marking keel on whorl sides, joined on last whorl by one of similar strength just above peribasal angulation, and 8 others of variable strength on ramp, apparently forming short, open spines or scales where they cross axial plicae. Tremata large, conical, 17 on last whorl.

Duntroonian or Waitakian, Cookson Volcanics, near "The Whaleback", Inland Kaikoura Road (uncommon).

The new species is apparently closely related to *H. (Notohaliotis) waitemataensis* (Otaian, Kawau Island), but differs in having fewer spiral cords on the sutural ramp, and in having spines or scales developed at intersections of spiral cords with axial plicae. The subcentral apex, the prominent spiral and scaly sculpture and the large tremata differentiate this species from other New Zealand haliotids.

By virtue of their rocky shore habitat, haliotids have a very poor fossil record. Only three extinct species have been described from New Zealand to date, but several additional species are known, mostly represented by fragmentary material, ranging in age from Mangaorapan to Opoitian.

Figured specimen (Pl. 13g, j): GS 9883, N32/f001, cutting, Inland Kaikoura Road near "The Whaleback", North Canterbury, Duntroonian or Waitakian (NZGS) x 1.

Pl. 14 i,j. *Astraea bicarinata* Suter, 1917 [*A. (Cyclocantha) bicarinata* Suter 1917, p. 6] (Turbinidae: Turbininae).

Large for genus (height 56 mm; diameter (including spines) greater than 90 mm, (excluding spines) 77 mm), trochiform, spire moderately low. Spire whorls strongly convex and clasping, spreading up to peripheral keel of previous whorl; last whorl with a prominent peripheral angulation at about 0.3 whorl height, bearing long, slightly forward-directed, anteriorly hollow spines, and another prominent peribasal angulation well below periphery; base concave; umbilicus narrowly open in small specimens but hidden by inner lip callus in adults. On spire whorls spines rest on surface of succeeding whorl. Sculpture on dorsal surface of prominent, slightly irregular, coarsely nodulose spiral cords that turn outward to become slightly radial near periphery, and of many very fine, very faintly gemmate lirae over the surface of, and parallel to, the more prominent cords. Basal sculpture of 2 very prominent nodulose cords, one at peribasal angulation and one halfway between it and periphery, 3 other major nodulose cords and many very fine ones, and low radial lamellae (margins of former inner lip callus pads) extending out from umbilicus. Operculum large, thin, flat, oval, almost smooth, with a weak marginal ridge.

Duntroonian-Altonian; basal shellbed, Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin, Altonian (type); Chatton Formation, Coal Brook Station, Wendon Valley (Duntroonian).

The style of sculpture, the long peripheral spines, the basal and particularly the umbilical sculpture, and the presence of an open umbilicus (if only in immature specimens) in *Astraea bicarinata* are very similar to corresponding characters in *A. heliotropium*, the type species of *Astraea* Röding, 1798, and there is little doubt that *A. bicarinata* is a typical *Astraea*, possibly ancestral to *A. heliotropium*. The large shell figured here differs from the few available specimens from the type locality only in its weaker basal cords and its more prominent cord between the peripheral and peribasal angulations; we judge them to be conspecific.

A. heliotropium (= *A. anthropophagus* (Marwick, 1928)) (Tongaporutuan-Recent) is a reasonably common fossil in New Zealand, and modern specimens are dredged commonly on the inner-mid shelf all around the country. Its main distinguishing characters are its very widely open umbilicus and its large size compared with overseas species usually referred to *Astraea*. *A. stirps* (Altonian-Lillburnian, Clifden) is only slightly different from *A. heliotropium*, differing in having a taller spire and a slightly narrower umbilicus. An unnamed, low-spired species with a deeply concave base and a wide umbilicus recorded from the Otekaike Limestone, Waitaki Valley (Waitakian) and Tarakohe Quarry, Takaka (Altonian), and the forms here included in *A. bicarinata* indicate that several lineages existed in New Zealand during the mid-Cenozoic. Earlier forms with a quite narrow, but still open, umbilicus are known from the Deborah Volcanic Formation at Kakanui (Whaingaroan) and from the Waiareka Volcanic Formation at Lorne, near Oamaru (Kaiaian), and indicate that *Astraea* evolved from a *Bolma*-like ancestor in New Zealand, probably during Paleocene or Early Eocene time, and that only New Zealand species discussed here and two Australian Cenozoic species should be included in *Astraea* (sensu stricto).

Figured specimens (Pl. 14i, j): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 0.67.

Pl. 14 c,g. *Guildfordia (Guildfordia)* n. sp. (Turbinidae: Turbininae).

Moderately large for genus (diameter 50-58 mm, not including spines), spire very low, gently convex. Periphery strongly keeled, with long, narrow, solid, oval-sectioned, strongly forward-directed spines protruding horizontally. Suture undulating strongly around bases of spines on previous whorls. Base gently convex except for a deeply concave depression in central quarter formed by thin, smooth callus filling umbilicus. Sculpture of many rows of closely spaced, low, rounded gemmules, coarsest near upper suture and becoming very fine just above peripheral spines; outer third of base almost smooth, with very low, indistinct radial costae and spiral threads. Columella thick, smooth; basal lip strongly excavated; outer lip swinging strongly forward from spines, then retracting strongly to suture, forming a marked sinus. Operculum thin, flat, oval, almost smooth, with low marginal ridge and weak "finger-print" sculpture.

Duntroonian-Waitakian; several localities in Otekaike Limestone in North Otago and South Canterbury, around Waitaki Valley, in shallow (inner-mid shelf) soft-bottom facies.

The operculum is commonly found in the aperture. This is a large, typical species of *Guildfordia* close to the living type species, *G. triumphans* (Philippi) (tropical western Pacific, from northern Australia to southern Japan), but differing in its larger size, its lower spire, its more numerous spines (nine or 10 on last whorl, rather than seven in *G. triumphans*), and its larger and deeper umbilical hollow. This is apparently the earliest true *Guildfordia* yet reported and is the only undoubted record from New Zealand.

Figured specimen (Pl. 14c, g): excavation for mysticete whale, Sister's Creek, Hakataramea Valley (Duntroonian) (G. Mason Collection) x 1.

Pl. 14 a,h. *Sarmaturbo* n. sp. (Turbinidae: Turbininae).

Large for family (height 80-90 mm), turbiniform, spire somewhat less than half total height. Protoconch depressed, very small, of slightly more than 1 whorl. Teleoconch of about 7 whorls, apex flat with a sharp, serrate peripheral keel that descends and becomes more rounded during growth, situated at, or somewhat above mid-whorl on later whorls; sutural ramp convex, sides subvertical. Last whorl with peribasal angulation and a peripheral keel between it and upper angulation; base slightly convex with a strongly projecting keel bordering inner lip callus. Axial sculpture of short, rounded, strongly opisthocline, non-collabral ridges bordering upper suture, extending at least halfway across ramp on early whorls, but gradually shortening to become rounded nodules or becoming obsolete on later whorls; serrations on shoulder angle changing into prominent rounded nodules during growth, becoming almost obsolete on last whorl of some shells. Spiral sculpture on ramp of numerous very fine threads, some shells with obscure coarser elements as well; a prominent cord appearing out of suture on penultimate whorl to become peripheral keel, accompanied by a weaker one above, and one of similar strength below, forming a peribasal keel; base with 4 somewhat narrower cords; all cords nodulose, the peripheral and peribasal cords most prominently. Aperture markedly prosocline, inner lip with prominent callus band. Operculum oval, central area of outer surface irregularly sculptured, remainder with deeply incised grooves.

Waitakian, Chatton Formation, Mataura River, near Brydone, Southland (not uncommon).

The new species differs from *S. superbus* (Otaian, Auckland), the type species of *Sarmaturbo* Powell, 1938, primarily in having more numerous and smaller nodules, particularly on the shoulder angulation. *S. colini* (Tongaporutuan, Hurupi Stream, Palliser Bay) also has sparse but large nodules on the shoulder angulation, and further differs from the Brydone species in its less prominent spiral sculpture and in having large nodules on the keel bordering the inner lip callus.

Sarmaturbo resembles *Sarmaticus* Gray, 1847 (type species *S. sarmaticus* (Linné, 1758); Recent, South Africa) in overall shell characters, but differs in its distinctive

operculum, which is grooved rather than papillose. The genus, which includes some of the largest of all New Zealand gastropods, has a recorded range of Waitakian to Tongaporutuan, and besides the species discussed here includes undescribed species from the shellbed at the junction of Porter and Thomas Rivers, Castle Hill Basin (Altonian) and from Haungakakahu Stream, East Cape (? Southland Series). All records of *Sarmaturbo* indicate a shallow-water, firm-bottom habitat.

Figured specimens (Pl. 14a, h): GS3600, F46/f8492, Mataura River, near Brydone, Southland, Waitakian (NZGS) x 1 (shell) and x 1.5 (operculum).

Pl. 14 f. *Gazameda grindleyi* (Marwick, 1971) [*Zeacolpus grindleyi* Marwick 1971a, p. 32] (Turritellidae).

Small for family (height 12-16 mm), narrowly conical. Protoconch very difficult to distinguish from teleoconch, turbinate, apparently of slightly more than 1 convex whorl, apex moderately exsert. Teleoconch whorls about 9, the first few gently convex, later ones flat-sided except for a weakly projecting cord margining lower suture and emerging on last whorl as peripheral keel; base flat or slightly concave. Spiral sculpture very feeble, scarcely distinguishable on some shells, 1 thread somewhat more prominent than others on a few specimens. Outer lip sinus moderately deep, apex well above middle of whorl, basal growth lines shallowly concave towards aperture.

Duntroonian, Waitakian?; Wharekuri Greensand, Waitaki River, opposite Wharekuri (type); head of Lake Waitaki (not uncommon near top of section).

Gazameda grindleyi is readily distinguished from all other New Zealand turritellids by its small size, its flat-sided adult whorls, its concave base and its very weak or obsolete sculpture. Although described as a species of *Zeacolpus* (sensu lato), it is much closer to some Australian species of *Gazameda*, particularly the Middle Miocene taxa *G. victoriensis victoriensis* (Cotton and Woods, 1935) and *G. victoriensis manyung* Garrard, 1972 (see Garrard 1972, pl. 28, fig. 16, 17) and is considered to be congeneric. *G. grindleyi* is the only New Zealand member of the genus we are aware of.

Figured specimen (Pl. 14f): GS11196, I40/f163, top of section at head of Lake Waitaki, Waitaki Valley, Duntroonian or Waitakian (NZGS) x 3.

Pl. 14 k. *Tropicolpus (Amplicolpus) healyi* Marwick, 1971a [p. 40-41] (Turritellidae).

Large for family (height 110-155 mm), stout, narrowly conical. Protoconch mamillate, of 3 smooth whorls. Teleoconch of about 16 whorls, early whorls convex or flat-sided, later whorls concave, "telescoped"; peribasal angulation well-defined, base almost flat or gently convex. Primary spirals (A, B, C) commencing at about the same stage, B initially strongest, A weakest, but C becoming stronger than B by 5th or 6th whorl, A gradually becoming subdued and overshadowed by secondary spirals; adult whorls with C forming a prominent, narrow ridge not far above suture, B scarcely distinguishable from secondaries. Base with several cords similar in strength to, or weaker than C, and fine interstitial threads. Outer lip sinus moderately deep, apex near middle of whorl, abapical limb steeper than adapical; basal sinus shallow. Figured specimen with prominent lamellae on last half-whorl, representing former positions of outer lip.

Duntroonian; Chatton Formation, Wendon Valley (type); Knapdale, near Gore, Southland; Shell Gully, Chatton; Wharekuri Greensand, Wharekuri.

Tropicolpus healyi is one of a number of large mid-Cenozoic New Zealand turritellids variously assigned to *Tropicolpus* (sensu stricto), *T. (Amplicolpus)* or *Maoricolpus* (see Marwick 1971a). *T. (Amplicolpus) cavershamensis* (Otaian-Altonian, widespread) is closest to *T. healyi*, but is rather more slender and does not have spiral C so strongly projecting on adult whorls.

Figured specimen (Pl. 14k): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 0.67.

Crepidula radiata (Hutton) (Pl. 14 b,e) is described below, in the chapter on Late Miocene Mollusca (with the specimen on Pl. 29 j).

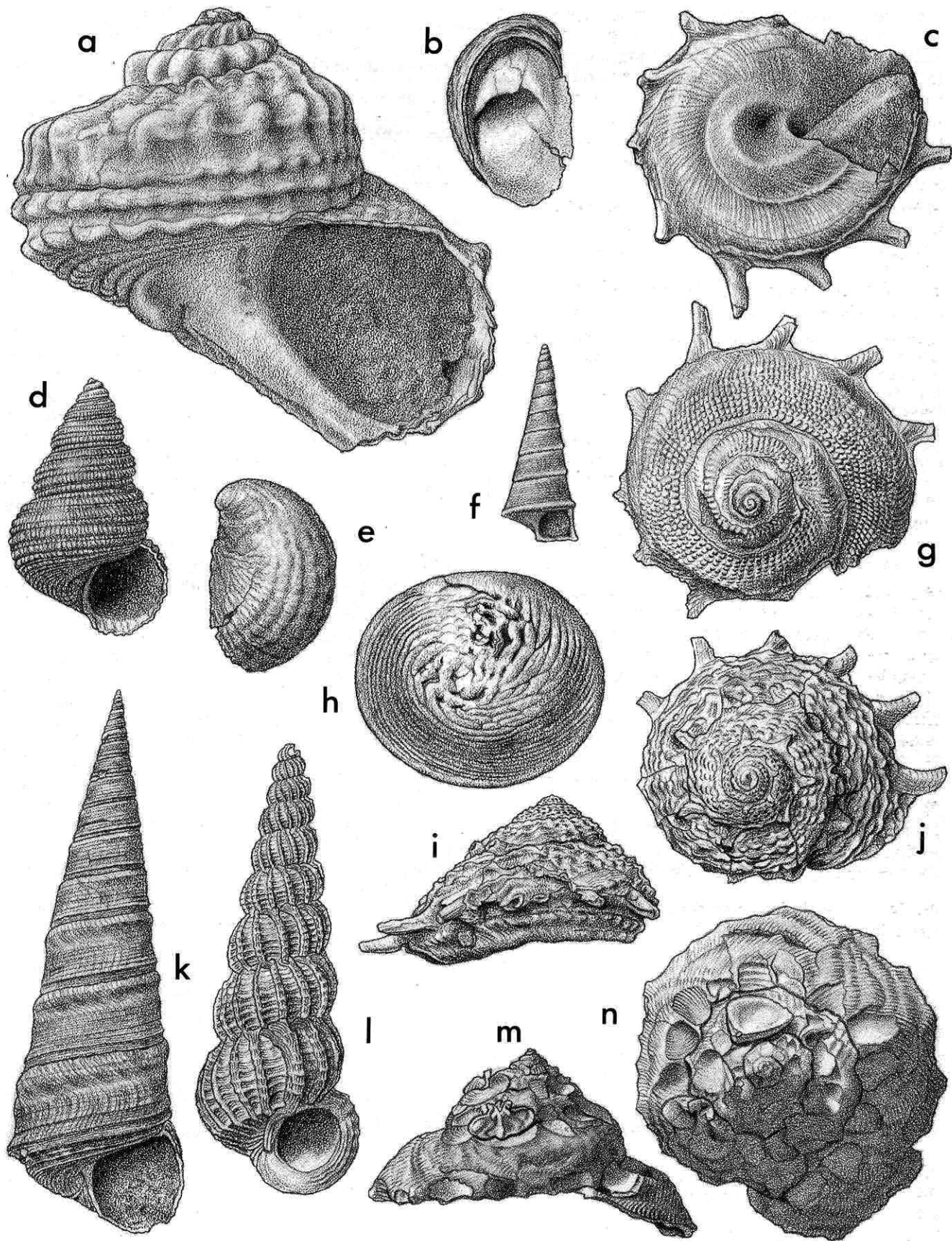
Pl. 14 m, n. *Xenophora prognata* (Finlay, 1926) [*Onustus prognatus* Finlay 1926b, p. 228] (Xenophoridae).

Moderately to very large for family (diameter 80-140 mm or more, including attached objects), trochiform, spire low, almost straight-sided; edge of upper surface projecting as ridge (or rim) around edge of flat or slightly concave base; no umbilicus. Sculpture on upper surface of rather indistinct, low, narrow, wavy collabral ridges and spiral cords; on base, of low, collabral ridges and very weak spiral threads. Attached objects consisting of large pebbles, concave-side-up bivalves (up to 50 mm wide) and much rarer gastropods, cemented into rim of each whorl, so forming part of upper surface of succeeding whorl. Aperture very low and wide, subrectangular; lower lip deeply excavated.

Runangan-Lillburnian; "Wharekuri Greensands", Duntroonian (type—probably from Waitaki River, opposite Wharekuri), and from numerous localities throughout New Zealand (Beu 1977b).

Plate 14 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (5).

- a,h. *Sarmaturbo* n.sp., x 1(a) and x 1.5(h).
- b,e. *Crepidula radiata* (Hutton), x 1; [Note: described in Late Miocene chapter, with specimen in Pl. 29 j].
- c,g. *Guildfordia (Guildfordia)* n.sp., x 1.
- d. *Gegania (Tubena) olsoni* (Maxwell), x 3.
- f. *Gazameda grindleyi* (Marwick), x 3.
- i,j. *Astraea bicarinata* Suter, x 0.67.
- k. *Tropicolpus (Amplicolpus) healyi* Marwick, x 0.67.
- l. *Cirsotrema lyratum* (Zyttel), x 1.5.
- m,n. *Xenophora prognata* (Finlay), x 1.



Topotypes of *Xenophora prognata* are among the largest known xenophorids ("carrier-shells"), commonly reaching 120 mm or more in diameter, but smaller specimens from other localities show no differences other than size. *X. neozelanica* (Opoitian-Recent) differs in its markedly taller spire and coarser basal sculpture. A quite distinct species is *X. flemingi* (Altonian-Clifdenian and possibly Lillburnian, Clifden and North Taranaki); this has flat sides, weak sculpture and very small attached objects. *X. neozelanica* occurs today on soft substrates on the shelf, in depths of about 10-150 m, and *X. prognata* seems to have lived in similar shallow facies. *X. flemingi* occurs in deeper-water siltstone, and at Clifden it occurs in different beds from *X. prognata*.

Figured specimen (Pl. 14m, n): GS7166, I40/f7551, Brother's Stream, Hakataramea Valley, Waitakian (NZGS) x 1.

Pl. 15 a. *Struthiolaria* (*Struthiolaria*) cf. "prior Finlay, 1926b" [p. 228] (*Struthiolariidae*).

The status of *S. prior* is uncertain, but it seems probable that it is not worth separating from *S. calcar* (= *S. subspinosa*) (see Pl. 20 g,h). Finlay (1926b, p. 228) separated it from *S. calcar* on the basis of its lower-placed shoulder angulation, its finer spiral sculpture and its more coarsely nodulose peribasal angulation, but these alleged differences do not seem to be constant. *S. prior* was based on two specimens from the Chatton Formation at Waikaia, Southland (Duntroonian), a locality apparently no longer accessible to collectors; the specimen figured here is from approximately coeval beds about 15 km to the south-east. It is figured here because of its interest as one of the earliest records of the genus.

Although *Struthiolaria* is one of the most distinctive and characteristic gastropod genera in the New Zealand mid- and late Cenozoic, its antecedents are unknown. The problem is exacerbated by the absence of any record of the family in the New Zealand region during the Late Eocene and Early Oligocene (Kaiatan-Whaingaroan). *Monalaria*, which was widespread during the Bortonian (see Pl. 6a,b), seems to be an unlikely candidate for an ancestor to *Struthiolaria*, if only because of its very different sculptural plan. The sculpture of early species of *Struthiolaria* such as *S. calcar* is instead very similar to that of the Early Paleocene *Conchothyra australis* (Pl. 12g,h), and despite important differences in columellar and outer-lip characters between these taxa, it seems likely that *Struthiolaria* was derived from *Conchothyra* or a related taxon, possibly outside the New Zealand region.

Figured specimen (Pl. 15a): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 1.5.

Pl. 15 f. *Magnatica* (*Magnatica*) *planispira* (Suter, 1917) [*Polinices planispirus* Suter 1917, p. 10; *Natica* (*Magnatica*) *suteri* Marwick, 1924d, p. 555-556 (unnecessary name change for *P. planispirus*); *Magnatica powelli* Laws 1932, p. 190-191]. Type species (as *N. suteri*) of *Magnatica* Marwick, 1924 (Naticidae: Naticinae).

Large for family (height 40-65 mm), robust, ovate or globose; spire of variable height, considerably lower in many shells than in figured specimen. Protoconch not known, teleoconch whorls expanding very rapidly. No sculpture apart from growth lines and very fine spiral striae. Aperture large, semilunar; inner lip almost straight, heavily callused

in parietal region, thickened abapically by low, rounded, circumumbilical ridge. Umbilicus of variable size, typically rather narrow but deep, with obscure grooves and ridges within. Outer lip sinuous, retracted to suture. Operculum large, ovate, rather thick.

Duntroonian-Altonian; Mount Harris Formation, Bluecliffs, South Canterbury, Otaian (type locality of *P. planispirus*) (very rare); Ardgowan Shellbed, Oamaru, Altonian (type locality of *M. powelli*) (uncommon) and numerous localities throughout New Zealand, mostly in inner to mid-shelf facies, but apparently extending into deeper waters (outer shelf or upper slope).

Magnatica planispira is a particularly common and conspicuous member of the faunules in the Wharekuri Greensand at Lake Waitaki and the Otekaie Limestone at Trig Z, Otiake. *M. powelli* cannot satisfactorily be separated from *M. planispira* and is here regarded as a synonym. Three other nominal species of *Magnatica* (sensu stricto) have been described; *M. approximata* was based on very poor material from "Wharekuri" (probably Whaingaroan rather than Duntroonian) and may be another synonym of *M. planispira*. The poorly known *M. fons* (Bortonian, Waihao Downs) seems to have been considerably smaller than *M. planispira* (height of holotype only 22.5 mm) and has a sharper circumumbilical ridge. *M. nuda* (Tongaporutuan, North Taranaki) is even smaller (height of holotype 13 mm) and has a relatively wide umbilicus. Marwick (1924d, p. 555) provided the replacement name *Natica suteri* for *P. planispirus* Suter, because of the prior *Natica planispira* Phillips, 1863. However, with recognition of *Magnatica* as a genus, Finlay (1927b, p. 500) reintroduced Suter's name, so it has escaped the requirements of ICZN Article 59(b).

M. planispira is readily distinguished from most other New Zealand naticids by its large size, its thick shell, its typically globose shape with rapidly expanding whorls, and its laterally restricted parietal callus. Some species of the subgenus *Magnatica* (*Spelaenacca*) (see below) are superficially similar but differ in having a step-like ridge ascending well within the umbilicus. The distinctive large operculum is found within the aperture of a few specimens (Graham 1965).

Figured specimen (Pl. 15f): GS10837, I40/f001, head of Lake Waitaki, Duntroonian (NZGS) x 1.

Pl. 15 i. *Magnatica* (*Spelaenacca*) *sutherlandi* (Marwick, 1924) [*Natica* (*Magnatica*) *sutherlandi* Marwick 1924d, p. 555; *M. (Spelaenacca) altior* Finlay 1926b, p. 228-229]. Type species (as *M. altior*) of *Spelaenacca* Finlay, 1926 (Naticidae: Naticinae).

Moderately large for family (height 32-42 mm), ovate, spire low, conic. Protoconch not clearly differentiated from teleoconch in available specimens. Teleoconch whorls rapidly expanding. No sculpture apart from growth lines. Aperture semilunar; inner lip thickened adapically by rounded circumumbilical ridge; parietal callus moderately thick. Umbilicus with a sharp-edged, step-like ridge within.

Duntroonian; Chatton Formation, Shell Gully, Chatton (type locality of *N. sutherlandi*) (not uncommon); Wharekuri Greensand, Wharekuri (type locality of *M. altior*) (uncommon).

Magnatica (*Spelaenacca*) *sutherlandi* is similar to *M. planispira* (see above), with which it occurs at both localities, but is taller-spined than most specimens of the latter species, and has less rapidly expanding teleoconch

whorls, lacking faint spiral sculpture, and has a sharp ridge well within the umbilicus. *M. (Spelaenacca) parilis* (Kaiatan, McCulloch's Bridge) is very similar to *M. sutherlandi*, but has a wider umbilicus and a more prominent intra-umbilical ridge. Other named species of *Spelaenacca* are considerably smaller than *M. sutherlandi* or *M. parilis*.

Spelaenacca has a recorded range of Wangaloan to Clifdenian. Although it is ranked as a subgenus of *Magnatica* it is possible that the two taxa are not as closely related as this classification suggests.

Figured specimen (Pl. 15i): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.5.

Pl. 15 h. *Globisium crassiliratum* Finlay, 1926b [p. 230] (Naticidae: Globisininae).

Small for genus (height 11-14 mm), globose, spire relatively elevated. Protoconch depressed dome-shaped, of about 2.5 smooth whorls. Teleoconch whorls strongly convex, sutures distinctly impressed. Sculpture of relatively prominent, rounded or flat-topped spiral cords with some interstitial threads, crossed by growth lines and ridges. Inner lip almost straight, parietal callus rather thick. Umbilicus relatively broad.

Duntroonian-Waitakian; Otekaike Limestone, Trig Z, Otiake, Waitakian (type); Campbell Park School, Otekaike; Wharekuri Greensand, Wharekuri.

Globisium crassiliratum is readily distinguished from other species of *Globisium* (particularly *G. miocaenicum*, which also occurs at the first two localities) by its small size, its relatively high spire, its coarse spiral sculpture and its rather wide umbilicus.

Figured specimen (Pl. 15h): GS9517, Campbell Park School, Waitaki Valley, Waitakian (NZGS) x 3.

Pl. 15 b. *Ficus* n. sp. (Ficidae).

Moderately large for genus (height 50-75 mm), fig-shaped, with low, weakly stepped spire of slightly concave outline. Protoconch low dome-shaped, of 2.75 smooth whorls, apex narrowly coiled, terminal sculptured zone not distinguishable on the rather poorly preserved material (all from sandstone). Teleoconch of about 4.5 whorls, each largely enveloped by succeeding whorl; sutural ramp wide, slightly concave. Last whorl very large, elongate, swollen and strongly convex apically, but contracting gradually to a long, curved neck abapically. Sculpture of many fine, low, closely spaced spiral cords, alternating regularly in strength on most specimens (but quite variable in detail), crossed by many low, weak, irregular axial costellae, larger shells typically with low, irregular folds on ramp and periphery. Aperture pyriform, with a moderately long, widely open siphonal canal, weakly deflected to left, no fasciole. Inner lip with a thin callus smear over columella, extending above top of aperture and visible as a smooth zone around lower third of penultimate whorl. Outer lip thin, simple, retracted to suture, with a very shallow sinus over sutural ramp.

Whaingaroan(?), Duntroonian-Waitakian; Wharekuri Greensand, Wharekuri; Otekaike Limestone, Waitaki Valley; Chatton Formation, Wendon Valley.

The unnamed species is similar to the Australian basal Miocene (Longfordian) species *F. altispira* (Pritchard, 1896) (Fossil Bluff near Wynyard, northern Tasmania), and apparently has an identical protoconch, but *F. altispira* has consistently finer and closer spiral cords and much more regular, fine, close axial threads than the New Zealand material. *F. imperfecta* (Altonian, Oamaru) was based on a very immature specimen from Target Gully Shellbed, but a much better specimen from South Oamaru shows that it is a low-spined, very finely sculptured species with a raised cord forming a slight shoulder angle, and low, rather long, narrowly crested axial folds situated regularly and extending down onto the last whorl (of a

small specimen). A similar, apparently also unnamed species is reasonably common in Altonian and Clifdenian siltstone at Clifden, and differs from *F. imperfecta* in its narrower form and its still finer spiral sculpture. *F. parva*, described from "Old Rifle Butts", Cape Wanbrow, Oamaru (Whaingaroan?) and recorded from several Kaiatan or Runangan localities in North Otago and South Canterbury, is a consistently small species (largest seen, from Lorne, 33 mm high) with very fine sculpture, a tall spire and a large, low protoconch of 3.0 whorls, of which only the last quarter-whorl has spiral threads.

Ficus is a well-known predator on echinoids in warm, shallow waters around tropical reefs and on the inner to mid-shelf, and this corresponds well with its shallow-water occurrences in New Zealand.

Figured specimen (Pl. 15b): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 1.

Pl. 15 c,g. *Typhis (Hirtotyphis) panoplus* Maxwell, 1971 [p. 778] (Muricidae: Typhinae).

Moderately large for genus (height 20-40 mm), biconic, spire 0.4-0.5 total height. Protoconch subcylindrical, of 2 smooth, convex whorls. Teleoconch of 4.5-6 whorls, each with 4 varices. Varices on last whorl with 3 prominent, tubular, slightly backward-curved spines, the topmost somewhat stronger than the others; varices on spire whorls typically with only top spine exposed but middle one exposed as well on some specimens. Intervariceal tubes long, directed backwards and upwards at 30-40°; terminal tube very long and slightly curved, up to half shell height in length. Aperture subcircular, peristome continuous, slightly reflected.

Waitakian; Brother's Stream, Hakataramea (type); Sisters' Creek, Hakataramea; Trig Z, Otiake. Uncommon at all localities.

Typhis panoplus differs from species of *Typhis* (sensu stricto) (e.g. *T. hebetatus*, Pl. 20r) in having three prominent spines on each varix on the last whorl, rather than the four to six much smaller ones present in the latter group. The only other known New Zealand species of *Hirtotyphis*, *T. (Hirtotyphis) aoteanus* (Tongaporutuan, Wairarapa), differs from *T. panoplus* in having the adapical variceal spine much stouter and the abapical spine heavily reduced.

Figured specimen (Pl. 15c, g): holotype, GS7166, I40/f7551, Brother's Stream, Hakataramea Valley, Waitakian (TM4932, NZGS) x 1.5.

Pl. 15 d. *Austrofusus (Austrofusus) affiliatus* Finlay, 1926b [p. 238] (Buccinidae).

Rather small for genus (height 27-37 mm), bucciniform, spire 0.5 total height. Protoconch conical, of about 4 whorls with opisthocyrte costae on last half whorl, otherwise smooth. Teleoconch of 6-6.5 whorls, first whorl convex, later whorls bluntly to sharply shouldered at 0.5-0.6 whorl height on spire, sutural ramp steep, sides subvertical or sloping inwards; last whorl with prominent peribasal angulation, contracted below to moderately long, twisted neck. Axial sculpture of prominent, rounded costae with somewhat broader interspaces, reaching from suture to suture on earliest whorls, but obsolete on upper part of base of last whorl, and in some shells becoming less distinct and more crowded near outer lip; 11-14 costae on penultimate whorl. Spiral sculpture of narrow, low, well-spaced cords, typically with interstitial threads, 3 cords on base typically considerably stronger than other spirals. Cords on angulations distinctly tubercular where they cross axial costae, other cords only slightly thickened or unaffected. Aperture ovate, columella concave above, strongly twisted to left below, forming a moderately long, slightly curved, notched siphonal canal; fasciole rounded, of variable development, much more prominent in some shells than in others. Outer lip with numerous fine lirae extending well within aperture, lirae developing at a very early stage of growth (height 14 mm).

Waitakian; Otekaike Limestone, Trig Z, Otiake (type); Campbell Park School, Otekaike; Brother's Stream and Sister's Creek, Hakataramea Valley; Mount Harris Formation, upper Tengawai River; Chatton Formation, Mataura River, near Brydone, Southland. Uncommon at Brydone, but common at other localities.

Austrofuscus affiliatus is distinguished from other species of *Austrofuscus* (sensu stricto) by its relatively small size and moderately fine spiral sculpture, by the development of rather prickly tubercles on the crests of the axial costae, and by having outer lip lirae developing at an unusually early stage of growth. *A. acuticostatus* (Pl. 6m) seems to be the most closely related species, differing in having much finer spiral sculpture.

Figured specimen (Pl. 15d): GS9516, I40/f6675, Trig Z, Otiake, Waitaki Valley, Waitakian (NZGS) x 1.5.

Pl. 15 j. *Cominella (Procominula) denselirata* (Finlay, 1926). [*Cominula (Procominula) denselirata* Finlay, 1926b, p. 242-243] (Buccinidae).

Small for genus (height 12-14 mm), ovate, spire a little less than half total height. Protoconch dome-shaped, of 1.2 strongly convex whorls, smooth except for a few weak axial costellae on last quarter-whorl. Teleoconch of 4.5 whorls, obtusely angled near middle on spire; last whorl excavated, with short neck. Axial sculpture of narrowly rounded costae with broad, concave interspaces, prominent from lower suture to shoulder angle on spire, but weaker or obsolete on ramp; barely persisting onto base; 8-10 costae on penultimate whorl. Spiral sculpture of numerous narrow, rather subdued cords with narrower interspaces, some shells with a slightly stronger cord on periphery. Aperture rather small with a short, left-deflected siphonal canal, notched anteriorly, forming a low fasciole. Outer lip smooth or finely lirate within.

Waitakian; Otekaike Limestone, Trig Z, Otiake (type) (moderately common); Campbell Park School (uncommon).

The subgenus *C. (Procominula)* includes small buccinids similar to *Cominella* (sensu stricto) but of smaller size and having a rather better-defined siphonal canal, and is recorded so far only from mid-shelf to upper bathyal

assemblages from North Otago and South Canterbury. *C. denselirata* differs from the other species primarily in its fine spiral sculpture.

Figured specimen (Pl. 15j): Trig Z, Otiake, Waitakian (NZGS, from an early collection) x 3.

Pl. 15 e. *Cominella (Josepha) chattonensis* (Finlay, 1926). [*Cominista chattonensis* Finlay 1926b, p. 244] (Buccinidae).

Size moderate for genus (height 25-35 mm), ovate, spire sharp, about half total height. Protoconch mamillate, of about 1.5 smooth whorls. Teleoconch of 6-7 whorls, obtusely angled below middle on spire, sutural ramp steep, slightly concave; last whorl only weakly excavated, anterior end rather broad. Axial sculpture of prominent rounded costae reaching from lower suture to shoulder angle on spire but obsolete on ramp; typically extending about halfway across base on last whorl, but reduced to elongate tubercles on periphery on some shells; 9-11 costae on penultimate whorl. Spiral sculpture of fine cords or threads over whole surface, but absent from much of many adult shells because of corrosion. Many shells with narrow spiral colour bands (pale orange as preserved), 6 on last whorl. Aperture large, ovate, columella bent to left below middle to form short, open, deeply notched siphonal canal; fasciole prominent, upper edge margined by narrow ridge, lower edge strongly projecting. Outer lip thin, smooth inside.

Duntroonian; Chatton Formation, Shell Gully, Chatton (type) (common).

Cominella chattonensis is similar to the Castlecliffian-Recent *C. (Josepha) glandiformis* but is considerably larger and has a less strongly concave sutural ramp, fewer but stronger axial costae and a more strongly projecting fasciole. *C. glandiformis* is a scavenger living on rocks or on mud-flats in estuaries only, but its several close Cenozoic relatives seem to have occupied the more normal shallow marine environment now occupied by *Cominella (Cominella)* species.

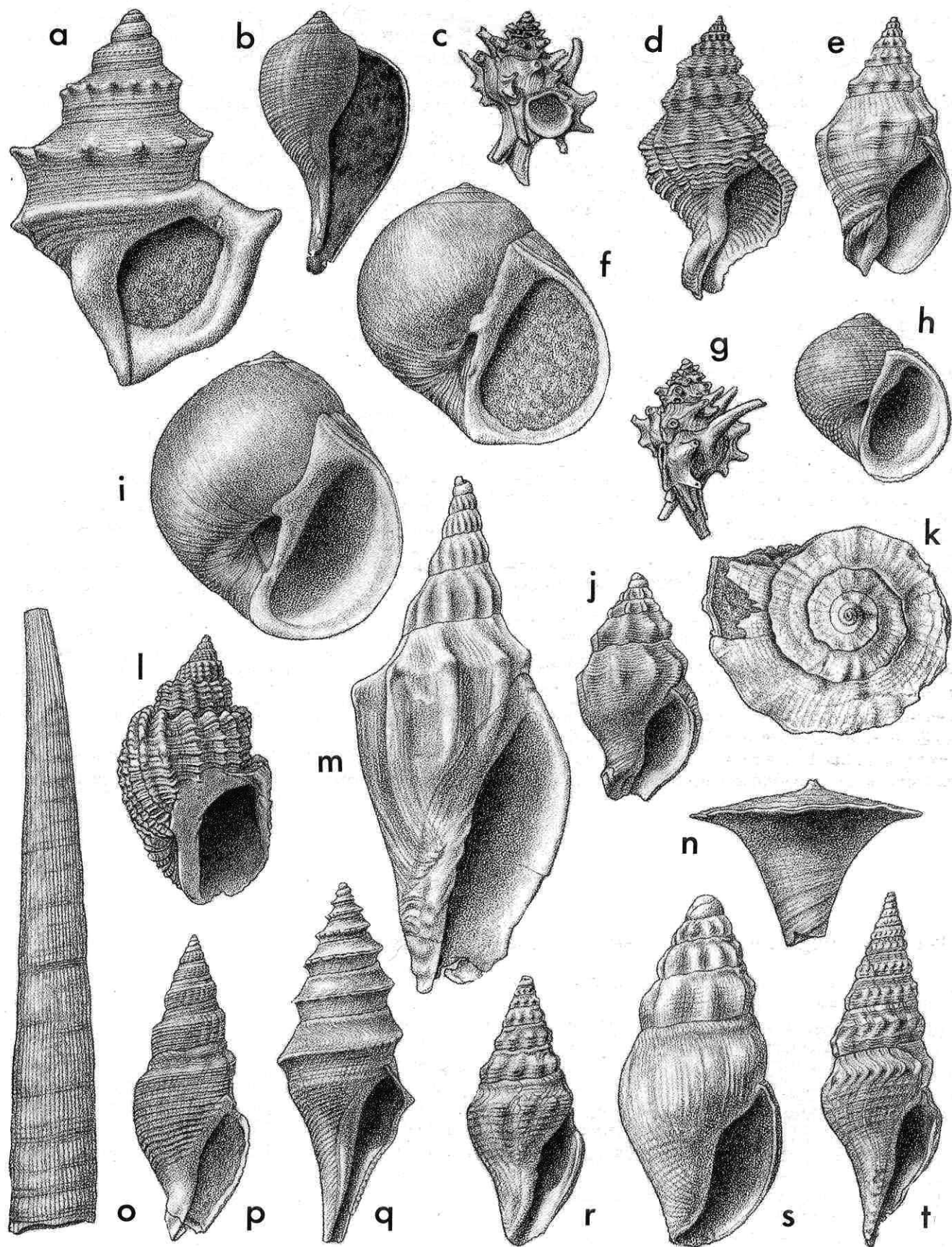
Figured specimen (Pl. 15e): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.5.

Pl. 15 m. *Alcithoe* (?) sp. (Volutidae: Zidoninae).

Size moderate for subfamily (height c.105 mm), broadly fusiform, spire

Plate 15 Late Oligocene-earliest Miocene (Duntroonian-Waitakian) Mollusca (6)

- a. *Struthiolaria (Struthiolaria)* cf. *prior* Finlay, x 1.5.
- b. *Ficus* n.sp., x 1.
- c,g. *Typhis (Hirtotyphis) panoplus* Maxwell, x 1.5.
- d. *Austrofuscus (Austrofuscus) affiliatus* Finlay, x 1.5.
- e. *Cominella (Josepha) chattonensis* (Finlay), x 1.5.
- f. *Magnatica (Magnatica) planispira* (Suter), x 1.
- h. *Globisium crassiliratum* Finlay, x 3.
- i. *Magnatica (Spelaenacca) sutherlandi* (Marwick), x 1.5.
- j. *Cominella (Procominula) denselirata* (Finlay), x 3.
- k,n. *Conus* (sensu lato) n.sp., x 2.
- l. *Scalptia*(?) *christiei* (Finlay), x 1.
- m. *Alcithoe* (?)sp., x 1.
- o. *Fissidentalium* n.sp., x 1.
- p. *Austrotoma inaequabilis* Marwick, x 1.5.
- q. *Parasyrinx (Parasyrinx) subalta* (Marshall and Murdoch), x 3.
- r. *Borsonia mitromorphoides* Suter, x 3.
- s. *Scrinium blandiatum* (Suter), x 8.
- t. *Eoturris uttlei* (Suter), x 2.



0.4 total height. Protoconch not known. Teleoconch of about 7 whorls, early whorls lightly convex, last 2 whorls becoming increasingly more strongly angled at or above middle on spire; last whorl feebly excavated below angulation, elongate. Axial sculpture on early whorls of narrow, slightly prosocline costellae reaching from suture to suture, on later whorls becoming obsolete on upper part of ramp and tubercular on shoulder angle; last whorl with 7-9 prominent, rounded costae with broad interspaces, those near outer lip less elongated axially than remainder. No spiral sculpture. Aperture large, inner lip almost straight with a thin callus smear extending some distance laterally; columella with 5 moderately prominent, subequal plaits and, on 1 shell, a 6th much weaker one above. Anterior notch deep; fasciole almost flush with whorl surface or slightly depressed. Outer lip thin, slightly flared.

Duntroonian; Chatton Formation, Wendon Valley; Shell Gully, Chatton (rare).

In the absence of the protoconch the generic location of this species must be rather uncertain, but the nature of the axial sculpture, particularly the development of tubercles on the shoulder angle, and the deep anterior notch suggest that it belongs in *Alcithoe* rather than *Spinomelon*. It has some resemblance to the highly variable *A. turrita* (Otaian-Altonian; Pl. 21s) and may be conspecific, although all other records of *A. turrita* are younger and from deeper-water facies than Wendon and Chatton. These Duntroonian records are included because they seem likely to represent the oldest known member of the most characteristic genus of volutes in the New Zealand Neogene.

Figured specimen (Pl. 15m): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Southland, Duntroonian (NZGS) x 1.

Pl. 15 k,n. *Conus* (sensu lato) n. sp. (Conidae).

Rather small for family (height c. 25 mm), spire very low. Protoconch not known, apical whorls projecting above rest of spire. Teleoconch apparently of about 6 whorls, upper surface rather irregular; last whorl with a thin, irregularly undulose peripheral keel, strongly concave below, apparently tapering to a long neck. Sculpture on upper surface of very weak spiral threads; base with more prominent, though very subdued cords.

Duntroonian, Chatton Formation, Wendon Valley; ?Waimumu Lime Quarry, Southland.

This distinctive cone is unlikely to be confused with any other New Zealand species. *C. trigonicus* (Pl. 8o, t) also has a very depressed spire, but differs from the above species in having relatively prominent spiral sculpture, a straight-sided or slightly concave last whorl, and a regularly curved, non-projecting periphery. We are not aware of any other Conidae in which the periphery protrudes to the degree it does in this new species.

Figured specimen (Pl. 15k, n): GS9805, F44/f9501, Coal Brook Station, Wendon Valley, Duntroonian (NZGS) x 2.

Pl. 15 t. *Eoturris uttlei* (Suter, 1917) [*Turris uttlei* Suter 1917, p. 47] (Turridae: Turrinae).

Size moderate for subfamily (height 22-38 mm), fusiform, spire slightly more than half total height. Protoconch not known, but presumably as in *E. complicata* (Pl. 8n). Teleoconch of 8-9 whorls, weakly angled near middle on spire; sutural ramp steep, concave, with moderate subsutural swelling, sides convex; last whorl excavated, with a moderately long, slightly curved neck. Axial sculpture of small, rounded, comma-shaped nodules, obsolete on ramp and scarcely extending below periphery, 16-17 on penultimate whorl, becoming obsolete on last whorl of some shells. Spiral sculpture of fine threads apparently over whole surface, with 1 or 2 somewhat stronger but rather subdued cords below periphery on spire whorls and 3 or 4 additional cords on base. Aperture pyriform with a moderately long siphonal canal. Anal sinus moderately deep, U-shaped, with apex just above periphery.

Waitakian; Otekaike Limestone, Trig Z, Otiake (type); Campbell Park School, Otekaike (uncommon).

Eoturris uttlei is distinguished from *E. complicata* (Pl. 8n) by its more weakly shouldered teleoconch whorls and by having comma-shaped rather than rounded peripheral nodules. This is the youngest known species of the genus.

Figured specimen (Pl. 15t): GS9517, I40/f9805, Campbell Park School, Otekaike, Waitakian (NZGS) x 2.

Pl. 15 q. *Parasyrinx* (*Parasyrinx*) *subalta* (Marshall and Murdoch, 1919) [*Leucosyrinx subaltus* Marshall and Murdoch 1919, p. 256] (Turridae: Turrinae).

Size moderate for subfamily (height 17-32 mm), fusiform-pagodiform, spire about half total height. Protoconch bulbous, of 1.5 smooth whorls. Teleoconch whorls 7-8, sharply keeled at or below middle on spire; sutural ramp steep, slightly concave; sides sloping inwards. Last whorl with peribasal angulation, considerably weaker than peripheral keel, excavated below with a moderately long, almost straight neck. No axial sculpture; spiral sculpture of fine threads on lower part of sutural ramp and below peripheral keel, extending onto base and neck. Aperture pyriform, with a narrow, long, unnotched siphonal canal. Anal sinus deep, U-shaped, apex near middle of ramp.

Duntroonian-Waitakian; Wharekuri Greensand, Wharekuri, Duntroonian (type); Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike; Kyeburn district; Mount Harris Formation, upper Tengawai River. Rare in Wharekuri Greensand, but common at other localities.

Parasyrinx subalta was probably ancestral to *P. alta* (Altonian; Pl. 22s), differing in having distinct spiral sculpture over most of the teleoconch rather than completely absent or confined to the lower part of the neck. *P. (Lirasyrinx) anomala* (Duntroonian, Wharekuri) has similar teleoconch sculpture to *P. subalta* but has a dome-shaped protoconch of about four whorls, the last two of which are spirally lirate.

Figured specimen (Pl. 15q): GS9517, I40/f9805, Campbell Park School, Otekaike Valley, Waitakian (NZGS) x 3.

Pl. 15 p. *Austrotoma inaequabilis* Marwick, 1929 [p. 922-923] (Turridae: Pseudotominae).

Size moderate for genus (height 30-40 mm), fusiform, spire 0.5-0.6 total height. Protoconch conical, of 3.5 whorls, initial whorl smooth, last whorl with spiral cords, last half with axial costellae. Teleoconch of 5-6 whorls, shouldered above middle on spire; sutural ramp strongly concave because of subsutural swelling; sides subvertical. Last whorl with well rounded periphery; whorl twisted anteriorly to form short neck. Axial sculpture commencing as narrow, low, rounded, opisthocline costae extending from shoulder angulation to lower suture, 16-18 per whorl, becoming obsolete on later whorls; numerous growth lines present over whole surface. Spiral sculpture of fine threads on ramp, 1 or 2 slightly stronger ones on subsutural swelling; more prominent but narrow cords below, 6-8 on penultimate whorl, and 10-12 additional cords on base and neck, some cords with interstitial threads. Finer spiral elements reticulated by growth lines, cords typically smooth and polished, only feebly crenulated. Aperture subrectangular; columella twisted anteriorly to form short, deeply notched siphonal canal. Fasciole prominent, ridge-margined. Inner lip thinly callused; outer lip thin, with a shallowly arcuate sinus on ramp, strongly convex below.

Duntroonian, Chatton Formation, Shell Gully, Chatton (type) (uncommon).

Austrotoma inaequabilis is distinguished from other species by its relatively slender shape, its narrow axial costae that become obsolete on about the fourth whorl, and its narrow spiral cords. *A. nervosa* (Pl. 22k) is similar, but is larger, has axial costae disappearing at an earlier stage of growth, and has more prominent spiral cords, most of which are without interstitial threads. Numerous species of *Austrotoma*, many of them undescribed, are known and

most require careful study before they can be identified confidently. The genus is very doubtfully recorded from the Wangaloan, and confidently from Whaingaroan to Waipian, in inner shelf to outer shelf or upper bathyal facies.

Figured specimen (Pl. 15p): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.5.

Pl. 15 r. *Borsonia mitromorphoides* Suter, 1917 [B. (*Cordieria*) *mitromorphoides* Suter 1917, p. 59] (Turridae: Borsoniinae).

Size moderate for subfamily (height 18-23 mm), shape rather variable, some shells (including holotype) with lower spire than figured specimen. Protoconch mamillate, of c. 2 smooth whorls. Teleoconch whorls weakly shouldered below middle on spire; sutural ramp slightly concave; last whorl excavated, with short neck. Axial sculpture of very short costae or nodules between shoulder angle and lower suture, becoming obsolete on later part of last whorl; 9-10 per whorl. Spiral sculpture very subdued, subobsolete on ramp, of fine threads below. Columella slightly convex, bearing 2, or in a few specimens 3, plaits. Outer lip with moderately deep, U-shaped anal sinus on ramp.

Duntroonian, Wharekuri Greensand, Wharekuri (type); head of Lake Waitaki (uncommon).

Borsonia includes fusiform or biconic turrids with a moderately deep, rounded anal sinus on the sutural ramp, and one or two (rarely three) distinct columellar plaits. The genus has a sporadic record in New Zealand, from Bor-tonian to Clifdenian. Extant species are bathyal, but fossil species are mostly from moderately shallow-water facies.

Figured specimen (Pl. 15r): "Wharekuri", Waitaki River, Duntroonian (NZGS) x 3.

Pl. 15 s. *Scrinium blandiatum* (Suter, 1917) [*Mangilia blandiata* Suter 1917, p. 55] (Turridae: Mitromorphinae).

Size moderate for subfamily (height 7-8 mm), elongate-ovate, spire 0.5-0.6 total height. Protoconch dome-shaped, of 1.2 whorls, smooth except for feeble axial costellae near end. Teleoconch of 4 whorls, weakly angled above middle on spire; sutural ramp strongly concave because of subsutural swelling, sides convex; last whorl weakly excavated. Axial sculpture of low, rather broadly rounded costae with broad, concave interspaces, almost obsolete on ramp, extending to lower suture on spire and dying out quickly on upper part of base of last whorl; becoming obsolete on later part of last whorl on some shells; 7-9 on penultimate whorl. Spiral sculpture very weak, of obscure threads and grooves, most prominent on base, and almost completely obsolete on some shells. Aperture ovate, columella smooth, bent to left anteriorly to form very short, unnotched siphonal canal. Outer lip thin, weakly flexuous, without a definite anal sinus.

Waitakian; Otekaike Limestone, Trig Z, Otiake (type); Campbell Park School, Otekaike (uncommon).

Scrinium blandiatum is distinguished from other New Zealand species of *Scrinium* by its small size, its strongly concave sutural ramp, its broadly rounded axial costae and its very feeble spiral sculpture. *S. callimorphum* (Duntroonian, Wharekuri) is considerably larger (height 16 mm) than *S. blandiatum* and has more prominent axial and spiral sculpture. *Scrinium* has a recorded range of Duntroonian to Recent in New Zealand and a similar range in Australia, but the Australian fossil species are only tentatively referred to the genus (Powell 1966, p. 67). Apart from the lack of columellar plaits, species such as *S. blandiatum* and *S. callimorphum* closely resemble species of *Cordieria* (Pl. 8m), a possible clue to their origin.

Figured specimen (Pl. 15s): GS9517, I40/f9805, Campbell Park School, Otekaike, Waitakian (NZGS) x 8.

Pl. 15 l. *Scalptia* (?) *christiei* (Finlay, 1924) [*Trigonostoma*

christiei Finlay 1924b, p. 466-467] (Cancellariidae: Cancellariinae).

Moderately large for family (height 40-53 mm), elongate-ovate, spire narrowly pointed, half total height. Protoconch mamillate of 2.5 strongly convex whorls, smooth except for weak spiral threads on last half-whorl. Teleoconch of 6-7 whorls, convex at first, soon developing a narrow horizontal shelf with its outer edge coronated by axial costae, shelf becoming channelled on later whorls on some shells; sides subvertical, slightly convex; last whorl convex, anterior end narrow. Axial sculpture of prominent, rounded, prosocline costae, reaching from suture to suture on early whorls but weakening considerably or even becoming obsolete on sutural shelf and becoming more widely and more irregularly spaced on later whorls; extending across base to fasciole on last whorl, and continuing, though much reduced, into pseudumbilicus; 13-15 costae on penultimate whorl. Spiral sculpture very weak or obsolete on sutural shelf; below shoulder consisting of low rounded or somewhat flattened prominent cords, each pair typically with a narrower interstitial cord and in some cases, threads as well; 4 or 5 primary cords on penultimate whorl and 7 or 8 additional ones on base of last whorl. Spirals crossing axial costae unchanged. Aperture ovate-trigonal, with a shallow anterior spout; columella inclined somewhat to right, bearing 2 prominent plaits and in some shells, a much weaker one anterior to them. Inner lip thickly callused in adult shells, outer edge detached in some specimens, smooth except for a few weak tubercles or ridges near anterior end. Outer lip almost straight, prosocline, smooth within. Fasciole prominent, convex, forming a small pseudumbilicus between it and inner lip.

Duntroonian, Chatton Formation, Shell Gully, Chatton (type), uncommon.

Scalptia (?) *christiei* is is one of the largest New Zealand cancellariids, rivalled in size only by *Maorivetia brevisrostris* (Pl. 22f). Although long included in *Trigonostoma* Blainville, 1827, it differs markedly from the type species, *T. scalare* (Gmelin, 1791) (Recent, Indo-Pacific), which has loosely coiled, almost disjunct teleoconch whorls, a very broad sutural shelf, a triangular aperture, and a true umbilicus. Finlay (1924b, p. 466) originally assigned *T. christiei* and the closely similar *T. waikaiaensis* Finlay, 1924 to the "section" *Ventri-lia* Jousseaume, 1887 but the species assigned to that taxon (based on the Recent Caribbean *V. ventrilia* Jousseaume, 1887, = *Cancellaria tenera* Philippi, 1848) share most of the important diagnostic characters of *Trigonostoma*. *T. christiei* and *T. waikaiaensis* are here referred somewhat doubtfully to *Scalptia* Jousseaume, 1887, which differs from *Trigonostoma* in having three rather than only two columellar plaits. Species referred to *Scalptia* further differ from *Trigonostoma* in being more narrowly umbilicate, or pseudumbilicate or even non-umbilicate. *S. christiei* differs from typical *Scalptia* species in its much larger size, in having a weak third plait (obsolete in some large shells) and in lacking internal lirae on the outer lip.

S. waikaiaensis was described on the basis of three specimens from Muddy Terrace, Waikaia, Southland, from a horizon of about the same age (Duntroonian) as *S. christiei* but no longer accessible. According to Finlay (1924b, p. 466) it differs from *S. christiei* in its smaller size and in having less strongly staged whorls and fewer axial costae, but more material is required before it can be determined if it is really a distinct species.

Figured specimen (Pl. 15l): GS9806, F45/f9668, Shell Gully, Chatton, Duntroonian (NZGS) x 1.

Pl. 14 d. *Gegania* (*Tubena*) *olsoni* (Maxwell, 1969) [*Tubena olsoni* Maxwell 1969, p. 180-181] (Mathildidae).

Moderately large for family (height 15-18 mm), turbiniform, spire 0.7 total height. Protoconch heterostrophic, inverted, of c. 1.5 smooth whorls. Teleoconch of 5 strongly convex whorls, last whorl capacious,

with a moderately wide umbilicus. Spiral sculpture rather variable, commencing as 2 or 3 narrow cords, which in some shells remain dominant throughout growth, but in others are rivalled by other cords appearing during growth. Last whorl with 11-15 low, rounded or flattened cords, some with interstitial threads, more crowded on base. Axial sculpture of fine growth ridges, varying considerably in strength and spacing, even on an individual, finely crenulating or nodulating spiral cords. Aperture subcircular, inner lip slightly expanded over umbilicus; edge of outer lip finely crenulate.

Bortonian-Otaian; Otekaike Limestone, Sister's Creek, Hakataramea Valley, Waitakian (type); Brother's Stream; Waihao Downs; Waihao Greensand, McCulloch's Bridge; Waiareka Volcanic Formation, Lorne; Wharekuri; Bluecliffs, Otaio River. Uncommon to rare.

Gegania (Tubena) viola (Altonian, Kakanui) — the type species of *Tubena* Marwick, 1943 — differs from *G. olsoni* in having biangulate teleoconch whorls and narrower spiral cords. *Tubena* differs from *Gegania* (sensu stricto) in being umbilicate, a difference that may not warrant even sub-generic separation. *Gegania* (sensu lato) has a recorded range of Mangaorapan to Recent in New Zealand, although the extant species *G. valkyrie* Powell, 1971 is atypical in that it has a shallow V-shaped notch in the outer lip. *Kaitangata* Finlay and Marwick, 1937 [type species *K. hendersoni* (Wangaloan, Wangaloa)] was originally referred to the Potamididae, but it may be closely related to — if not congeneric with — *Gegania*; the protoconch is unfortunately not known.

Figured specimen (Pl. 14d): GS4901, I40/f7515, Sister's Creek, Hakataramea Valley, Waitakian (NZGS) x 3.

Pl. 14 l. *Cirsotrema (Cirsotrema) lyratum* (Zittel, 1864) [*Scalaria lyrata* Zittel 1864, p. 41; *Scalaria browni* Zittel 1864, p. 42; *S. rugulosa* "Sowerby" (not of Sowerby, 1846); *S. rugulosa lyrata*; *Epitonium (Cirsotrema) rugulosum lyratum*; *E. (Cirsotrema) lyratum*; *Cirsotrema browni*] (Epitoniidae).

Rather large for family (height 45-85 mm), spire very elevated. Protoconch not known. Teleoconch of at least 10 strongly convex whorls; sutures obscured by fusion of adapical ends of axial costae to supramarginal cord on previous whorl. Last whorl with well-developed basal disc, its outer edge well below periphery, flat except for narrow fasciole adjacent to aperture. Axial sculpture of prominent, prosocline costae composed of numerous lamellae fused together, convex or almost flat on front (adapertural) face, concave behind. Varices at irregular intervals, typically markedly thicker than costae, with from 1-13 costae between each pair of varices; 13-15 axials per whorl. Costae and varices slightly excavated adapically, with a small spine on edge of sulcus; all axials extending across base to fasciole. Spiral sculpture of 6-8 narrow, low cords that surmount axials, with fine threads in between, the latter reticulated by growth lines. Cord margining lower suture emerging on last whorl as edge of basal disc. Aperture circular, peristome continuous, basal lip slightly truncate.

Whaingaroan-Duntroonian, ?Waitakian; Aotea Harbour, Southwest Auckland, Duntroonian ? (type locality of both *S. lyrata* and *S. browni*).

Cirsotrema lyratum is recorded very widely from throughout North and South Islands, particularly from glauconitic sandstone and from limestone. Many of the records appear, however, to refer to other species. *C. lyratum* is here restricted to relatively large specimens in which the varices are noticeably more prominent than the costae, and the spiral cords are relatively strong and surmount the axials. Unfortunately, the limits of the species are very uncertain. *C. kuriense* (Pl. 6c) and *C. caelicola* (Altonian, Kakanui) have varices that are barely distinguishable from the costae. In *C. gagei* (Pl. 9m) the costae are blade-like, the varices are much more massive than the costae, and the spiral sculpture is very weak.

Unlike the vast majority of gastropods, the shells of species of *Cirsotrema* (and of some other epitoniids) are calcitic, and are therefore often preserved in faunules from which aragonitic species have been removed by diagenesis.

Figured specimen (Pl. 14l): Waitaki River, opposite Wharekuri, Duntroonian (NZGS, ex Suter Collection) x 1.5.

Pl. 15 o. *Fissidentalium* n. sp. (Dentaliidae)

Large for family (length 100-150 mm), thick-shelled except near aperture, distinctly curved proximally but almost straight over most of its length. Well preserved shells with narrow apical slit. Longitudinal sculpture commencing as narrow, rounded or subtriangular costae which are soon joined by secondary costellae, all tending to become subequal, broader, lower and more flattened during growth, in some large specimens becoming obsolete near aperture; about 45 costae on mature shells. Well preserved shells with numerous very fine longitudinal threads between and on costae. Transverse sculpture of numerous, closely spaced fine ridges that cross longitudinal costae unchanged, quite distinct on early part of shell but gradually becoming subobsolete distally.

Duntroonian, Wharekuri Greensand, Wharekuri; head of Lake Waitaki.

Shells of this type have been recorded from numerous localities, ranging in age from Duntroonian to Tongaporutuan, as "*Dentalium solidum* Hutton, 1873", but several distinct species seem to be involved. The lectotype of *D. solidum* is from "Waikari", North Canterbury, and is probably of Tongaporutuan age; probable topotypes differ from the Wharekuri species in having much weaker transverse sculpture.

Figured specimen (Pl. 15o): GS476, I40/f9379, Waitaki River, opposite Wharekuri, Duntroonian (NZGS) x 1.

CHAPTER 11. EARLY-MIDDLE MIOCENE FAUNAS (OTAIAN-LILLBURNIAN STAGES): PLATES 16-26

EARLY MIOCENE (OTAIAN AND ALTONIAN STAGES)

INTRODUCTION

The Early Miocene was a particularly important period

in the geological history of New Zealand, for at this time there was profound change in the style of marine sedimentation in the region — one that almost certainly reflects an equally far-reaching change in the nature of

tectonic activity. Whereas Paleogene sedimentary sequences are thin (except in a few local basins) and include rock units that are laterally continuous over wide areas, and are usually fine-grained and have high proportions of biogenic and authigenic components, those of Neogene age are for the most part of considerable thickness (several thousands of metres in many east coast North Island sequences), in many areas are of relatively local extent, and are predominantly terrigenous, with only minor development of limestone and greensand. Even in the relatively stable South Canterbury region the thickness of Early Miocene rocks (Mount Harris Formation and Southburn Sand) typically exceeds that of all of the Paleogene sequence combined. In the light of current geological knowledge, the most plausible explanation for this change in sedimentation patterns is the initiation of the Australian-Pacific plate boundary through New Zealand (i.e., commencement of dextral movement on the Alpine Fault), which Kamp (1986) and Kamp and Fitzgerald (1987) suggest took place at about 23 Ma (i.e., close to the Oligocene-Miocene boundary). (It should be noted, however, that Norris et al. (1978) and Norris and Carter (1982) favour a Late Eocene or Early Oligocene date for this event). Dramatic evidence for vigorous tectonic activity in New Zealand during the Early Miocene comes from Marlborough, where a spectacular mass debris deposit, the Great Marlborough Conglomerate, began to accumulate during Altonian time (Lensen in Suggate et al. 1978, p.486-7; Lewis et al. 1980). Even more striking, and regionally more significant, is evidence that the Northland Allochthon, a thick (as much as 2.5 km) pile of sedimentary and volcanic rocks of Cretaceous to Oligocene age, was emplaced from the north during Late Oligocene or Early Miocene time (Ballance and Spörli 1979).

The inception of a new tectonic/sedimentological regime during Early Miocene time must have had an important effect on the development of the New Zealand marine molluscan fauna; not only would the increase in areal extent of shallow-water terrigenous sediment have led to a corresponding increase in molluscan diversity—a conclusion that follows from an extension of the MacArthur-Wilson equilibrium theory of island biogeography to the marine realm (see Schopf et al. 1978)—but also the formation of discrete depositional basins would have facilitated speciation, particularly in molluscan groups with limited dispersal ability. Much of the history of shallow-water molluscs in the New Zealand Neogene record is one of diversification in such groups, e.g. Glycymerididae, Limopsidae, Limidae, Pectinidae (in part—some are free-swimming, and some seem to have had long larval lives), Carditidae, Mactridae, Veneridae, Trochidae, Rissoacea, Turritellidae, Struthiolariidae, Naticidae, Buccinidae (particularly *Austrofuscus*, *Buccinulum*, *Cominella* and *Penion*), Columbelloidae, Olividae, Volutidae, some Turridae, and Pyramidelloidae.

The Early Miocene is important to our understanding of the New Zealand Cenozoic molluscan fauna for another reason, as well—it is the first time since the Bortonian that significant molluscan faunules are recorded from northern New Zealand (i.e., Northland). Nearly all of the Paleogene faunules of any note are from the South Island, the main exceptions being the Bortonian faunule from Pahi, Kaipara Harbour, and a few small

ones of Landon Series age from South Auckland. Early Neogene molluscan faunules from such localities as the north shore of Parengarenga Harbour, Hokianga Harbour and Waimamaku Valley, Pakaurangi Point and Puketotara Peninsula in Kaipara Harbour, Cape Rodney, Muriwai Beach, and Waiheke Island include some of the most diverse assemblages recorded from the New Zealand Cenozoic, and the number of species from the combined Otaian and Altonian faunas in Northland greatly exceeds that known from the “classic” localities of similar age in North Otago and South Canterbury. Furthermore, there is little similarity between the faunas of these two areas; not only do they have very few species in common, but also many genus-group taxa recorded from Northland are not known from the North Otago-South Canterbury region (and to a lesser extent vice versa) (see Table 1). The differences are sufficiently great to warrant recognition of two distinct provinces (in the original sense of Woodward (1856, p.349) who maintained that at least 50% of the species in a region should be endemic to justify its recognition as a province). However, it should be noted that some of the taxa otherwise restricted to Northland during the Early Miocene (e.g., *Spondylus*, *Septifer*, *Hyphantosoma*, *Cypraea* (sensu lato), and *Oniscidia*) are also recorded from Southland Altonian rocks, so the “warm” province probably extended along the present west coast of the South Island into southernmost New Zealand at this time. (Some of these warm-water taxa are also recorded from the Clifdenian of Westland and Southland). It should also be stressed that the “temperate” province fauna includes a considerable number of taxa that are either extinct in New Zealand or survive in only the northernmost part of the country, and therefore indicate that conditions were warmer than at present (see below).

The marked differences between the molluscan faunas of Northland on the one hand, and the east coast of the South Island on the other, persist to the present day (although the concept of distinct marine provinces around New Zealand has fallen out of favour), and probably existed throughout much of the Cenozoic, so it is unfortunate that so little is known of the Paleogene and post-Early Miocene faunas of northern New Zealand. We therefore cannot be sure that taxa first recorded from the Northland Early Miocene were not present considerably earlier in that region. This should be borne in mind in the following account, in which the faunas of the warm and temperate provinces are discussed separately.

THE TEMPERATE FAUNA (FIG. 16): PLATES 16-22

Waitakian molluscan faunules from the upper part of the Otekaieke Limestone in North Otago and South Canterbury are probably earliest Miocene in age, and have been discussed in the previous chapter. With the exception of faunules from the Gee Greensand at Target Gully, Oamaru (Altonian at this locality), the only diverse Otaian and Altonian faunules from North Otago and South Canterbury come from two lithological units—a widely distributed siltstone and, in some sections, an overlying sandstone. The siltstone unit has gone under a variety of names (Pareora beds (or Formation), Mount Harris beds (or Formation), Rifle Butts Siltstone, and Bluecliffs Silt) but there can be little doubt that a single

Table 1 Some genera restricted to the warm or temperate provinces during Early Miocene (Otaian and Altonian stages) in New Zealand.

"Warm" fauna only (Northland, Westland & Southland)		"Temperate" fauna only (North Otago-South Canterbury)
<i>Brevinucula</i>	<i>Eudolium</i>	<i>Varinucula</i>
<i>Pseudotindaria</i>	<i>Latirogona</i>	<i>Notolimopsis</i>
<i>Acar</i>	<i>Mitrella</i>	<i>Trichomya</i>
<i>Cratis</i>	<i>Chicoreus</i>	" <i>Cyclocardia</i> "
<i>Septifer</i>	<i>Rugotypis</i>	<i>Condylocuna</i>
<i>Spondylus</i>	<i>Clifdenia</i>	<i>Finlayella</i>
<i>Dimya</i>	<i>Ēumitra</i>	<i>Peronaea</i>
<i>Ctenoides</i>	<i>Microvoluta</i>	<i>Austrodosinia</i>
<i>Cardita</i>	<i>Hiwia</i>	<i>Kereia</i>
<i>Salaputium</i>	<i>Oniscidia</i>	<i>Thoristella</i>
<i>Hyphantosoma</i>	<i>Spinaspira</i>	<i>Batillaria</i>
<i>Rohea</i>	<i>Lyria</i>	<i>Globisinum</i>
<i>Parapholas</i>	<i>Echinoturris</i>	<i>Galeodea</i>
<i>Pectinodonta</i>	<i>Cochlespira</i>	<i>Eucominia</i>
<i>Cocculina</i>	<i>Gemmula</i>	<i>Cominella</i>
<i>Munditia</i>	<i>Splendrillia</i>	<i>Procominula</i>
<i>Calliotropis</i>	<i>Microdrillia</i>	<i>Egotistica</i>
<i>Kaiparathina</i>	<i>Etrema</i>	<i>Zelandiella</i>
<i>Opella</i>	<i>Cryptodaphne</i>	" <i>Pleia</i> "
<i>Cirsochilus</i>	<i>Eubela</i>	<i>Parvimitra</i>
<i>Seguenzia</i>	<i>Mioawateria</i>	<i>Proximitra</i>
<i>Fluxinella</i>	<i>Tatara</i>	<i>Waimatea</i>
<i>Merelina</i>	<i>Discotectonica</i>	<i>Protoginella</i> (s.s)
<i>Manawatawhia</i>	<i>Granosolarium</i>	<i>Alocospira</i>
<i>Horologia</i>	<i>Spirolaxis</i>	<i>Alcithoe</i> (s.s)
<i>Inella</i>	<i>Fimbriatella</i>	<i>Insolentia</i>
<i>Triforis</i>	<i>Mathilda</i>	<i>Scrinium</i>
<i>Larochella</i>	<i>Crenilabium</i>	<i>Maorivetia</i>
<i>Scalaronoba</i>	<i>Taita</i>	<i>Aphera</i>
<i>Hipponix</i>	<i>Bartrumella</i>	<i>Turehua</i>
<i>Cheilea</i>	<i>Chrysallida</i>	<i>Costosyrnola</i>
<i>Archierato</i>	<i>Vaginella</i>	<i>Pukeuria</i>
<i>Cypraea</i>	<i>Williamia</i>	
<i>Ranella</i>	<i>Cryptoplax</i>	
<i>Cabestana</i>		

formation is involved. Unfortunately, Field and Browne (1986, p.39-41) have chosen to resurrect for this formation the very obscure name Tokama Siltstone, proposed by Mason (1941, p.120, as Tokama "Series") for siltstone and sandstone overlying the White Rock Limestone in the Grey River area, North Canterbury, and almost entirely ignored for more than 40 years. We feel strongly that a more familiar name should have been chosen, and have decided that Mount Harris Formation is the most appropriate name for this unit, the source of so many well known molluscs and other fossils. (We would have used the earliest name, Pareora Formation, but this was consistently used for both the siltstone and the sandstone, and the name is in current use for a chronostratigraphic series). In the type area (Waihao district, South Canterbury) the Mount Harris Formation includes sandstone interbedded with siltstone, but this does not preclude the use of the name for the siltstone with little or no sandstone at Bluecliffs and near the Old Rifle Butts, Cape Wanbrow, Oamaru. Mount Harris Formation varies considerably in age—in the upper

Tengawai River it is Waitakian throughout, at Bluecliffs it is Waitakian and Otaian, in the Waihao district Otaian and Altonian, and in northeast Otago it is Altonian throughout. Except for a very limited outcrop of probable Opoitian age in South Oamaru, and a Pleistocene shellbed underlying loess at Cape Wanbrow, it is the youngest marine unit exposed in coastal North Otago.

No nomenclatural problems are associated with the sandstone, however, for which the name Southburn Sand (Gair 1959, p.274) is available. This unit is Altonian throughout in most sections, but coarse, current-bedded sandstone overlying Mount Harris Formation in the upper Tengawai River is probably Waitakian.

No Otaian faunules of any note are known from North Canterbury, but diverse Altonian assemblages are recorded from several localities. In Castle Hill Basin, abundant molluscs occur in the lower part of the Enys Formation (Gage 1970, p.525-530), a sequence of shallow-marine to estuarine and non-marine sandstone and siltstone that forms the upper part of the Cenozoic succession in this area. In the Waipara district, shallow-

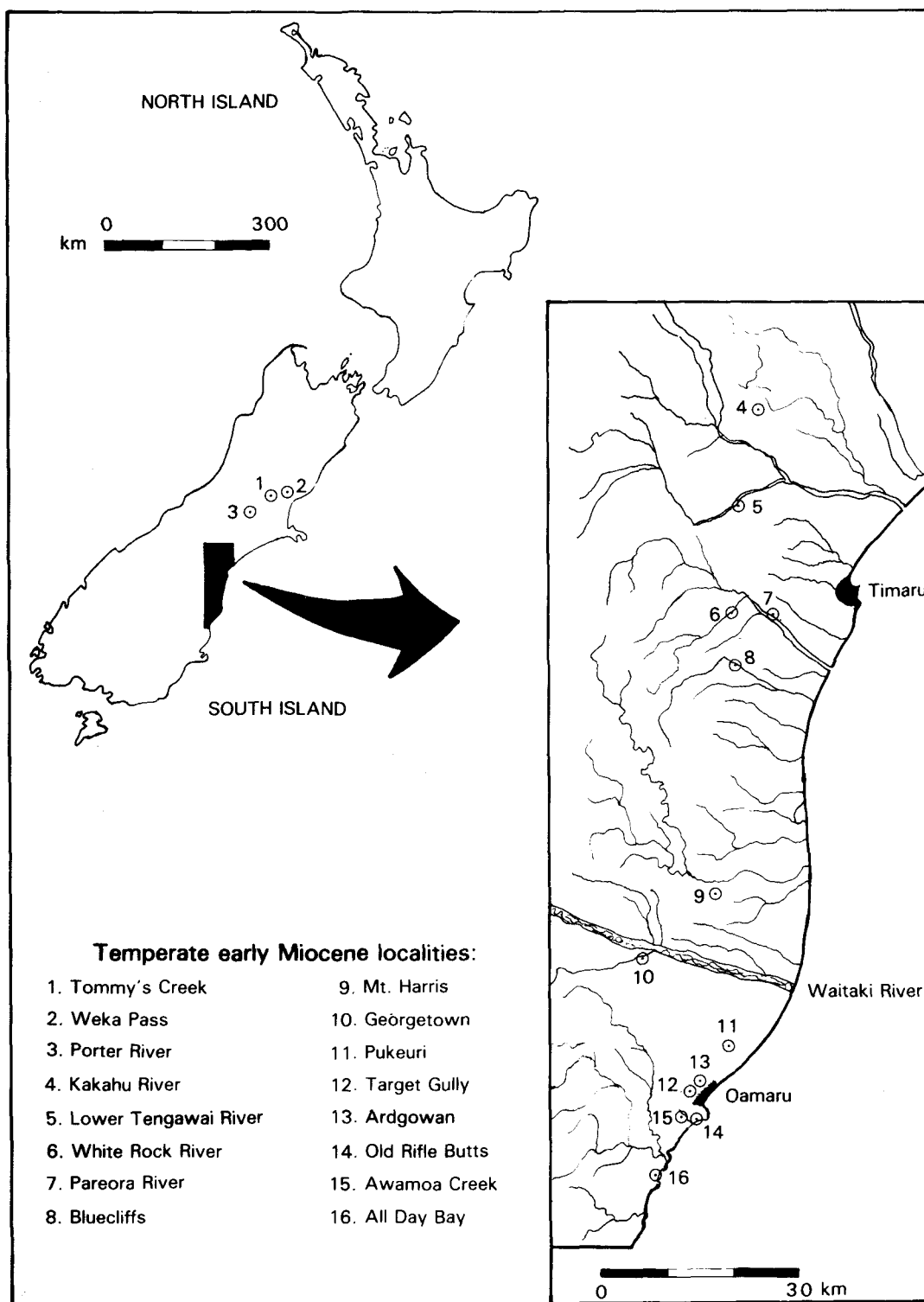


Figure 16 The main molluscan fossil localities in the temperate Early Miocene (Otaian and Altonian) province.

water Altonian faunules are recorded from the upper part of the Mount Brown Formation, which consists of calcareous sandstone with interbedded siltstone, shellbeds and coquina limestone, and on the whole represents a deeper-water facies than the Enys Formation.

Otaian faunules

The only diverse Otaian molluscan faunules recorded from the east coast of the South Island are in the Mount Harris Formation in South Canterbury. The best-known

is from the Otaian stratotype at Bluecliffs, Otaio River – an almost identical assemblage occurs at the foot of Mt. Horrible, Pareora River, and similar faunules occur in the Waihao district. The Bluecliffs faunule probably lived at outer shelf or upper bathyal depths and includes *Neilo awamoana*, *Limopsis zealandica*, *Lima colorata*, *Lentipecten hochstetteri*, *Spissatella trailli*, *Zeacolpus woodhouseae*, *Proterato neozelanica*, *Taniella notocenica*, *Friginatica vaughani*, “*Uberella*” *acerva*, *Globisium miocaenicum*, *Galeodea apodemetes*, *Sassia maoria*, *S.*

zealta, *Austrofusus* (*Neocola*) *apudalpha*, *Cominella* (*Procominula*) *pulchra*, *Egotistica scirrhoma*, *Penion finlayi*, "*Pleia*" *otaioensis*, *Coluzea dentata*, *Exilia dalli*, *Typhis hebetatus*, *Xymene* n.sp., *Proximitra rutidoloma*, *Peculator* (*Parvimitra*) *paucinoda*, *Alcithoe turrata*, *Spinomelon parki*, *Zeacuminia biplex*, *Austrotoma lawsi*, *Comitas fusiformis*, *Inquisitor* n.sp., *Austroclavus marshalli*, *Vexithara nodosolirata*, *Neoguraleus* (*Fusiguraleus*) *flexicostatus*, and *Turehua lividorupis*.

Altonian faunules

North Otago-South Canterbury

The Altonian molluscan fauna from North Otago and South Canterbury is one of the most diverse and best known in the New Zealand Cenozoic, over 350 species having been recorded from such famous localities as Sutherlands, White Rock River, Awamoa Creek, Target Gully Shellbed, Ardogowan Shellbed and Pukeuri. The first two of these localities are in the Southburn Sand, a shallow-water (inner shelf) unit that is largely restricted to South Canterbury, although it occurs in an isolated outcrop on the right (south) bank of the Waitaki River near Georgetown. Characteristic Southburn Sand species include *Cucullaea australis*, *Limopsis catenata*, *Glycymerita* (*Glycymerita*) *robusta*, *G.* (*Mania*) *aff. huttoni*, *Lentipecten hochstetteri*, *Anomia trigonopsis*, *Pteromyrtea laminata*, *Hedecardium* (*Titanocardium*) *cantuariense*, *Scalpomactra continua*, *Maorimactra acuminella*, *Tellinota arta*, *Gari oamarutica*, *Bassina speighti*, *Dosinia* (*Austrodosinia*) *magna*, *Eumarcia* (*Eumarcia*) *pareoraensis*, *E.* (*Atamarcia*) *enysi*, *Notocorbula humerosa*, *Conominolia woodsi*, *Pareora striolata*, *Tropicolpus abscisus*, *Cirsotrema* n.sp., *Struthiolaria* (*Callusaria*) *spinosa*, *Crepidula* sp., *Tanea sublata*, *Friginatica vaughani*, *Polinices huttoni*, *Zelandiella subnodosa*, *Nassicola finlayi*, *Penion marwicki*, *Nassarius* (*Hima*) *socialis*, *Amalda* (*Alocospira*) *hebera*, *Zeacuminia pareoraensis*, *Austrotoma minor*, *Bathytoma haasti*, *Tomopleura excavata*, *Scrinium ordinatum*, *Neoguraleus* (*Fusiguraleus*) *leptosoma*, *Inglisella cincta*, *Maorivetia brevirostris*, and *Fissidentalium* n.sp.

Most of the important Altonian localities, however, are in the deeper-water Mount Harris Formation, particularly in the Oamaru district and (in the upper part of the unit) in the lower Waihao Valley. Faunules from siltstone facies at Pukeuri road cutting, Awamoa Creek and Old Rifle Butts, Cape Wanbrow differ markedly from those in the Southburn Sand in lacking most of the larger bivalves and in having a much greater variety of gastropods, especially neogastropods (including turrids). These faunules include *Linucula* n.sp., *Neilo awamoana*, *Limopsis zealandica*, *Notolimopsis* n.sp., *Cycloclamys* n.sp., *Pododesmus incisurus*, *Lima colorata*, *Myrtea valdesculpta*, *Neolepton antipodum*, "*Cyclocardia*" *awamoensis*, *Spissatella trailli*, *Zenatia* n.sp. *aff. acinaces*, *Turia pukeuriensis*, *Notocallista parki*, *Calliostoma fragile*, *Brookula* spp., *Zetela awamoana*, *Attenuata polyvineta*, *Alvania* (*Linemera*) *awamoensis*, *Nozeba candida*, *Pareora striolata*, *Zeacolpus pukeuriensis*, *Z. awamoensis*, *Struthiolaria calcar*, *Proterato neozelanica*, *Lachryma submorosa*, *Globisium miocaenicum*, *Taniella notocenica*, *Friginatica vaughani*, *Polinices* (*Polinella*) *modestus*, *Galeodea apodemetes*, *Sassia maoria*,

Buccinulum protensum, *Cominella* (*Procominula*) *pukeuriensis*, *Nassarius* (*Hima*) *socialis*, *Zemitrella haroldi*, *Coluzea dentata*, *Typhis hebetatus*, *Xymene* n.sp., *Proximitra apicalis*, *Peculator* (*Parvimitra*) *pukeuriensis*, *Protopinella conica*, *Deviginella*(?) *harrisi*, *Alcithoe* (*Leporemax*) *lepida*, *A.* (*Leporemax*) *scopi*, *Teremelon tumidior*, *Conilithes wollastoni*, *Austrotoma nervosa*, *Comitas fusiformis*, *Parasyrinx alta*, *Inquisitor awamoensis*, *Austroclavus marshalli*, *Eremopsis* spp., *Mauidrillia* spp., *Rugobela* spp., and *Inglisella pukeuriensis*.

Faunules from shellbeds in the Mount Harris Formation (Awamoa Beach, Ardogowan, and Target Gully) are even more diverse than those from the siltstone, and include specimens from a variety of biotopes. Ardogowan Shellbed is notable for the abundance of the "giant" turritellid *Tropicolpus* (*Amplicolpus*) *cavershamensis*, many specimens of which retain their colour pattern. Target Gully Shellbed is one of the richest in the New Zealand Cenozoic, with a recorded faunule of 250-300 species, and has Scientific Reserve status.

North Canterbury

Rich Altonian faunules are known from several localities in North Canterbury, but have never been as intensively studied as their southern counterparts. The best-known one is probably that from the shellbed at the base of the Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin. This is from a "hard-ground" facies otherwise unknown in the east coast Altonian, and includes several distinctive species (many of large size) that are rare in or absent from other Altonian assemblages, e.g. *Limatula exulans*, *Maoricardium gudexi*, *Dosinia* (*Austrodosinia*) *magna*, *Gastrochaena* n.sp., "*Benthastelena*" *transenna*, *Astraea bicarinata*, *Sarmaturbo* n.sp., and *Paracomina* n.sp. Overlying this shellbed are the Altonian "*Struthiolaria* beds" with a restricted, probably estuarine faunule including *Eumarcia* (*Eumarcia*) n.sp., *Zefallacia australis*, *Batillaria hectori*, *Taxonina* n.sp., and the very abundant *Struthiolaria* (*Callusaria*) *tuberculata*.

An assemblage from Tommy's Creek, Upper Waipara River is more like those from North Otago and South Canterbury than the Castle Hill Basin faunules, and includes *Pododesmus incisurus*, *Polinices huttoni*, *Friginatica vaughani*, *Zeacolpus pukeuriensis*, *Struthiolaria calcar*, *S.* (*Callusaria*) *spinosa*, *Austrofusus* (*Neocola*) *alpha*, *A.* (*Neocola*) n.sp. *aff. apudalpha*, *Nassicola* cf. *contracta*, *Comitas fusiformis*, *Bathytoma haasti*, and *Austrotoma minor*.

Other important Altonian faunules occur at Weka Pass, particularly in the "Neothyris shellbed" and a thin bed with common *Struthiolaria calcar* near the top of the Mount Brown Formation. These shallow-water assemblages include *Cucullaea australis*, *Tucetona finlayi*, *Glycymeris* sp., *Limopsis* cf. *catenata*, *Mesopeplum* sp., *Lima colorata*, "*Cyclocardia*" *awamoensis*, *Nemocardium* (*Varicardium*) *patulum*, *Dosinia* (*Raina*) *bensoni*, *Eumarcia* (*Atamarcia*) *curta*, *Zeacolpus pukeuriensis*, *Struthiolaria calcar*, *Polinices huttoni*, *Austrofusus* (*Neocola*) *beta*, *Morum* (*Oniscidia*) *finlayi*, *Alcithoe cylindrica*, *Teremelon elegantissima*, *Comitas fusiformis*, *C. latescens*, *Conus* n.sp., and *Maorivetia brevirostris*. The presence of *Austrofusus beta* suggests that these assemblages are younger ("late" Altonian) than the one from Tommy's Creek, Waipara (with *A. alpha*). The occurrence of *Morum* (*Oniscidia*) and

the cone (apparently conspecific with an undescribed species in the Altonian at Clifden, Southland) is evidence for warmer conditions than those prevailing in South Canterbury and North Otago.

THE WARM FAUNA (FIG. 17): PLATES 23-26

Northland and Auckland

Rocks of Early Miocene age are widespread in Northland, but because of poor outcrop and great lateral variation (related to contemporaneous volcanism and tectonism) their relationships to one another and to underlying rocks are still not well understood. Ballance et al. (1978) reviewed the stratigraphic nomenclature of Late Oligocene and Early Miocene rocks of northern New Zealand, and proposed that they be included in a unit they named Akarana Supergroup, comprising seven groups. Four of these groups are relevant to the present discussion—Parengarenga Group, which includes flysch, andesitic conglomerate, siltstone and sandstone, known only in the North Cape—Parengarenga Harbour area; Otaua Group, mudstone and fine sandstone with some flysch and conglomerate in the Hokianga Harbour—Waimamaku Valley area; Waitakere Group, andesitic conglomerate and other volcanoclastic rocks, and intrusive and extrusive andesite and basalt, in western Northland from Waiuku to Hokianga Harbour; and Waitemata Group, flysch, conglomerate, sandstone and mudstone, much of it volcanic-derived, from the Waikato River to Brynderwyn, with a minor occurrence at Cape Colville, Coromandel Peninsula.

Otaian Faunules

Rich Otaian molluscan assemblages are recorded from three main areas in Northland—the north shore of Parengarenga Harbour, Hokianga district (particularly in Waimamaku Valley), and Kaipara Harbour (particularly Hukateri Peninsula). The best-known faunules are from the Pakaurangi Formation (included in the Waitakere Group by Ballance et al. 1978) near Pakaurangi Point, Hukateri Peninsula, Kaipara (Jones 1970); one from near the top of the Waiteroa Member is exceptionally diverse and is the source of most of the small molluscs described by Laws (1939a, 1941b, 1944). This faunule—which includes abundant planktonic molluscs (heteropods, thecosome pteropods, and many protoconchs) and extremely rare land snails (Climo and Maxwell in prep.) as well as a diverse benthonic assemblage—probably owes its variety to mixing of several biotopes by mass-debris flow. The following taxa are representative: *Ledella pakaurangiensis*, *Saccella duplicarina*, *Sarepta aucklandica*, *Jupiteria* spp., *Arca* cf. *waitemataensis*, *Barbatia*(?) *mundiformata*, *Cycloclamys shepherdii*, *Parvamussium aucklandicum*, *Dimya kaiparaensis*, *Spondylus aucklandicus*, *Chama* sp., *Glyptoactis* (*Fasciculicardia*) *subintermedia*, *Marama* (*Hina*) *tumida*, *Pitar* (*Hyphantosoma*) *sculpturata*, *Abra marshalli*, *Caryocorbula nitens*, *Notocorbula inerrans*, *Anatoma miocenica*, *Emarginula* spp., *Zetela hutchinsoniana*, *Argalista kaiparaensis*, *Crosseola* spp., *Orbitestella* spp., *Eatoniella* (*Dardanula*) spp., *Pusillina* (*Haurakia*) *sodalis*, *Merelina saginata*, *Ihungia aequalis*, *Pareora pinguis*, cerithiopsids, triphorids, *Chicoreus* (*Siratus*) *komiticus*, *Nassarius* (*Hima*) *separabilis*, *Mitrella inconspicua*, *Conus armoricus*, *Gemmula kaiparaensis*,

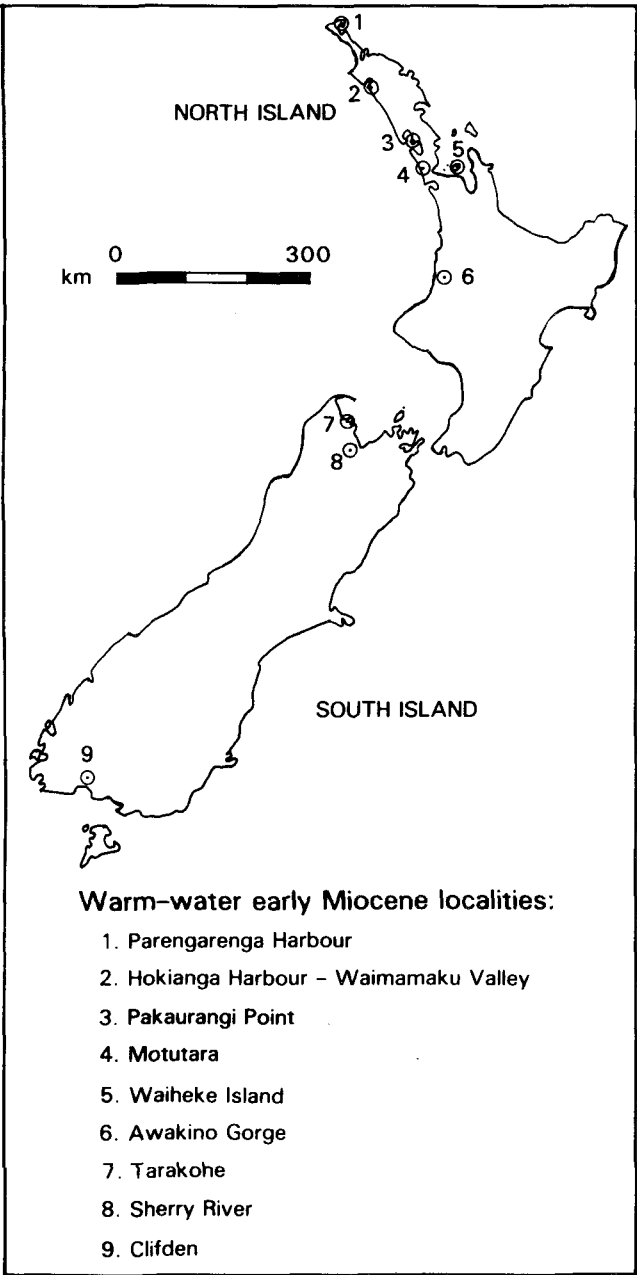


Figure 17 The main molluscan fossil localities in the warm-water Early Miocene (Otaian and Altonian) province.

Austroclavus kaipara, *Nepotilla bartrumi*, pyramidellids, *Spiratella ferax*, *S. atypica*, and *Vaginella torpedo*.

Molluscan faunules from Hokianga district were documented by Laws (1947, 1948) and, more recently, by Wakefield (1976). Most of the important localities are in the Waimamaku Valley on the south side of the harbour, but there are also some on the north side, particularly the Otueka Hill cutting on the road to Mitimiti. The shallow-water assemblage from the Waititi Formation in Pinehill Stream, Waimamaku Valley is representative, and includes *Saccella duplicarina*, *Jupiteria* cf. *leachi*, *Acar harringtoni*, *Septifer torquatus*, *Cardita marwicki*, *Pleuromeris instata*, *Haliotis* n.sp., *Monodilepas* n.sp., *Puncturella* n.sp., *Lodderena* n.sp., *Euchelus* (*Herpetopoma*) *parvumbilicata*, *Argalista provariecostata*, *Alvania* (*Linemera*) *waimamakuensis*, *Merelina* spp., *Pusillina* (*Haurakia*) *chemnitzia*, *Rissoina heterolira*, *Amphithalamus*

(*Notoscrobs*) *semiornatus*, *Pisinna* spp., *Eatoniella* (*Dardanula*) spp., *Bittium* (*Zebittium*) n.sp., *Pareora pinguis*, *Teinostoma* n.sp., *Hipponyx* sp., "*Neojanac*" cf. *kaawaensis*, *Bembicium hokianga*, cerithiopsids, triphorids, *Williamia maxwelli*, and *Cryptoplax* n.sp.

Rich Otaian faunules have been collected from several localities on the north shore of Parengarenga Harbour (Wakefield 1976). One of these, from thin shell-rich bands and lenses in the Pahuape Formation at the mouth of Waioha Stream, has a mixture of shallow-water and much deeper-water (probably upper bathyal) assemblages, including *Brevinucula* n.sp., *Ledella pakaurangiensis*, *Saccella* cf. *redunca*, *Pseudotindaria* n.sp., *Cirsonella*(?) n.sp., *Seguenzia glabella*, *Fluxinella maxwelli*, *Eatoniella* (*Dardanula*) spp., *Pareora* aff. *striolata*, *Taniella* n.sp., *Uberella cicatrix*, *Austrofusus* (*Neocola*) *flexuosus*, *Mioawateria* n.sp., *Eubela awakinoensis*, *Hokianga* n.sp., *Inglisella* spp., "*Waipaoa*" *grata*, and *Ringicula* spp.

The richest Otaian faunules recorded from the Auckland area are from the base of the Waitemata Group at two nearby localities on Waiheke Island—Oneroa (described by Powell and Bartrum 1929) and Squadron (or Church) Bay (Powell 1938a). These faunules, which have many species in common, are of very shallow-water facies and include representatives of several taxa otherwise rare or unknown in the New Zealand fossil fauna. Characteristic species include *Arca waitemataensis*, *Perna tetleyi*, *Pteria oneroaensis*, "*Isognomon*" n.sp., *Eucrassatella ampla*, *Megacardita squadronensis*, *Bartrumia oneroaensis*, *Scalpomactra biconvexa*, *Lutrarina trapezoidalis*, *Dosinia* (*Raina*) *bensoni*, *Hedecardium* (*Titanocardium*) *greyi*, *Parapholas aucklandica*, *Haliotis* sp., *Turbo* (*Modelia*) aff. *granosus*, *Sarmaturbo superbus*, *Cellana thomsoni*, *Bembicium priscum*, *Zefallacia benesulcata*, *Pyrazus consobrinus*, *P. waitemataensis*, *Maoricolpus waitemataensis*, *Tropicolpus* (*Amplicolpus*) *gittosinus*, *Struthiolaria lawsi*, *Cabestana tetleyi*, *Sassia arthritica*, *Morum* (*Oniscidia*) *harpaforme*, *Penion exoptatus*, *Paracomina lignaria*, *P. finlayi*, *Murexsul echinophorus*, *Lepsiella maxima*, *L. intermedia*, and *Austrotoma finlayi*.

Altonian Faunules

The best-known Northland Altonian faunules are from the upper part of the Pakaurangi Formation at Pakaurangi Point, Kaipara, particularly from the Pakaurangi Member, the probable source of most of the species described by Marshall (1918). The very diverse assemblage indicates a moderately deep-water environment, probably in the outer shelf or upper bathyal zones (Jones 1970, p.153). It includes *Saccella duplicarina*, *Ledella pakaurangiensis*, *Cucullaea* n.sp., *Septifer torquatus*, *Mesopeplum costatostriatum*, *Lentipecten hochstetteri*, *Anomia trigonopsis*, *Lima colorata*, *Chama* n.sp.?, *Glyptoactis* (*Fasciculicardia*) *subintermedia*, *Pteromyrtea* spp., *Marama* (*Hina*) *tumida*, *Pitar* (*Hyphantosoma*) *sculpturata*, *Notocallista* aff. *parki*, *Placamen* n.sp., *Serratina ferrari*, *Caryocorbula kaiparaensis*, *C. nitens*, *Notocorbula inerrans*, *N. illecta*, *Kaiparathina praeclens*, *Guildfordia* (*Opella*) *subfimbriata*, *Zeacolpus lawsi*, *Pareora pinguis*, *Friginatica vaughani*, *Taniella notocenica*, *Echinophoria pollens*, *Chicoreus* (*Siratus*) *komiticus*, *Mitrella inconspicua*, *Austrofusus* (*Neocola*) *flexuosus*, *Falsicolus kaiparaensis*, *Eumitra nitens*, *Clifdenia turneri inflata*, *Amalda* (*Spinaspira*) *spinigera*, *Conus armoricus*, *Austrotoma*

excavata, *A. kaiparaensis*, *Gemmula kaiparaensis*, *Comitas kaipara*, *Zemacies climacota*, *Z. ordinaria*, *Inquisitor komiticus*, *Bathytoma bartrumi*, *Crenilabium zealandicum*, and *Cylichnania bartrumi*.

A considerably less diverse assemblage in siltstone (Paratoetoe Formation) at Paratoetoe, north shore of Parengarenga Harbour, differs markedly from the Pakaurangi faunule, and probably represents a deeper-water facies. Characteristic species include *Limopsis* n.sp., *Guildfordia* (*Opella*) n.sp., *Friginatica vaughani*, *Echinophoria pollens*, *Sassia zealta*, *Austrofusus* (*Neocola*) n.sp., *Falsicolus* n.sp. aff. *kaiparaensis*, *F. corrugatus*, *Janiopsis*(?) n.sp., *Austrotoma* n.sp. aff. *clifdenica*, *Gemmula clifdenensis*, *G. n.sp.*, *Cochlespira* (*Cochlespira*) n.sp., *Comitas* n.sp., *Zemacies elatior*, *Inquisitor* n.sp., *Bathytoma* n.sp., *Borsonia* n.sp., *Vexithara* n.sp., *Mathilda* n.sp., and *Fissidentalium* aff. *solidum*. Faunules from sandstone overlying the siltstone at Paratoetoe are of shallower facies and are much more diverse, and besides many of the above species, include *Spondylus aucklandicus*, *Septifer torquatus*, *Chama* sp., *Polinices* sp., *Struthiolaria* (*Callusaria*) aff. *tuberculata*, *Cominella* sp., and *Morum* (*Oniscidia*) cf. *finlayi*, as well as numerous cerithiopsids, rissoids, turrids and cancellariids.

Powell (1935b) described a small but highly distinctive bathyal molluscan faunule from Motutara, near Muriwai, west Auckland. Among the species present are *Saccella motutaraensis*, *Propeamusium zitteli*, *Lucinoma taylori*, *Thyasira bartrumi*, *Elliptotellina protensa*, *Calliotropis motutaraensis*, *Cirsochilus priscus*, *Hipponix centrifugalis*, *Taniella motutaraensis*, *Echinophoria toreuma*, *Falsicolus gemmatus*, *Bathytoma mitchelsoni*, and "*Lornia*" *marwicki*.

North Taranaki

Early Miocene molluscan faunules have been collected from a considerable number of localities in the Awakino and Mokau districts, North Taranaki, particularly from the Mahoenui Mudstone (Otaian) and Mokau Sandstone (Altonian). Identifications given in Henderson and Ongley (1923) are badly out of date, and the faunules have not been studied critically in recent years, but they include some taxa with southern affinities as well as several characteristic Northland forms. Mahoenui Mudstone exposed in the road cutting east of the Awakino Gorge tunnel is the type locality of several species described by Laws and by Powell (see Fleming 1972, p.177-8). The faunule includes *Caryocorbula kaiparaensis*, *Struthiolaria* cf. *calcar*, *Zeacolpus woodhouseae* or *Z. awamoensis*, *Z. lawsi*, *Echinophoria* cf. *pollens*, *Austrofusus* (*Neocola*) cf. *apudalpha*, *Gemmula kaiparaensis*, *Inquisitor komiticus*, *Austroclavus awakinoensis*, *Mauidrillia imparilirata*, *Cryptodaphne pseudodrillia*, and *Eubela awakinoensis*. Faunules from the Mokau Sandstone are typically of rather shallow-water facies—one from the Tongaporutu River near the junction with Papakino Stream includes *Cucullaea ponderosa*, *Limopsis* aff. *gisbornensis*, *Lima colorata*, *Lentipecten hochstetteri*, *Hedecardium* (*Titanocardium*) n.sp., *Dosinia* (*Raina*) cf. *bensoni*, *Marama hendersoni*, *Zeacolpus pukeuriensis*, *Austrofusus* (*Neocola*) cf. *beta* cf. *gamma*, *Amalda* (*Spinaspira* ?) sp., *Metamelon* sp., *Conus* n.sp. A (as in Altonian of Clifden), *Conus* n.sp. B, and *Bathytoma* cf. *haasti*. The stage of development of the *Austrofusus* (*Neocola*) indicates a stratigraphic position late in the Altonian or early in the Clifdenian.

Nelson

Otaian rocks are absent from most of the west coast of the South Island, and the only diverse molluscan faunules of this age in this region are from the Sherry River and Burmeister Formations in the Kaka district, north-west Nelson (Maxwell in Johnston 1971). The material is poorly preserved, but the Sherry River Formation is noteworthy for containing *Spondylus*, and the Burmeister Formation for containing the oldest known occurrence of the widespread, deep-water marginellid *Hiwia amplificata*.

Altonian rocks are considerably more widespread in the Nelson-Westland region than those of Otaian age, and contain reasonably diverse molluscan faunules at several localities. The faunule from the lower part of the Tarakohe Mudstone at Tarakohe Quarry, near Takaka, is poorly preserved but is of interest for including several moderately deep-water (outer shelf or upper bathyal) taxa (Fleming 1970). It includes *Lentipecten hochstetteri*, *Serripecten hutchinsoni*, *Lima colorata*, *Pododesmus incisurus*, *Spissatella* cf. *clifdenensis*, *Procardia dolicha*, *Euciroa ulrichi*, *Perotrochus marwicki*, *Astraea* n.sp., *Guildfordia* (*Opella*) *hendersoni*, *Ficus* sp., *Xenophora* sp., *Morum* (*Oniscidia*) sp., and *Aturia cubaensis*.

Faunules from the Karamea district, by contrast, are of shallow-water facies. The lower Altonian index species *Austrofusus* (*Neocola*) *alpha* is present in the lower part of the Q Creek Formation at the mouth of Little Wanganui River (Neef 1981, p.189-190), but is absent from the corresponding part of the Oparara Valley sequence, probably because of deposition in deeper water. A faunule from higher in the Little Wanganui section, however, has typical *A. (Neocola) beta* and is of late Altonian age (equivalent to Calamity Point Sandstone or Long Beach Shellbed in the Clifden section). Other species in this younger faunule include *Glycymerita* aff. *robusta*, *Cucullaea* aff. *ponderosa*, *Limopsis* aff. *catenata*, *Spissatella clifdenensis*, *Fraginatica vaughani*, *Polinices huttoni*, *Cirsotrema* n.sp., *Struthiolaria calcar*, *Austrotoma* n.sp. aff. *echinata*, and *Bathytoma finlayi*.

Southland

The Early Miocene is represented in central Southland ("Shelf Region" of Wood in Suggate et al. 1978, p.524) by a rubbly bryozoan-brachiopod limestone, Forest Hill Limestone, up to about 30 m thick. This unit is particularly noteworthy for its abundant brachiopods, but it also contains abundant *Lentipecten hochstetteri* and less common *Serripecten hutchinsoni* and other pectinids. In western Southland ("Geosynclinal Region" of Wood), however, Early Miocene rocks are generally much thicker and more diverse and, except for the Clifden Limestone, are predominantly terrigenous. The Clifden Limestone contains few molluscs other than pectinids, but the overlying sandstone and siltstone are richly fossiliferous where they are exposed by the Waiau River near Clifden.

The Clifden Section

The section exposed along the right bank of the Waiau River upstream from Clifden Bridge was first described (albeit very briefly) by Park (1921) who noted that a "rich harvest" of fossils awaited collectors there. The Clifden section soon became established as one of the most important fossil localities in New Zealand, although its

stratigraphic significance was not appreciated for more than 20 years because it was originally thought that most of the sequence was of pre-"Awamoan" ("Ototaran" and "Hutchinsonian") age. Paleontological evidence, particularly from Foraminifera, gradually led to the conclusion that the Clifden beds are considerably younger than had been thought, and in 1947 Finlay and Marwick proposed four new stages, Altonian, Clifdenian, Lillburnian and Waiauian, based on faunal changes observed in the Clifden sequence and elsewhere in New Zealand. (Scott (1972) later showed that the "Awamoan" and "Hutchinsonian" stages are equivalent to the lower part of the Altonian, and recommended they be expunged from the local standard stage classification).

The Altonian stratotype is about 100 m thick, but the lower 40 m consists of Clifden Limestone, with very few macrofossils. Moderately diverse molluscan faunules are present in the overlying Otahu Formation, but the richest assemblages are from the lower part of the Nga Pari Formation (Fouraye Siltstone, Calamity Point Sandstone and Long Beach Shellbed members). Typical specimens of the biostratigraphically important gastropod *Austrofusus* (*Neocola*) *alpha* are present in the Otahu Formation and the Fouraye Siltstone (the latter unit being the type horizon), but in the overlying Calamity Point Sandstone they are greatly outnumbered by the *A. (Neocola) beta* morphotype (see discussion below under "Neocola bioseries"). By latest Altonian time (Long Beach Shellbed) the *A. (Neocola) alpha* morphotype seems to have disappeared completely. Other probable evolutionary changes that seem to have taken place during the Altonian include the replacement of the volute *Alcithoe* (*Leporemax*) *bathgatei* (Fouraye Siltstone) by *A. (Leporemax) phymatias* (Calamity Point Sandstone and Long Beach Shellbed), and the apparently contemporaneous change from *Austrotoma* n.sp. (also present in Altonian siltstone at Parengarenga Harbour) to *A. clifdenica*. Another change—but not an evolutionary one—is the replacement of *Bathytoma haasti* (Otahu Formation) by *B. finlayi* (Fouraye Siltstone and younger units, up to Lillburnian), a member of a different species-group.

The richly diverse shallow-water assemblage in the Calamity Point Sandstone serves as an example of the Altonian fauna at Clifden. It includes *Glycymeris* sp., *Glycymerita* aff. *robusta*, *Limopsis catenata*, *Cosa* n.sp., *Serripecten hutchinsoni*, *Anomia trigonopsis*, *Spissatella clifdenensis*, *Glyptoactis* (*Fasciculicardia*) *subintermedia*, *Nemocardium* (*Varicardium*) *patulum*, *Notocallista parki*, *Pitar* (*Hyphantosoma*) aff. *sculpturata*, *Dosina firmocosta*, *Solecortus bensoni*, *Astraea stirps*, *Zeacolpus pukeuriensis*, *Struthiolaria calcar*, *Cypraea* (*Notadusta*) *clifdenensis*, *Sassia neozelanica*, *S. maoria*, *S. zealta*, *S. tortirostris*, *Echinophoria pollens*, *Austrofusus* (*Neocola*) *beta*, *Buccinulum longicolle*, *B. tuberculatum*, *Penion parans*, *Coluzea kiosk*, *Murexsul scobinus*, *Rugotyphis francescae*, *Typhis aculeatus*, *Chicoreus* (*Siratus*) aff. *syngenes*, *Amalda* (*Spinaspira*) *stortha*, *Clifdenia turneri turneri*, *Alcithoe* (*Leporemax*) *phymatias*, *Teremelon pretiosa*, *Metamelon clifdenensis*, *Austrotoma clifdenica*, *Zemacies elatior*, *Gemmula* n.sp., *Bathytoma finlayi*, and *Aturia cubaensis*. A preliminary listing of the many diverse and distinctive Clifden faunules (Altonian to Waiauian) was provided by Fleming (in Fleming et al. 1969, p.80-95).

Composition of Otaian and Altonian faunas

The Otaian and Altonian molluscan faunas are by far the most diverse known from the New Zealand Cenozoic record, about 500 genus-group taxa being known (but by no means all yet recorded in publications) from each stage. Much of this diversity is attributable to the presence of rich, well-preserved faunules in Northland and Auckland that differ radically from coeval faunules in Canterbury and North Otago, but it is also partly a reflection of the generally warm marine conditions that prevailed in New Zealand during Early Miocene time (see below). Unfortunately, because so little is known of the Paleogene or post-Early Miocene molluscan faunas of northern New Zealand, we cannot rule out the possibility that many of the groups listed below as restricted Otaian or Altonian taxa, or as having made their appearance in New Zealand at this time, did not in fact have a much longer stratigraphic range in Northland.

The only genus-group taxa recorded solely from the Otaian Stage are *Parapholas*, *Kaiparapelta*, *Hokianga*, *Maoriscaphander*, and *Cryptoplax*. However, a considerable number of genus-group taxa (nearly all of them known only from Northland and Auckland at this time) appeared during the Otaian, i.e., *Perna*, *Pteromyrtea*, *Borniola*, *Cardita*, *Volupicuna*, *Pitar* (*Hyphantosoma*), *Tawera*, *Cocculina*, *Coccopygia*, *Notocrater*, *Lodderena*, *Munditia*, *Cirsonella*, *Crosseola*, *Kaiparathina*, *Guildfordia* (*Opella*), *Cirsochilus*, *Fluxinella*, *Seguenzia*, *Ihungia*, *Manawatawhia*, *Powellisetia*, *Scrupus*, *Liratonella*, *Caecum* (*Fartulum*), *Scalaronoba*, *Zeradina*, *Ranella*, *Eudolium*, *Nassarius* (*Hima*), *Chicoreus* (*Siratus*), *Coralliophila*, *Uromitra*, *Hiwia*, *Amalda* (*Spinaspira*), *Eubela*, *Mioawateria*, *Nepotilla*, *Discotectonica*, *Taita*, *Chemnitzia*, *Cavolinia*, and *Striacadulus*. Only two genera, *Megacardita* and *Veruturris*, are last known in the Otaian in New Zealand.

There are also several species that seem useful for distinguishing the Otaian from older and younger stages, at least in the North Otago-South Canterbury region. Such well-known species as *Neilo awamoana*, *Serripecten hutchinsoni*, *Lima colorata*, *Spissatella trailli*, *Tropicolpus cavershamensis*, *Proximitra rutidolomum*, *Alcithoe turrita*, *Spinomelon parki*, and *Bathytoma haasti* are first recorded from the Otaian Stage, whereas *Tropicolpus gittosinus*, *Zeacolpus woodhouseae*, *Exilia dalli*, *Austrofusus* (*Neocola*) *apudulpha*, *Austrotoma finlayi*, and *Turehua lividorupis* are last known from this stage. A very large number of species are recorded solely from the Otaian Stage, but most of these are rare and known from only a single locality, or seem to be restricted to a narrow range of facies. The following species are restricted to the Otaian Stage in South Canterbury: "*Uberella*" *acerva*, *Penion finlayi*, *Austrotoma lawsi*, *Parasyrinx* n.sp., and *Vexithara nodosolirata*.

A few genus-group taxa are known only from the Altonian Stage, but it would be unwise to attach much biostratigraphic significance to their occurrence: *Bentharca*, *Plesiostrochus*, *Vesanula*, *Etrema*, *Aphera*, *Pukeuria*, *Mathilda* (sensu stricto), and *Pharcidella*. Among those taxa apparently making their appearance in New Zealand during the Altonian Stage are *Zealeda*, *Glycymerita* (*Mania*), *Lucinoma*, *Scintillona*, *Rexithaerus*, *Rohea*, *Eumarcia* (sensu stricto), *Cominella* (sensu stricto), *Glaphyrina*, *Cantharus* (*Zeapolia*), *Rugotyphis*, *Microvoluta*, *Lyria*, *Cochlespira* (sensu

stricto), *Cosmasyrinx*, *Splendrillia* (sensu stricto), *Aoteadrillia*, *Bathytoma* (*Micantapex*), *Phenatoma*, *Nipteraxis*, *Waikura*, and *Spirula*. Taxa recorded last in the Altonian include *Notolimopsis*, "*Cyclocardia*", *Gastrochaena*, *Placamen*, *Tapes*, *Procardia*, *Cirsochilus*, *Batillaria*, *Tropicolpus* (*Amplicolpus*), *Archierato*, *Magnatica* (*Spelaenacca*), *Cominella* (*Procominula*), *Paracomina*, *Egotistica*, *Eumitra*, *Marshallaria*, *Parasyrinx* (sensu stricto), and *Fusiaphera*.

Species recorded solely from the Altonian Stage include *Hedecardium* (*Titanocardium*) *cantuariense*, *Zeacolpus awamoensis*, *Struthiolaria tuberculata*, *Buccinum protensum*, *Austrofusus* (*Neocola*) *alpha* (lower part of the stage, replaced by *A. beta* in the upper part), *Austrofusus* (sensu stricto) *spiniferus*, *Cominella* (*Procominula*) *pukeuriensis*, *Penion marwicki*, *Nassicola finlayi*, *Proximitra apicalis*, *Alcithoe* (*Leporemax*) *bathgatei* (replaced by *A. phymatias* in the upper part of the stage), *Conilithes wollastoni*, *Austrotoma* n.sp. aff. *clifdenica* (replaced by *A. clifdenica* in the upper part of the stage), *Austrotoma nervosa*, *Comitas latescens*, *Parasyrinx alta*, *Inquisitor awamoensis*, *Vexithara vexilliformis*, and *Rugobela tenuilirata*. Those first recorded from the Altonian Stage include *Purpurocardia perscrupulosa*, *Nemocardium* (*Varicardium*) *patulum*, *Maoricardium gudexi*, *Dosina firmocosta*, *Rohea trigonalis*, *Maoricolpus horni*, *Zeacolpus pukeuriensis*, *Struthiolaria* (*Callusaria*) *spinosa*, *Cypraea* (*Notadusta*) *clifdenensis*, *Austrofusus magnificus*, *Clifdenia turneri*, *Metamelon clifdenensis*, *Amalda* (*Spinaspira*) *stortha*, *Gemmula clifdenensis*, *Gemmula* n.sp. (serrate-keeled), *Zemacies elatior*, and *Bathytoma finlayi*. Species last known in the Altonian Stage include *Limopsis zealandica*, "*Cyclocardia*" *awamoensis*, *Spissatella trailli*, *Kuia vellicata*, *Myadora delta*, *Tropicolpus cavershamensis*, *Zeacolpus lawsi*, *Proterato neozelanica*, *Magnatica planispira*, *Galeodea apodemetes*, *Sassia maoria*, *Typhis hebetatus*, *Coluzea dentata*, *Amalda* (*Baryspira*) *robusta*, *Spinomelon parki*, *Alcithoe turrita*, *Comitas fusiformis*, and *Bathytoma haasti*. Most of these species are known only from North Otago and South Canterbury (i.e. from the temperate province) and their disappearance from the fossil record may in part reflect the virtual cessation of marine sedimentation in this region during Altonian time.

Climate

Abundant evidence – from oxygen isotope studies, as well as from molluscs and other invertebrates – indicates that the period from Otaian to Clifdenian was one of the warmest during the Cenozoic in New Zealand (see Hornibrook in Suggate et al. 1978, p.440, for a summary), with the peak of temperatures apparently occurring during the late Altonian to Clifdenian. Hermatypic (reef-building) corals are widely recorded from the Otaian and Altonian of Northland and Auckland, and from Cape Colville, Coromandel Peninsula (Squires 1958, p.17-18; 1962; Hayward 1977), and may well have penetrated much further south during the warmest period. Squires (1962) suggested that the generic composition of the coral fauna indicates a temperature range of 19-28°C (subtropical to marginally tropical) in Northland during Early Miocene time. Larger Foraminifera (characteristic of shallow tropical seas) were widespread in Northland and Auckland during the Otaian

and Altonian, but apparently did not reach Southland until Altonian time (Hornibrook in Wood 1969, p.99), indicating that sea temperatures during the Altonian were significantly higher than during the Otaian.

Many of the molluscan genera recorded from Otaian and Altonian rocks have distinctly warm-water affinities. Some are known only from Northland, but others had spread into Southland by late Altonian times, if not earlier. Climatically significant taxa include *Septifer*, *Spondylus*, *Ctenoides*, *Placamen*, *Pitar* (*Hyphantosoma*), *Parapholas*, *Cheilea*, Cypraeidae, *Eudolium*, *Chicoreus* (*Siratus*), *Morum* (*Oniscidia*), *Lyria*, *Cochlespira*, *Gemmula*, *Microdrillia*, *Granosolarium*, and *Cryptoplax*, nearly all of which are recorded only from the warm province during Otaian and Altonian time (*Placamen* and *Morum* (*Oniscidia*) are present in the Altonian of North Canterbury, but not in North Otago or South Canterbury). The climate in northern New Zealand was certainly subtropical if not marginally tropical during the Otaian and Altonian Stages, and by the Altonian, subtropical conditions prevailed in Southland. However, even in the temperate fauna there are taxa such as *Arca*, *Trichomya*, *Chama*, *Maoricardium*, *Solecurtus*, *Tapes*, *Clavagella*, *Ficus* and Conidae that indicate that temperatures were considerably higher than those prevailing off the North Otago-South Canterbury coast at present. The absence of many other warm-water taxa from this temperate province during the Early Miocene does not necessarily imply that temperatures were particularly cool, but rather that the region was isolated from any warm oceanic current systems similar to the present day East Australian Current, which apparently bathed Northland and the west coast of the South Island during the Early Miocene, bringing with it larvae of numerous tropical and subtropical molluscs.

B. MIDDLE MIOCENE FAUNAS (CLIFDENIAN AND LILLBURNIAN STAGES): ALSO ON PLATES 23-26.

INTRODUCTION (Figure 18)

Note that, although we have considered Waiauan Mollusca in with the similar Tongaporutuan fauna (below), the Waiauan Stage is now included in the Middle Miocene (see Figure 1, 2).

Middle Miocene molluscs are less well known than those from the Early or Late Miocene, partly because rocks of this age seem for the most part to have been deposited in relatively deep water, and in only a few places contain diverse, well-preserved molluscan faunules. The main areas of marine deposition during Clifdenian and Lillburnian time seem to have been along the east coast of the North Island (particularly in the Gisborne district), Marlborough, Karamea-Oparara district, Westland, and western Southland. In contrast, marine Clifdenian and Lillburnian rocks are absent from, or are of only local occurrence in, Northland, Canterbury, and Otago. Siltstone and flysch are typical Middle Miocene rock types; sandstone is much less well represented, but conglomerate emplaced by debris-flows occurs widely in the predominantly fine-grained sequences in the Gisborne-East Cape district.

Because almost all Middle Miocene faunules are from the same areas as the Early Miocene warm-water province, and because many molluscan species are

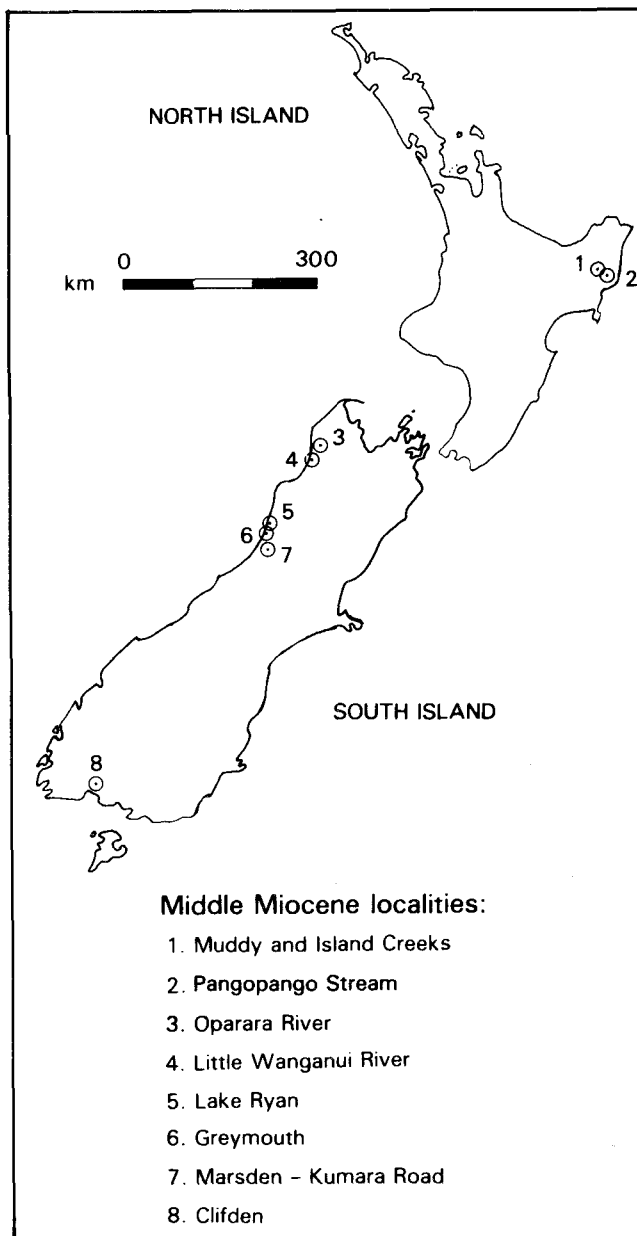


Figure 18 The main molluscan fossil localities of Clifdenian – Lillburnian (Middle Miocene) age.

common to Early and Middle Miocene faunas, Middle Miocene molluscs have been included in the same plates as Early Miocene warm-water molluscs (Pls. 23-26).

East Cape-Gisborne district

Sparse molluscan faunules of Clifdenian age have been recorded from massive mudstone (Ihungia Formation) at several localities inland from the east coast of the North Island north of Gisborne, particularly from Island and Muddy Creeks (Marwick 1931; ages given by Fleming 1966b). The lithology and faunal composition indicate a moderately deep-water (probably upper bathyal) depositional environment for these rocks. The faunules vary considerably in composition, but typically include at least some of the following: *Linucula waipaoa*, *Saccella arowhana*, *Ledella pakaurangiensis*, *Pteudotindaria nugax*, *Minormalletia* spp., *Parvamussium vafer*, *Myrtea supraflexa*, *Ihungia* spp., *Uberella cicatrix*, *Nassarius*

(*Hima*) sp., *Hiwia amplificata*, *Bathytoma* (*Micantapex*) spp., *Cosmasyrinx* spp., *Splendrillia* (sensu lato) spp., and *Striocadulus prosperus*.

The Lillburnian Stage is represented in the Gisborne district by a thick sequence of alternating sandstone and siltstone with interbedded thin conglomerate debris-flows (lower part of the Tutamoe Formation). Molluscan faunules from the siltstone facies have a deep-water (upper bathyal) aspect and contain many genera present in other bathyal Miocene assemblages. The faunule from a tributary of Wharekopae River, near Ngatapa, inland from Gisborne, listed by Marwick (1931, p.37) under GS 1340 is typical, and includes *Pseudotindaria nugax*, *Ledella pakaurangiensis*, *Jupiteria leachi*, *Bathyarca pectinata*, *Parvamussium vafer*, *Volupicuna tuta*, *Ihungia bicarina*, *Attenuata* n.sp., *Uberella cicatrix*, *Taniella* cf. *mima*, *Exilia leachi*, *Hiwia amplificata*, *Microvoluta* n.sp., *Bathytoma* (*Micantapex*) *ngatapa*, *Tomopleura* (*Maoritomella*) *rupta*, *Anapepta nucleosa*, *Oamaruia*(?) *gibbera*, *Turbonilla ngatapa*, *Odostomia ancisa*, *Waikura clivosa*, and *Ringicula* (*Ringiculina*) *ngatapa*.

Assemblages from the interbedded conglomerate lithofacies ("Tutamoe conglomerate") include apparently autochthonous deep-water species as well as thick-shelled, shallow-water species in a battered condition, apparently emplaced in the upper bathyal depositional site by debris-flows. The best known faunule is that in Pangopango Stream, inland from Tolaga Bay, which includes common large *Neilo*(?) n.sp., and less common, abraded and broken specimens of *Glycymerita marwicki*, *Limopsis gibbornensis*, *Maoricolpus ongleyi*, *Polinices huttoni*, *Struthiolaria* (*Callusaria*) cf. *callosa*, *Cypraea* sp., *Sassia tortirostris*, *Austrofusus* (*Neocola*) *demissus*, *Penion crawfordi*, *Zelandiella calcarata*, *Cominella crassinodosa*, *Falsiculus ectypa*, *Mauira* sp., *Lamprodomina neozelanica*, *Zemacies* sp., and *Fissidentalium* aff. *solidum*.

A third lithotype within the thick Lillburnian mudstone sequences in the Gisborne district is the "Modiolus limestone" (Ongley and MacPherson 1928, p.65; see also their map of Tutamoe Survey District). This unusual lithology, a white or pale grey, massive limestone, at many localities with vague to obvious tubular structures and scattered molluscs, occurs widely in the east coast of the North Island, always as small pods, from 10 m to 100 m across, within thick Lillburnian mudstone sequences. The molluscan faunules differ slightly from locality to locality, but a deep-water, byssally attached mytilid closely resembling *Idasola* is present at almost all localities; less common taxa include *Lucinoma* aff. *taylori*, small, poorly preserved Trochidae, and small Lepetellidae close to *Lepetella* (common at some localities). Deep-water lepetellid limpets are restricted at present to polychaete tubes of the bathyal genus *Hyalonoecia*, and so these occurrences appear to represent large accumulations of biogenic material (at least in part *Hyalonoecia* tubes) on a bathyal sea-floor.

Nelson

Assemblages from the Fenian Creek and Scorpion Creek Sandstones in the Oparara River and its tributaries (Neef 1981) are the only inner shelf molluscan assemblages recorded from the Clifdenian Stage. They differ from Altonian faunules from the same area mainly by containing *Austrofusus* (*Neocola*) *gamma*—the *A. beta*

morphotype is either very rare or absent. Other molluscs present (some of which are probably also biostratigraphically significant) include *Glycymerita rangatira*, *Limopsis* aff. *catenata*, *Lima colorata*, *Eumarcia* (*Atamarcia*) n.sp. aff. *thomsoni*, *Zeacolpus luteolapis*, *Polinices* cf. *huttoni*, *P.* (*Polinella*) aff. *scalptus*, *Struthiolaria* aff. *calcar*, *Echinophoria pollens*, *Sassia pahaoaensis*, *Zelandiella* n.sp., *Metamelon clifdenensis*, *Conilithes* n.sp., *Conus* (n. subgen.) n.sp., *Austrotoma clifdenica*, *A.* n.sp. aff. *echinata*, *Zeacuminia orycta*, and *Fissidentalium* aff. *solidum*.

Westland

Clifdenian faunules from the Stillwater Mudstone in the Greymouth area are mostly of deep-water (bathyal) aspect and resemble those from the Gisborne district. Shallow-water assemblages, poorly preserved and probably emplaced by debris-flows, are recorded from near Lake Ryan, Cobden, and from the basal beds at Alexander Street, Greymouth. The Lake Ryan faunule includes *Serripecten hutchinsoni*, *Lima colorata*, *Spondylus aucklandicus*, *Septifer torquatus*, *Spissatella* cf. *clifdenensis*, *Marama* (*Marama*) sp., *M.* (*Hina*) cf. *tumida*, *Maoricolpus ongleyi*, *Morum* (*Oniscidia*) cf. *finlayi*, and *Bathytoma* cf. *finlayi*. Most of these taxa are recorded also from the late Altonian or Clifdenian beds at Clifden, Southland.

The rich assemblage from the mudstone at Alexander Street includes *Saccella* n.sp. aff. *motutaraensis*, *Ledella pakaurangiensis*, *Seguenzia serrata*, *Taniella mima*, *Ancillina wellmani*, *Microvoluta* aff. *balteata*, *Terefundus* n.sp., *Hiwia amplificata*, *Cochlespira* n.sp., *Paracomitas* (*Macrosinus*) n.sp. aff. *beui*, *Cosmasyrinx monilifera*, *Borsonia* cf. *clifdenensis*, *Microdrillia* n.sp., *Splendrillia* n.sp., *Eubela* n.sp., *Anapepta nucleosa*, and "Waipaoa" *grata*.

Other diverse Clifdenian faunules are recorded from Eason Hill, Greymouth, from Sawyer's Creek near Boddytown, and from near the old Marsden-Kumara Road. No diverse Lillburnian faunules are recorded from Westland.

Southland

The Clifdenian stratotype at Clifden consists of c.40 m of siltstone passing up into fine sandstone (Slip Point Siltstone), overlying the Long Beach Shellbed (late Altonian). Molluscs are uncommon in the lowest few metres, but include some specimens of *Austrofusus* (*Neocola*) of *A. gamma* morphology, as well as others more closely resembling *A. beta* from the Long Beach Shellbed. Specimens from higher in the unit are overwhelmingly dominated by *A. gamma*. Molluscan diversity increases throughout the Slip Point Siltstone, apparently reflecting a gradual shallowing. The faunule from the upper part of the unit is very diverse, and includes *Ledella clifdenensis*, *Zealeda inflatella*, *Bathyarca* n.sp., *Limopsis* n.sp. aff. *zealandica*, *Cosa* n.sp., *Lentipecten hochstetteri*, *Spondylus* cf. *aucklandicus*, *Pododesmus paucicostatus*, *Glyptoactis* (*Fasciculicardia*) *subintermedia*, *Notocorbula illecta*, *N. inerrans*, *Zeacolpus luteolapis*, *Z. pukeuriensis*, *Struthiolaria calcar*, *Sassia pahaoaensis*, *S. neozelanica*, *S. tortirostris*, *Murexsul* (?) *clifdenensis*, *Chicoreus* (*Siratus*) *syngenes*, *Penion clifdenensis*, *Austrofusus* (*Austrofusus*) *magnificus*, *A.* (*Neocola*) *gamma*, *Cominella ridicula*, *Nassarius* (*Hima*) sp., *Falsiculus excellens*, *F. inurbanus*, *Amalda* (*Spinaspira*) *stortha*, *Lyria zelandica*, *Alcithoe*

(*Leporemax*) aff. *phymatias*, *Metamelon clifdenensis*, *Conus* n.sp., *Austrotoma clifdenica*, *A. echinata*, *Zemacies elatior*, *Z. simulacrum*, *Gemmula clifdenensis*, *Etrempsopsis erecta*, *Austroclavus finlayi*, *Borsonia clifdenensis*, *Tomopleura clifdenica*, *Neoguraleus (Fusiguraleus) platycostatus*, and *Ringicula* n.sp.

The boundary between the Clifdenian and Lillburnian stratotypes in the Clifden section is placed at a thin bed with concretions and common large oysters, near the top of the Slip Point Siltstone. The lowest Lillburnian faunule, from the top of the Slip Point Siltstone, is essentially similar to that from below the concretionary bed. The overlying unit, the Third Bay Sandstone, is poorly exposed and its molluscan fauna consequently is not well known, but rich shallow-water Lillburnian assemblages have been recorded (Fleming in Fleming et al. 1969) from the lower part of the Park Bluff Sandstone, particularly the Lill Sand member. The Lill Sand faunule includes *Saccella* aff. *probellula*, *Tucetona finlayi*, *Glycymerita robusta*, *Cucullaea ponderosa*, *Limopsis* aff. *catenata*, *Serripecten hutchinsoni*, *Lentipecten hochstetteri*, "Hinnites" *marwicki*, *Lima colorata*, "Isognomon" aff. *zealandicus*, *Eucrassatella ampla*, *Glyptoactis (Fasciculicardia) subintermedia*, *Divaricella huttoniana*, *Nemocardium (Varicardium) patulum*, *Maoricardium* aff. *gudexi*, *Dosinia (Raina) bensoni*, *Callistotapes finlayi*, *Rohea trigonalis*, *Eumarcia (Atamarcia)* aff. *thomsoni*, *Turia waiatauensis*, *Zeacolpus pukeuriensis*, *Z. willetti*, *Polinices huttoni*, *Rugotypis* cf. *francesae*, *Austrofusus (Austrofusus) magnificus*, *A. (Neocola)* aff. *gamma*, *Nassicola contracta*, *Penion clifdenensis*, *Lamprodomina neozelanica*, and *Ringicula* n.sp.

Composition of Clifdenian and Lillburnian faunas

Two genus-group taxa, *Trachycardium (Regozara)* and *Splendrillia (Syntomodrillia)*, are so far known only from the Clifdenian Stage, and a third is possibly represented by a highly sculptured *Conus* from Oparara River, west Nelson. No genus-group taxa are recorded solely from the Lillburnian Stage.

Taxa appearing first during Clifdenian time include *Nassaria (Microfusus)*, *Pakaurangia*, *Leucosyrinx*, *Paracomitas (Macrosinus)*, and *Thatcheria*. The following are recorded last from the Clifdenian Stage—*Cantharus (Zeapolia)*, *Chicoreus (Siratus)*, *Ancillina*, *Nebularia*, *Insolentia*, *Borsonia*, *Microdrillia*, and *Tatara*.

Lillburnian entrants are *Resania*, *Lamprodomina*, and *Gemmaterebra*; of these, *Lamprodomina* is probably the most useful taxon biostratigraphically. Taxa last recorded from the Lillburnian Stage are *Glyptoactis (Fasciculicardia)*, *Rohea*, *Rugotypis*, *Morum (Oniscidia)*, and *Maoridaphne*.

Clifdenian and Altonian molluscan faunules are very similar on the whole, and are most readily distinguished if a representative selection of specimens of *Austrofusus (Neocola)* is available. The change from *A. beta* to *A. gamma* is a gradual one, but typical prickly-sculptured shells of the *A. gamma* morphotype appear near the base of the Clifdenian stratotype and quickly come to dominate populations of the subgenus. Other species that are first recorded in the Clifdenian and are potentially useful in biostratigraphy include *Sassia pahaoaensis* (replacing *S. maoria*), *Struthiolaria (Callusaria) callosa* (replacing *S. spinosa* which, however, reappears at Clifden in Waiauan rocks), *Austrotoma echinata* (possibly descended from an unnamed species in the Altonian and

Clifdenian of Karamea district), and *Zemacies simulacrum* (related undescribed species occur in the Altonian). Several species of Turridae described by Powell (1942)—particularly in *Austroclavus*, *Etrempsopsis*, and *Neoguraleus (Fusiguraleus)*—could also be useful, but require critical re-examination to take into account the much more extensive collections now available from Clifden and elsewhere.

The differences between faunules from the Clifdenian and Lillburnian stratotypes are quite marked, but this probably owes more to a disparity in depositional environments than to a difference in age. Shallow-water Lillburnian assemblages are rare away from Clifden, and Lillburnian molluscan biostratigraphy is poorly developed. On present evidence the appearance of *Lamprodomina* is the most reliable criterion for recognition of the Lillburnian Stage in shallow-water facies.

Climate

The Clifdenian fauna includes *Arca*, *Spondylus*, *Septifer*, *Chama*, *Trachycardium (Regozara)*, *Cypraea (Notadusta)*, *Ficus*, *Chicoreus (Siratus)*, *Morum (Oniscidia)*, Conidae, and *Microdrillia*, indicating that sea temperatures in Southland and Westland were at least as high as during Altonian time. By contrast, the only significant recorded warm-water taxa from the Lillburnian are *Arca*, *Morum (Oniscidia)*, Conidae and *Pseudomalaxis*—this may indicate that sea temperatures were significantly lower during Lillburnian than during Clifdenian time, or may merely reflect the scarcity of shallow-water Lillburnian faunas and our consequent lack of knowledge of the molluscan fauna that inhabited New Zealand during Lillburnian time.

1. REPRESENTATIVE TEMPERATE EARLY MIOCENE MOLLUSCA: PLATES 16-22

Pl. 16 b,d,f. *Varinucula sagittata* (Suter, 1917) [*Nucula sagittata* Suter 1917, p. 65] (Nuculidae: Nuculinae).

Moderately large for family (length 9-12 mm), ovate, strongly inequilateral, moderately inflated, interior nacreous. Lunule and escutcheon narrow, slightly flattened. Radial sculpture of numerous fine costellae, more prominent on flanks than on lunule or escutcheon. Commarginal sculpture of narrow, low, locally anastomosing, rounded ridges with interspaces of similar width to 1 ridge or slightly wider, relatively prominent and stronger than radial costellae on flanks, but almost obsolete on lunule and escutcheon. Lunule with short, rather irregular ridges transverse to both radial and commarginal elements, producing a chevron pattern on articulated shells. Hinge with 8-10 posterior and 16-20 anterior teeth, proximal teeth small, almost straight-sectioned, distal teeth chevron-sectioned. Resilifer projecting strongly, directed forwards, upper edge fused to lower part of hinge plate. Ventral margin finely crenulate.

Altonian; Mount Brown Formation, Bobby's Creek, Waipara (type); Southburn Sand, Sutherlands, Tengawai River; Ardgowan Shellbed, Oamaru (moderately common).

Varinucula is an endemic genus that differs from other nuculid genera in having short transverse ridges along the lunule, as well as relatively distinct commarginal sculpture. The Recent type species, *V. gallinacea* (Finlay, 1930), is less strongly inflated than *V. sagittata* and has more regular transverse ridges. The only other species of the genus so far described, *V. crepida* (Lillburnian-Waiauan), has more prominent radial sculpture than *V. sagittata*.

Figured specimens: (Pl. 16d, f) holotype, Bobby's Creek, Waipara River, Altonian (TM4075, NZGS); (Pl. 16b)

GS9521, J41/f8030, Ardgowan Shellbed, Oamaru, Altonian (NZGS) both x 3.

Pl. 16 a,c. *Neilo awamoana* Finlay, 1926b [p. 255] (Mallettiidae).

Size moderate for genus (length 25-35 mm), subrectangular; anterior end rounded, posterior end truncate, slightly sinuous; postero-umbonal ridge well-defined, posterior area with 2 very weak radial subangulations producing a shallow sulcus. Lunule narrow, depressed; escutcheon very well defined, bounded by a sharp ridge. Commarginal sculpture prominent, variable, of narrow, rather sharp ridges, of similar strength on posterior area as on flanks, but not extending onto lunule or escutcheon; c. 2.2 per mm centrally. Hinge prominent, anterior series with 18-24, posterior series with 27-30 chevron-sectioned teeth. No resilifer, but a shallow embayment for external ligament extending back from hinge rather less than half length of posterior part of hinge. Adductor muscle scars subequal; pallial sinus short, rounded.

Otaian-Altonian; Mount Harris Formation, Mt Harris, Otaian-Altonian (type); Bluecliffs, Otaio River; Awamoa Creek and other Altonian localities in Oamaru district. Common at most localities, particularly in off-shore siltstone facies.

Neilo sinangula (Duntroonian, Wharekuri) is very similar to *N. awamoana* and was classed as a subspecies of the latter by Marshall (1978, p. 430-431). The only important difference between the two taxa is that commarginal sculpture tends to be considerably weaker on the posterior area (particularly distally) than on the flanks in Wharekuri shells, but similar in strength in typical *N. awamoana*. In this respect specimens of *Neilo* from Brother's Stream and Sister's Creek, Hakataramea Valley (Waitakian) are more similar to Wharekuri shells than to younger specimens and are therefore assigned to *N. sinangula*. Finlay (1926b, p. 255) claimed that *N. awamoana* was ancestral to the Nukumaruan-Recent *N. australis*, but Marshall (1978) concluded that it was probably the ancestor of *N. wairoana* (Nukumaruan) and its Recent subspecies *N. wairoana delli* Marshall, 1978. The latter taxon is confined to the upper bathyal zone, but *N. awamoana* seems to have extended into considerably shallower, probably mid-shelf depths.

Figured specimen (Pl. 16a, c): GS958, J41/f8497, Old Rifle Butts, Cape Wanbrow, Oamaru, Altonian (NZGS) x 2.

Pl. 16 e,g. *Limopsis zealandica* Hutton, 1873b [p. 28-29] (Limopsidae).

Size moderate for genus (height 20-28 mm), rather robust, moderately strongly inflated, shape variable, juveniles more equilateral than adults. Commarginal sculpture of rounded or imbricate growth ridges of

variable strength and spacing, less prominent medially than distally or towards anterior and posterior ends. Radial sculpture of fine costellae, most prominent on posterior half, obsolete on the rest of many shells, typically more prominent on growth ridges, where they form small v-shaped ridges, than between. Cardinal area prominent, dorsal margins convex; resilifer large, broadly triangular. Hinge asymmetrical, teeth varying considerably in thickness and spacing, those in posterior series more divergent than those in anterior series. Anterior adductor muscle scar small, at distal end of hinge, bounded on inner side by a sharp myophoric ridge; posterior scar larger and set much lower, myophoric ridge absent from most specimens. Area inside pallial line roughened, with fine radial ridges. Margin smooth, broadly and sharply bevelled.

Waitakian-Altonian; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type) and other North Otago Altonian localities; Bluecliffs, Otaio River; Trig Z, Otiake; Campbell Park School, Otekaieke. Common to abundant at most localities.

Limopsis zealandica is distinguished from other New Zealand limopsids by its moderately large, oblique, inflated shell, by its strongly asymmetrical hinge, and by the fine radial sculpture, which is typically obsolete on the anterior part of the shell. *L. gisbornensis* (= *L. retifera* Marwick, 1931 (preoccupied)) is similar to *L. zealandica* in shape but has much more prominent radial sculpture.

Figured specimen (Pl. 16e, g): GS9520, J41/f8024, Awamoa Creek, Oamaru, Altonian (NZGS) x 2.

Pl. 16 h,j. *Limopsis catenata* Suter, 1917 [p.67; "*Limopsis zitteli* Ihering, 1907" of authors, not of Ihering] (Limopsidae).

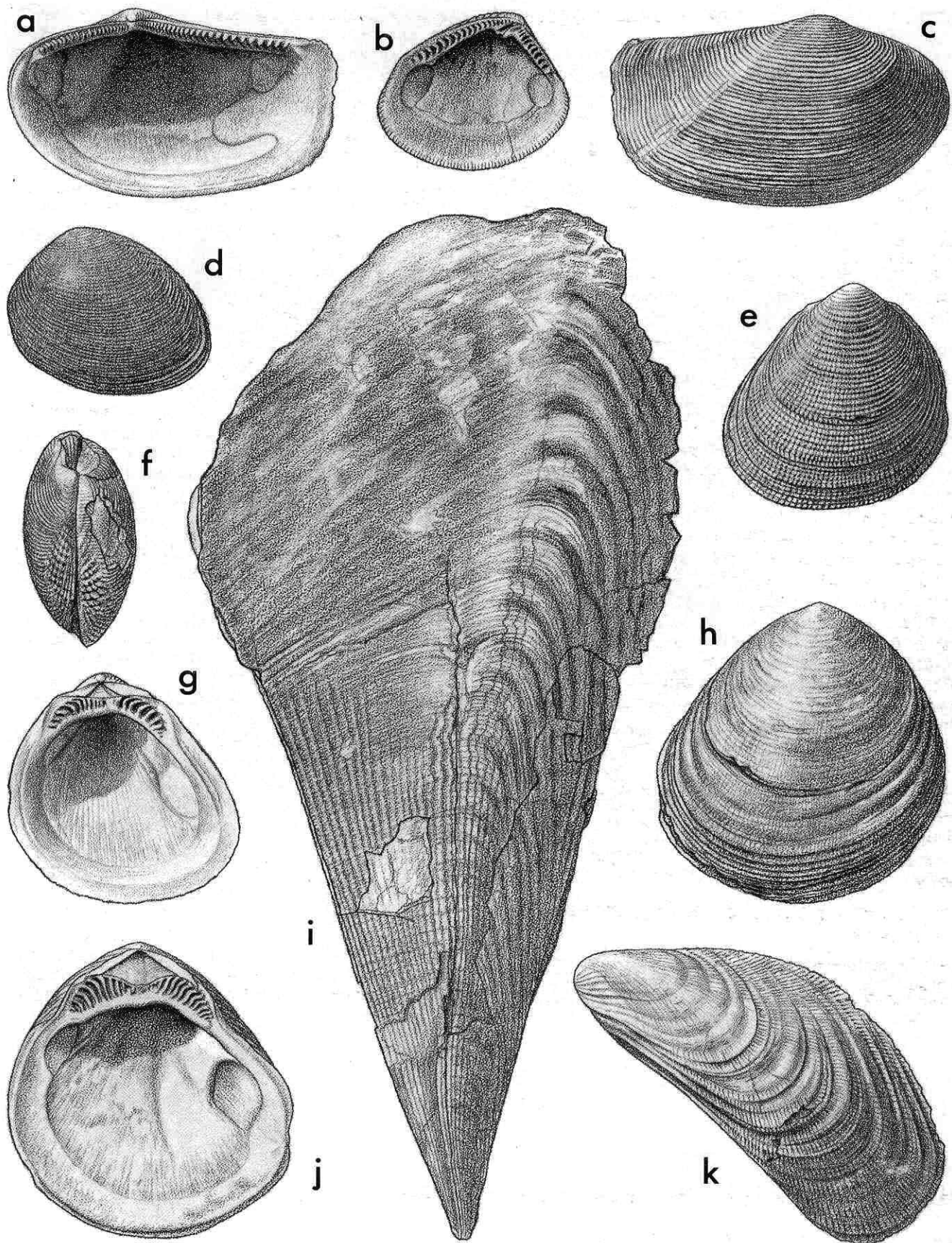
Distinguished from *L. zealandica* (above) by its much larger size (height 30-40 mm), its more trigonal and less oblique shape, its more prominent radial sculpture (particularly near the middle of the shell), its more symmetrical hinge and its larger resilifer.

Duntroonian-Waiauian; Target Gully Shellbed, Oamaru, Altonian (type); Ardgowan Shellbed; Southburn Sand, Sutherlands, Tengawai River; Wharekuri Greensand, Wharekuri; Calamity Point Sandstone, Long Beach and Nissen Shellbeds, Clifden. Common at most localities, characteristic of shallow-water sandstone and shellbeds.

Shells of this type have in the past been referred to *Limopsis zitteli* Ihering (= "*L. insolita* Sowerby" of Zittel (1864) and Hutton (1873b), not of Sowerby) but the identity of that species is uncertain. Hutton (1873b, p. 28) recorded "*L. insolita*" from The Cliffs, Nelson (Whaingaroan), from Kaniere, Westland (Kapitean or Opoitian) and from Waikari, North Canterbury (probably Tongaporutuan), but no material so identified remains in collections. Suter (1914, p. 38) selected a

Plate 16 Temperate Early Miocene (Otaian-Altonian) Mollusca (1).

- a,c. *Neilo awamoana* Finlay, x 2.
- b,d,f. *Varinucula sagittata* (Suter), x 3.
- e,g. *Limopsis zealandica* Hutton, x 2.
- h,j. *Limopsis catenata* Suter, x 1.5.
- i. *Pinna* cf. *distans* Hutton, x 0.67.
- k. *Trichomya huttoni* (Cossmann), x 1.5.



specimen from The Cliffs as the lectotype, but all available specimens from this locality are very poorly preserved and cannot be satisfactorily compared with other *Limopsis*. *L. zitteli* is therefore best regarded as a *nomen dubium*, and Suter's name is accordingly resurrected for this species (which is here interpreted in a rather broad sense).

L. parma (Duntroonian, Chatton) is similar to *L. catenata* but is considerably smaller and more rounded in outline, has a smoother shell and has a smaller resilifer. *L. lawsi* (Tongaporutuan, Hurupi Stream area, southern Wairarapa, and Blind River, Marlborough) is smaller than *L. catenata*, has weaker radial sculpture and has a more asymmetrical hinge.

Figured specimen (Pl. 16h, j): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 16 k. *Trichomya huttoni* (Cossmann, 1916) [*Mytilus striatus* Hutton 1885b, p. 332 (not of Montague, 1803, etc.); *Mytilus huttoni* Cossmann 1916, p. 11 (new name for *M. striatus* Hutton, preoccupied); *M. (Aulacomya) huttoni*] (Mytilidae: Mytilinae).

Size moderate for family (length 35–50 mm), mytiliform (i.e. beaks terminal), strongly inflated; dorsal margin long, almost straight; ventral margin weakly concave. Radial sculpture of numerous, narrow, low, flattened costellae, additional ones appearing during growth by intercalation as well as by bifurcation, those on posterior area swinging around towards dorsal margin, so producing a divaricate pattern. Radial costellae absent from proximal part of anterior area. Commarginal sculpture of growth lines. Interior nacreous, margins finely crenulate. Anterior adductor muscle scar elongate, close to umbo; posterior scar subquadrate. Ligamental groove parallel to, and somewhat below dorsal margin, extending almost entire length of margin.

Altonian; "Broken River" (type—probably from the Altonian shellbed at the base of the Enys Formation, junction of Porter and Thomas Rivers); Target Gully Shellbed, Oamaru (not uncommon); Awamoa Creek (rare).

Trichomya huttoni is readily distinguished from other New Zealand mytilids by its moderately large size, its mytiliform shape, its fine radial sculpture and its absence of an umbonal septum. A related species, characterised by its larger size, its more alate shape and its more strongly concave ventral margin, is recorded from the Harper River, Canterbury (Waitakian). The genus is extinct in New Zealand but still lives in Australia, byssally attached to hard substrates in shallow water (less than 20 m).

Figured specimen (Pl. 16k): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 16 i. *Pinna* cf. *distans* Hutton, 1873 [*Pinna distans* Hutton 1873b, p. 126; "*Pinna lata* Hutton" of Murdoch 1924, p. 157 (not of Hutton 1873b)] (Pinnidae).

Moderately large for genus (height c. 300 mm), narrowly triangular (apical angle about 35°), of rhomboidal section medially (with a low median radial ridge from umbo to mid-valve), flattened distally. Outer layer prismatic calcite, up to 5 mm thick; inner layer nacreous aragonite. Radial sculpture of about 20 narrow costae with considerably wider interspaces over proximal half of shell, obsolete over ventral third. Commarginal sculpture on proximal half of narrow, well spaced ridges intersecting radial costae; remainder of shell with fine growth lines dorsally, very prominent rounded folds ventrally. Interior (visible in very few specimens) with very deeply subdivided nacreous layer, the long, narrow embayment of pallial line producing a weakened shell area (and consequently a radial crack near umbo of most specimens) coincident with exterior median ridge.

Duntroonian(?)–Altonian; Altonian, Mount Harris Formation, Awamoa Creek, Oamaru, not uncommon (at least locally) but difficult to collect.

Murdoch (1924, p. 157) referred the figured specimen to *Pinna lata*, which is based on a specimen from "Cobden" near Greymouth, probably of Whaingaroan age. The type specimen is lost but Hutton's exceedingly brief description is of a broadly triangular shell (apical angle 60°) with sculpture of commarginal striae. A probable near-topotype from Point Elizabeth in the NZGS collection is broadly triangular (axe-head-shaped) and has weak radial sculpture as well as growth lines; it does not resemble the Awamoa specimen. The latter is much closer in shape to *P. distans*, which was described from "Caversham" (near Dunedin), and is therefore probably of Otaian or Altonian age. The holotype, however, is a steinkern with fewer (c. 11), much stronger and more widely spaced radial costae than the Awamoa shell, so the latter can only be tentatively assigned to *P. distans*. *Pinna* has a sporadic record in New Zealand from at least Piripauan (Late Cretaceous) to Altonian, and was present during Triassic and Jurassic time, but most of the available material is poorly preserved, and species-level taxonomy is consequently very unsatisfactory. Rosewater (1961, p. 218) claimed that *P. distans* and *P. lata* are "part of *Atrina pectinata zealandica* Gray" (the modern "horse mussel"), but *A. pectinata zealandica* is not known older than Tongaporutuan, and all earlier records appear to be of *Pinna* (sensu stricto). All Eocene to Early Miocene material we have seen shows at least some sign of the median external ridge and umbonal crack characteristic of *Pinna*, and some unusually well preserved specimens (e.g., from Duntroonian–Waitakian limestone at Curiosity Shop, Rakaia River) clearly reveal the bilobed internal nacreous area of *Pinna*.

Hutton (1873b, p. 26) described a third "species" of *Pinna*, *P. plicata*, questionably from Culverden, North Canterbury. This was shown by J.A. Thomson (in Suter 1915, p. 53) to be a fragment of the trace fossil *Zoophycus*, probably produced by a polychaete worm.

Figured specimen (Pl. 16i): Awamoa Creek, Oamaru, Altonian (TM2828, NZGS; figured by Murdoch 1924, pl. 9, fig. 2) (x 0.67).

Pl. 17 f,g. *Serripecten hutchinsoni* (Hutton, 1873) [*Pecten hutchinsoni* Hutton 1873b, p. 31; *Pecten beethami* Hutton 1873b, p. 31; *P. (Patinopecten) hutchinsoni*; *P. (Patinopecten) beethami*; *Serripecten beethami*]. Type species of *Serripecten* Marwick, 1928 (Pectinidae).

Large for family (length 90–150 mm), longer than high; inequivalve, left valve less inflated than right, disc flattened near dorsal margins. Prominent shell gape at both anterior and posterior ends. Ears very large, growing allometrically, up to 0.67 length of disc in large shells; dorsal margins of right ears divergent, serrated by projecting growth ridges; margins of left valve colinear, smooth. Byssal notch deep in young shells, less prominent in adults, fasciole well marked; no ctenolium. Ears separated from disc by grooves or channels of variable development, typically more prominent on posterior ears. Sculpture on right disc of 38–49 prominent radial costae, rounded or somewhat flattened and nearly smooth at first, then becoming finely scaly and more triangular in section, those towards anterior and posterior margins more assymetrical than in middle. A single, finely scaly costella appearing between each pair of costae at 40–45 mm from umbo, well developed in some shells, scarcely developed in others. Additional costellae appearing in interspaces in some large shells. All secondary and tertiary radials remaining much weaker than primaries. Commarginal sculpture of weak growth ridges only, shell surface having an overall slightly polished appearance. Radial sculpture on left valve commencing as about 26 narrow, rather subdued, almost smooth costellae, becoming much more numerous (through intercalation) and finely scaly during growth,

largest shells with as many as 120 narrow costae, most of which are similar in strength. Commarginal sculpture of very fine, low, imbricate lamellae, most of which are not continuous across disc, most prominent on crests of costae where they form small scales. Sculpture on ears similar to that on corresponding disc. Resilifer large, cardinal crura well developed. Adductor muscle scar very large.

Duntroonian?, Otaian-Tongaporutuan; Kaipuke Cliffs, Northwest Nelson, Altonian (type locality of *P. hutchinsoni*); "Upoko Ngaruru" (type locality of *P. beethami*—i.e. Upokongaruru River, a tributary of Wainuioru River, East Wairarapa, Clifdenian-Waiauian?), and from numerous localities in North and South Islands, in a wide range of lithofacies.

Serripecten hutchinsoni is one of the most widely recorded and most characteristic molluscs in the New Zealand mid-Cenozoic and is most common in shallow-water sandstone and shellbeds. It is readily distinguished from other mid-Cenozoic pectens by its large size (exceeded only by *Athlopecten athleta*), its very large ears and its highly discrepant sculpture. Other New Zealand species of *Serripecten* are much smaller than *S. hutchinsoni* and differ in sculptural details, particularly in the number of radial costae on the left valve. The south-eastern Australian Neogene species *Serripecten yahliensis* (Tenison Woods, 1876) closely resembles *S. hutchinsoni* in almost all characters, differing only in its narrower grooves between ears and the disc, and in its less obviously serrate costae on the right valve. It seems likely that the two species are closely related phylogenetically.

Figured specimens (Pl. 17f, g): GS11187, D45/f8824, Lill Sand, Clifden, Lillburnian (NZGS) x 0.67.

Pl. 17 a,b. "*Hinnites*" *trilli* Hutton, 1873 [*Hinnites trilli* Hutton 1873b, p. 32; *Chlamys oamarutica* Murdoch 1924, p.158] (Pectinidae).

Size moderate for genus (height 90 mm), robust; early *Chlamys*-like ("neanic") stage more or less equilateral, later stage oblique, irregular, ostreiform, attached to substrate by right valve. Change between 2 different styles of growth marked by strong hump or step in shell profile. Byssal notch well developed in neanic stage, apparently obsolete in adult. Sculpture on left valve *Chlamys*-stage of 11 or 12 narrow, widely spaced, broadly triangular, finely scaly, radial costae, with secondary and tertiary costellae (which eventually rival the primary costae in strength) appearing during growth. Surface of neanic stage except crests of costae covered with dense rasp-like microsculpture of very small intersecting scales. Neanic sculpture persisting onto early ostreiform stage then replaced by about 35 subequal, low, rounded, wavy costae bearing low, well spaced scales. Hinge without crura; resilifer prominent, oblique. Adductor muscle scar large, circular.

Altonian; Mount Harris Formation, Awamoa (type locality of *H. trilli*); Target Gully Shellbed (type locality of *C. oamarutica*); Old Rifle Butts, Cape Wanbrow; basal shellbed, Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin. Rare or uncommon at all localities.

"*Hinnites*" *marwicki* (Lillburnian-Waiauian), the only other species of the genus so far described from New Zealand, differs in having far fewer (only 20) costae on the ostreiform stage. The earliest local record of the genus is from the Kaiatan or Runangan of Nelson; other records are from the Duntroonian or Waitakian Cookson Volcanics in North Canterbury, from the Chatton Formation, Mataura River, Southland (Waitakian) and from the Otekaike Limestone near Duntroon, North Otago (Waitakian).

Hinnites has long been assumed to be a "form genus", i.e. a polyphyletic group in which have been included

several different *Chlamys*-like species that have independently evolved a cemented habit. This being so, it is unlikely that the New Zealand species—which may constitute a monophyletic group—are closely related to the type species of *Hinnites*, *H. crispa* (Brocchi, 1814) (Pliocene, Italy). On the other hand they do not seem to be related to the western North American species *H. giganteus* (Gray, 1825), type species of *Crassadoma* Bernard, 1986 (Bernard 1986, p. 73). *H. trilli* and *H. marwicki* have a very distinctive microsculpture which should give some clue as to their origin; in this context, it may be significant that a similar type of microsculpture is present in the Late Paleocene pecten *Chlamys mercuria* (Pl. 4e, f). The common southern Australian Miocene species *Hinnites corioensis* McCoy, 1879 has similar microsculpture to that of the New Zealand species, and seems likely to belong in the same monophyletic group.

Figured specimen (Pl. 17a, b): holotype of *Hinnites trilli*, Awamoa, Oamaru (probably mouth of Awamoa Creek), Altonian (TM2846, NZGS) x 1.

Pl. 18 a,b. *Anomia trigonopsis* Hutton, 1877 [*Anomia alectus* of Hutton 1873a, p. 83 (not of Gray, 1850); *A. cytaeum* of Hutton 1873a, p. 83 (not of Gray, 1850); *Anomia trigonopsis* Hutton 1877b, p. 598; *Anomia walteri* Hector 1895, p. 292; *A. huttoni* Suter 1913c, p. 843; *A. undata* of Suter 1913c, p. 843 (not of Hutton 1885); *A. poculifera* Marshall 1918, p. 20] (Anomiidae: Anomiinae).

Moderately large for family (length up to 90 mm, height to 76 mm), subcircular, weakly inflated; right valve thin and fragile, not often found fossil. Left valve thicker but of lamellar-calcitic structure, most fossils flaky and fragile; attached to hard substrate (shells, or more usually rocks) by a calcified byssal plug passing through a foramen (a constricted byssal notch; see description under *Pododesmus incisurus*, below) near umbo of right valve; byssal plug smaller than foramen, therefore remaining attached to substrate on death. Sculpture on left valve only, exceedingly variable, from almost smooth or irregularly hummocky, or with very fine radial costellae to quite coarse, nodulose costae. (Illustrated shell has moderately coarse sculpture). Many specimens show additional xenomorphic sculpture (copying that of the substrate). Ligament internal, dorsal, attached to a prominent but relatively small, simple crus with flat dorsal face in right valve, and to matching pit below dorsal margin in left valve. White aragonitic central area of right valve with large, smooth, circular byssal adductor muscle scar; left valve with 3 scars arranged in a triangle, a large subcircular one above 2 much smaller, similar ones.

Bortonian?, Duntroonian-Recent; Southburn Sand, White Rock River, Altonian (type locality of *A. trigonopsis*); Pakaurangi Formation, Pakaurangi Point, Otaian or Altonian (type locality of *A. poculifera*); Paihia, Bay of Islands, Recent (type locality of *A. walteri*). Widely recorded from throughout New Zealand.

The presence of three muscle scars in the left valve easily distinguishes *Anomia trigonopsis* from most other New Zealand Anomiidae (the large, uppermost scar and small, central one are scars of the divided byssal retractor muscle, and the lowermost small scar is of the valve adductor; Yonge 1977). The exception is *Patro undatus* (Pl. 39d,f), which differs in having a prismatic (rather than lamellar) right valve, and in having the three muscle scars in the left valve arranged in a nearly straight line, the lowest (valve adductor) being the largest. All New Zealand (and probably Australian) *Anomia* specimens examined appear to be conspecific, and in view of the great range of variation in shape and sculpture it is difficult to find meaningful specific criteria in the genus; most bivalve taxonomists now agree that there appear to

be very few living species, and there are certainly no obvious shell differences between *A. trigonopsis* and the type species *A. ephippium* Linné, 1758 (Recent, North Atlantic and Mediterranean).

Figured specimen (Pl. 18a, b): Oneroa, Waiheke Island, Auckland, Otaian (NZGS, ex Fleming Colln) x 1.

Pl. 18 c,f. *Pododesmus (Pododesmus) incisurus* (Hutton, 1873) [*Placunanomia incisura* Hutton 1873b, p. 34; *Monia zelandica* (Gray) of Boreham 1965, p. 46 (in part)] (Anomiidae: Placunanomiinae).

Size moderate for family (height 35-57 mm), suboval, a little higher than long, relatively thick-shelled and robust. Most specimens reasonably flat, but some weakly folded near margin; inflation slight (only 7 mm in an articulated shell 57 mm high). Attached to hard substrates (usually molluscan shells) by a thick, calcified byssal plug passing through a foramen (a deep byssal notch that becomes surrounded by shell margin during growth, leaving a shallow groove at the junction of shell edges) in right valve a short distance below dorsal margin. Byssal plug pale brown in all specimens, coarsely striated on internal face. Sculpture of regular, high, narrow radial costellae on both valves (except for a small attachment area near right valve umbo), very variable in prominence, but in most specimens relatively coarse, about 2 mm apart distally, and bearing many small, semitubular spines. Ligament internal, attached in right valve to a prominent, high, triangular, bilobed crus; in left valve to a matching pit below dorsal margin. Most of shell calcitic; a central white (aragonitic) layer is irregularly oval in left valve but hooks around byssal plug in right valve. Within aragonitic area, a small, smooth oval adductor muscle scar in each valve, and a small, oval, radially wrinkled byssal retractor scar in left valve.

Waitakian-Altonian; "Pareora Beds, Rangitata", Otaian? (type); recorded widely from shallow shelf faunules, particularly common at some Altonian localities near Oamaru.

Pododesmus incisurus is easily distinguished from *Anomia* (e.g. *A. trigonopsis*, above) by having only two muscle scars in the left valve (three in *Anomia*), by the byssal adductor scar being radially wrinkled, by the large, bilobed ligamental crus (lower and with flat dorsal face in *Anomia*), by the very distinctive, coarsely striated byssal plug (not constricted by the shell and so left attached to the substrate in *Anomia*) and by the coarse, narrow, spinose radial costae (low and irregular in *Anomia*). A very few specimens of *P. incisurus* have been seen with xenomorphic sculpture (reflecting the high relief of the substrate); this is much more common in *Anomia*. Other species of *Pododesmus* are *P. maxwelli* (Whaingaroan-Duntroonian, Aotea Harbour and Otago-Southland), with a smaller byssal plug, much finer sculpture, a more strongly triangular resilial crus, and a thinner shell which is thrown into two or three very deep radial folds; and *P. paucicostatus* (Clifdenian-Waiauan,

Canterbury and Southland), which is closely similar to *P. incisurus* but has much coarser radial sculpture.

Yonge (1977, p. 459) found no anatomical differences between *Pododesmus* and *Monia zelandica*, the type species of *Monia* Gray, 1849, and considered *Monia* to be a synonym of *Pododesmus*. However, species assigned to *Monia* have a thinner right valve than *Pododesmus* (sensu stricto), a simpler ligamental crus like that of *Anomia*, and a much larger byssal plug that is not constricted by the shell margins, and this group is worthy of subgeneric rank under *Pododesmus*. *P. (Monia) zelandicus* (Opoitian-Recent) resembles *Anomia* in most shell characters, but has sculpture like that of *P. incisurus* and only two muscle scars in the left valve.

Figured specimens (Pl. 18c, f): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) (left valve interior and right valve exterior) x 1.

Pl. 18 e,h. *Lima colorata* Hutton, 1873 [*Lima colorata* Hutton 1873b, p.33; ? *Lima paucisulcata* Hutton 1873b, p. 33; *L. colorata colorata*] (Limidae).

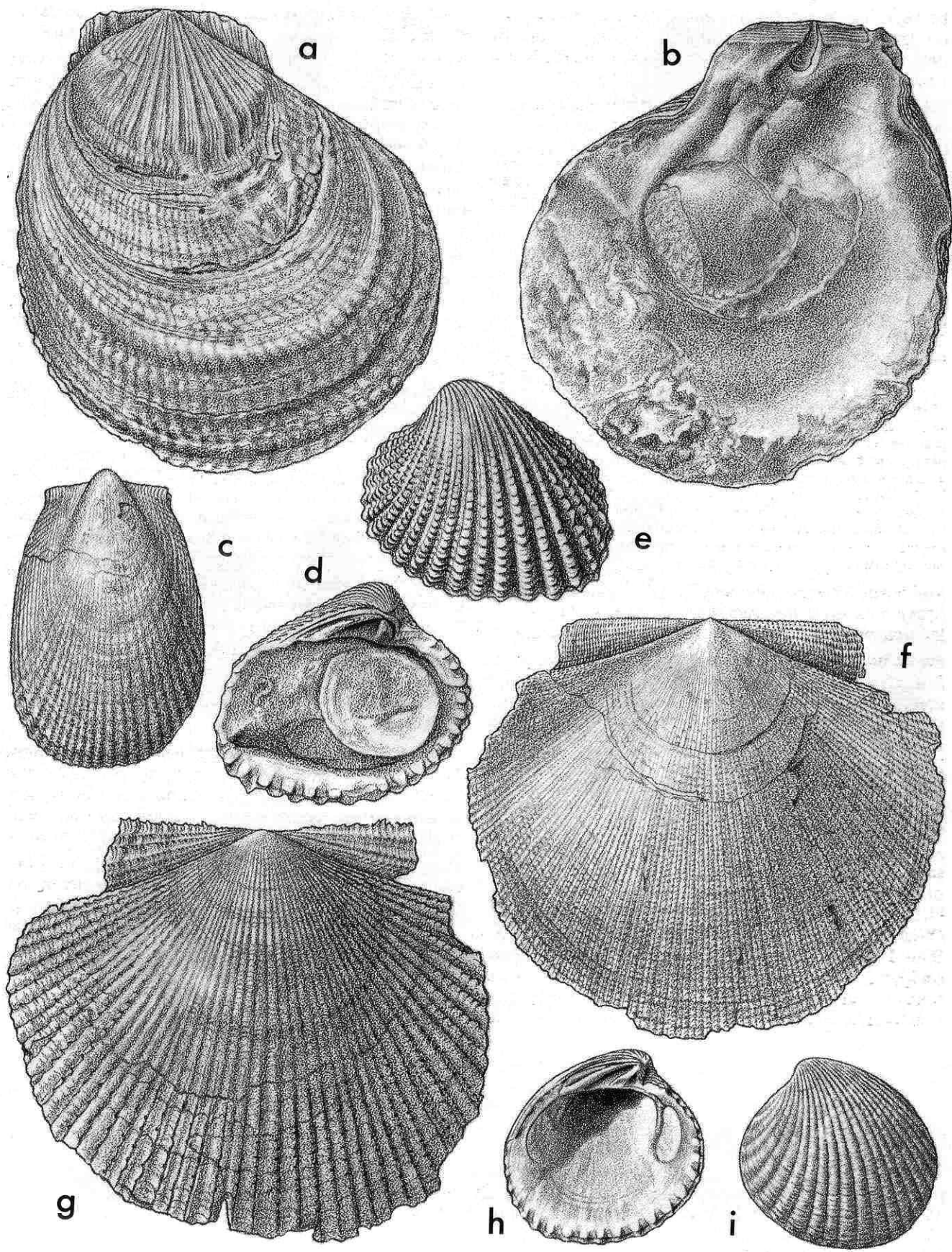
Rather large for genus (height 65-108 mm), robust, strongly oblique, exterior of many specimens red or black. Posterior ear well developed, anterior ear much smaller, scarcely projecting beyond antero-dorsal margin. Anterior area strongly depressed, flattened or slightly concave. Flanks with 18-23 prominent radial costae of squarish section, crests flattened or slightly convex, becoming more convex distally, showing through on interior of some shells. Crests with sparse scales, usually worn off and typically best developed towards anterior and posterior margins of flanks. Interspaces smooth except for fine oblique ridges proximally and exceedingly fine commarginal and radial striae elsewhere. Anterior area with growth ridges and a variable number of low, narrow, scaly or nodulose radial costae, in some shells present across whole width, in others confined to posterior part. Anterior ear with rather coarse growth ridges; posterior ear with growth ridges and scattered scales, with weak radial costae in only a few specimens. Cardinal area highly variable in size; resilifer large.

Otaian-Waiauan, probably ranging younger; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type locality of *L. colorata*); Kaipuke Cliffs, northwest Nelson, Altonian (type locality of *L. paucisulcata*) and many localities in North and South Islands, locally very common.

The upper limit of the stratigraphic range of *Lima colorata* is uncertain, partly because of the scarcity of well preserved *Lima* after the Waiauan. Boreham (1965, p. 37-43) took a very broad view of *L. colorata* and included in her concept of the species *L. paucisulcata*, *L. crassa* Hutton, 1873 (Waipipian, Lower Waipara) (not *L. crassa* Forbes, 1844), *L. zelandica* (Recent) and *L. mestayerae* Marwick, 1924 (Nukumarian, Hawke's Bay). The first

Plate 17 Temperate Early Miocene (Otaian-Altonian) Mollusca (2).

- a,b. "Hinnites" *trailli* Hutton, x 1.
- c. *Limatula (Stabilima) exulans* Fleming, x 1.5.
- d,e. *Purpurocardia perscrupulosa* (Marwick), x 1.
- f,g. *Serripecten hutchinsoni* (Hutton), x 0.67.
- h,i. "Cyclocardia" *awamoensis* (Harris), x 1.



of these probably belongs in *L. colorata*, if only because of its age (Altonian ?), although topotypes have an unusually low rib-count (17-19, mean 18) (Boreham) 1965, p. 38-40). The type specimen of *L. crassa* is a fragment of a much larger shell (height c. 90 mm)—it may be a Waipipian specimen of *L. colorata* or may have been reworked from an older (possibly Waiauan) horizon. A left valve of *Lima* from the Whenuataru Tuff, Motutapu Point, Pitt Island (Waipipian) is closer to *L. colorata* than to *L. zealandica*, but differs from topotypes of *L. colorata* in having fewer but stronger and more widely separated radial costellae on the anterior area. More specimens of *Lima* from Pliocene localities are required before an extension of the range of *L. colorata* into the Waipipian can be confirmed. *L. zealandica*, however, differs from typical *L. colorata* in its smaller size (height of largest specimen seen c. 70 mm) and thinner shell (so radial costae are clearly expressed on the interior and muscle scars are far less distinct), in having much weaker radial sculpture on the anterior area, and in having much coarser microsculpture (of oblique or chevron-shaped ridges) between the radial costae. It is here regarded as a distinct species. *L. mestayerae* has similar microsculpture to *L. zealandica* and is considered to be conspecific, although its consistently small size may be regarded as grounds for maintaining it as a distinct taxon (e.g. a subspecies of *L. zealandica*).

Lima paleata (Whaingaroan-Waitakian) is very similar to *L. colorata* but differs in having more numerous radial costae (24-30). Boreham (1965, p. 43) classed it as a subspecies of *L. colorata*, but it is here afforded species status.

Although *Lima* has a long stratigraphic range (Jurassic-Recent; Cox and Hertlein in Moore 1969, p. N386), the oldest known Cenozoic record of the genus in the New Zealand region is from the Runangan (Bridge Point, Kakanui). Its apparent absence from older horizons may result from lack of suitable lithofacies (which seems unlikely) or may indicate that the genus did not arrive here until the Late Eocene.

Figured specimen (Pl. 18e, h): GS9520, J41/f8029, Awamo Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 17 c. *Limatula (Stabilima) exulans* Fleming, 1978 ["*Lima jeffreysiana* Tate" of Suter in Speight 1917, p. 348, 354 (in part); *Limatula (Stabilima) jeffreysiana exulans* Fleming 1978, p.68] (Limidae).

Large for genus (height 35-42 mm), equilateral, strongly inflated. Dorsal

margins moderately long, sloping away from umbones; ears well defined, bounded below by shallow concavity in shell margin. Median radial sculpture of 18-24 narrow, well spaced, triangular-sectioned costae, almost smooth except distally where they become slightly nodulose or scabrous. Anterior and posterior areas with 9-20 much finer, beaded radial costellae, separated from median costae by zones without definite radial sculpture. Commarginal sculpture of growth ridges. Resilifer very large, projecting below cardinal area.

Altonian, shellbed at base of Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin (type) (not uncommon).

Limatula exulans is distinguished from other New Zealand *Limatula* species by its relatively large size (although it is rivalled in this respect by Recent specimens of *L. maoria* from the Chatham Islands), in having distinct ears, and in having radial costellae on the anterior and posterior areas of adult shells (absent from adults of *L. maoria*). Fleming (1978, p. 68-69) considered this species to be closely related to the Australian Miocene *L. jeffreysiana* Tate, 1885, differing from it primarily in its larger size and in sculptural details.

Limatula ranges from Late Cretaceous (Piripauan) to Recent in New Zealand and is represented by numerous species, most of which require careful examination for identification (see Fleming 1978). We have not followed Fleming (1978) in ranking New Zealand taxa as subspecies of overseas species, and we consider the successional members of some species groups (which may represent evolving lineages) to be discrete species, rather than chronosubspecies.

Figured specimen (Pl. 17c): holotype, GS3188, K34/f9073, Porter River, Castle Hill Basin, Canterbury, Altonian (TM5502, NZGS) x 1.5.

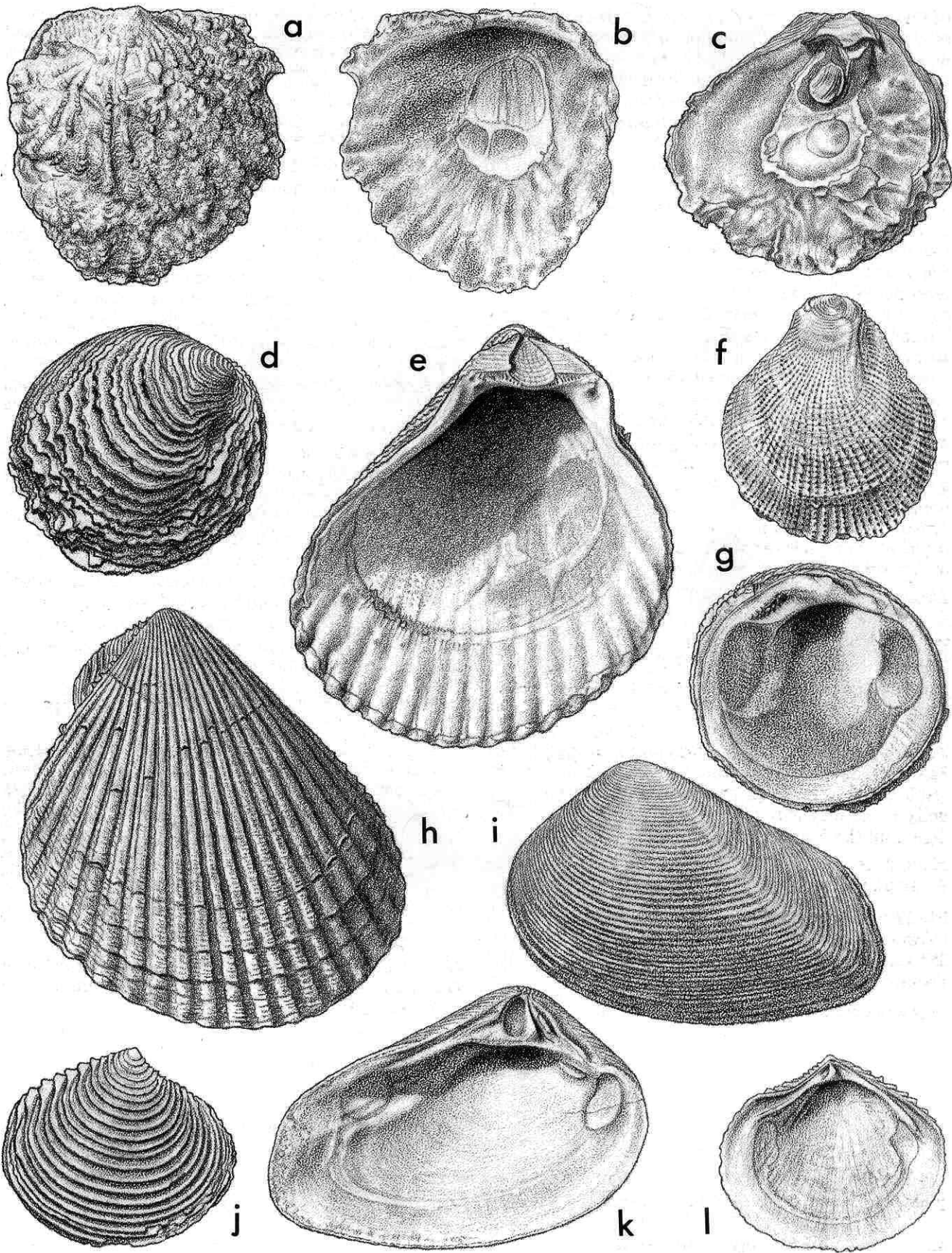
Pl. 18 j,l. *Myrtea valdesculpta* Marwick, 1943 [p. 185] (Lucinidae).

Small for family (length 4-8 mm), subtrigonal-ovate, moderately inflated. Beaks sub-central, orthogyrous. Lunule and escutcheon lanceolate, strongly differentiated. Commarginal sculpture of distant, narrow lamellae raised into subtriangular spines along dorsal margins, particularly on posterodorsal margin. Spacing between lamellae very variable, but typically 3-4 per mm. Interspaces smooth apart from growth lines in some shells, but with fine, rather irregular radial ridges in others. Left hinge with very weak anterior and posterior lateral teeth, a narrowly triangular anterior cardinal and a similar posterior cardinal tooth. Right hinge with strong, distant anterior and posterior laterals and a narrow, triangular median cardinal tooth. Adductor muscle scars ovate, subequal. Internal margins smooth.

Altonian; Target Gully Shellbed (type) and other North Otago and South Canterbury localities, where it is the most common lucinid.

Plate 18 Temperate Early Miocene (Otaian-Altonian) Mollusca (3).

- a,b. *Anomia trigonopsis* Hutton, x 1.
- c,f. *Pododesmus (Pododesmus) incisurus* (Hutton), x 1.
- d,g. *Chama* sp., x 1.5.
- e,h. *Lima colorata* Hutton, x 1.
- i,k. *Spissatella trailli* (Hutton), x 1.5.
- j,l. *Myrtea valdesculpta* Marwick, x 6.



Myrtea valdesculpta closely resembles *M. staminifera* (Dunroonian, Chatton), but differs in having a straighter anterodorsal margin. In view of the considerable variability present in New Zealand species of *Myrtea*, however, it is possible that these species are not really distinct. *Myrtea* has a recorded range of Dunroonian to Opoitian in New Zealand; elsewhere the genus has a wide bathymetric range (from about five metres down to mid-bathyal depths).

Figured specimen (Pl. 18j, l): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 6.

Pl. 18 d,g. *Chama* sp. (Chamidae).

Size moderate for genus (length 30-35 mm), right (free) valve subcircular, moderately inflated. Left valve not known but presumably like that of *C. huttoni* Hector, 1886, i.e. subtrigonal with a flattened anterior attachment area, and more inflated than right valve; cemented to hard substrates. Commarginal sculpture of very prominent, imbricate lamellae, produced into broad frills on well preserved shells and bearing fine radial grooves and ridges. Right hinge with prominent socket on lower part of plate, its upper side strongly and crudely rugose; a rather crude, elongate posterior cardinal tooth and a much narrower and lower ridge bordering the distal portion of a deeply incised ligamental groove. Adductor muscle scars large, ovate, area inside pallial line calcitic and therefore differently preserved from that outside. Internal margins smooth.

Altonian, Target Gully Shellbed, Oamaru (uncommon); ? Pakaurangi Point.

The new (?) species is possibly conspecific with *C. huttoni* (Nukumaru, Castlepoint, Wairarapa) but apparently has more distinct radial sculpture on the commarginal lamellae, although the available material of *C. huttoni* is not well-enough preserved to confirm this. The only other species of *Chama* to have been described from New Zealand, *C. pittensis* (Waipian, Pitt Island), is only doubtfully distinct from *C. huttoni*. A very distinct chamid, recorded from Otaian beds in Northland, differs from *C. huttoni* and the Target Gully species in its larger size (length up to 80 mm) and in having sculpture of finely spinose growth ridges rather than distinct lamellae.

Chama ranges from about Mangaorapan (upper Waihao River, South Canterbury) to Nukumaru in New Zealand. Extant species occur elsewhere in warm, shallow waters, cemented to hard substrates.

Figured specimen (Pl. 18d, g): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 17 h,i. "*Cyclocardia*" *awamoensis* (Harris, 1897) [*Venericardia intermedia* Hutton 1873b, p.24 (secondary homonym of *Chama intermedia* Brocchi, 1814; *Venericardia intermedia* of Borson, 1825); *Cardita awamoensis* Harris 1897, p. 360 (new name for *Venericardia intermedia* Hutton 1873, preoccupied); *V. pseutes* Suter 1917, p. 73; *V. awamoensis*; *V. (Megacardita) awamoensis*; *V. (Cyclocardia) awamoensis*] (Carditidae: Venericardiinae).

Size moderate for family (height 30-40 mm), ovate-subquadrate, moderately inflated, typically longer than high. Lunule very small, deeply impressed, its margin sloping strongly backwards; escutcheon narrow, vertical. Radial sculpture of 21-24 prominent costae, rounded or somewhat flattened, with interspaces of similar width, over proximal half of shell but becoming lower, more rounded and less well defined towards ventral margin. Crests with fine nodules on umbones, later smooth or with fine growth lines. Left hinge with thin, strongly backward-sloping anterior cardinal tooth and a long, thin, slightly arched posterior cardinal. Right hinge with low, tubercular anterior cardinal tooth that is almost completely obsolete in some shells, a rather narrow, slightly arched median cardinal, and a lamellar posterior cardinal that in many shells is barely distinguishable from nymph.

Dunroonian ?, Altonian; Mount Harris Formation, Altonian, Awamoa Creek (type locality of *C. awamoensis*), very common here and at many localities in North Otago and, less commonly, in South Canterbury. Type of *V. pseutes* from "Oamaru".

Specimens of "*Cyclocardia*" from the Wharekuri Greensand at the head of Lake Waitaki (Dunroonian) are similar to Altonian shells in most characters, but are generally larger (height up to 50 mm) and have more numerous (25-27) radial costae. They may represent an unnamed species. "*Cyclocardia*" *christiei* (Pl. 10g, i) is larger and more oblique than *C. awamoensis*, and has more prominent radial sculpture.

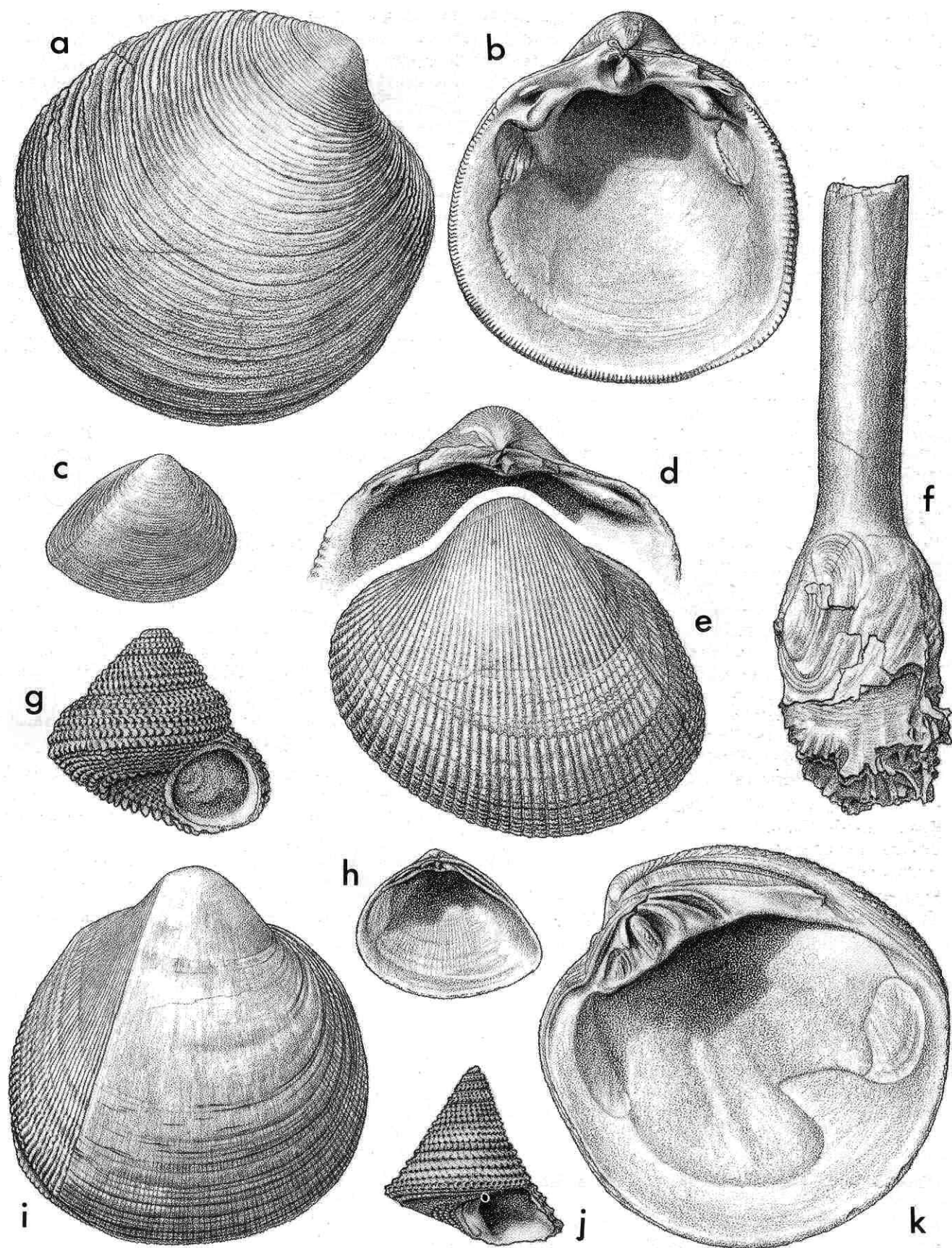
Figured specimen (Pl. 17h, i): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 17 d,e. *Purpurocardia perscrupulosa* (Marwick, 1932) [*Venericardia perscrupulosa* Marwick 1932, p. 497; *V. (Purpurocardia) perscrupulosa*] (Carditidae: Venericardiinae).

Size moderate for family (length 47-57 mm), suboblong, considerably longer than high, beaks situated at about 0.25 anterior-posterior distance; posterior area slightly concave. Lunule small, pouting. Radial sculpture of 25-28 very prominent tuberculate or spinose costae of triangular section, the third one from posterodorsal margin considerably

Plate 19 Temperate Early Miocene (Otaian-Altonian) Mollusca (4).

- a,k. *Dosinia (Raina) bensoni* Marwick, x 1.
- b,i. *Nemocardium (Varicardium) patulum* (Hutton), x 1.
- c,h. *Maorimacra acuminella* Finlay, x 3.
- d,e. *Hedecardium (Titanocardium) cantuariense* (Laws), x 0.67.
- f. *Clavagella oamarutica* Maxwell, x 1.5.
- g. *Zetela awamoana* Laws, x 8.
- j. *Calliostoma (sensu lato) fragile* Finlay, x 4.



stronger than those on either side and having more prominent scales than other costae. Left hinge with a strong, erect, triangular anterior cardinal tooth free of lunular margin, and a long, slender, slightly arched posterior cardinal. Right hinge with anterior cardinal tooth confluent with lunular margin, a prominent, broadly triangular median cardinal, and a thin posterior cardinal fused to the nymph.

Altonian-Waiuan; Altonian, Target Gully Shellbed, Oamaru (type); Ardgowan Shellbed, Oamaru; Glenmark Limestone, Weka Pass; Burnt Hill, Oxford; Double Corner shellbeds, Lower Waipara Gorge; "Nissen no. 1 shellbed", Clifden. Uncommon at all localities.

Purpurocardia perscrupulosa differs from other New Zealand venericardiines in its relatively elongate shape, its truncate posterior end, and its very prominent, triangular-sectioned, tuberculate radial costae.

Figured specimen (Pl. 17d, e): holotype, GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (TM4320, NZGS) x 1.

Pl. 18 i,k. *Spissatella trailli* (Hutton, 1873) [*Crassatella trailli* Hutton 1873b, p. 24; *Crassatellites trailli* [sic]; *Crassatellites obesus* (A. Adams) (not of Adams)]. Type species of *Spissatella* Finlay, 1926 (Crassatellidae).

Size moderate for genus (length 40-50 mm), suboblong, moderately elongate (length: height 1.28-1.55) and inflated; posterior area well defined. Lunule strongly impressed in both valves; escutcheon much more prominent and more deeply impressed in right valve than in left. Commarginal sculpture of relatively prominent, low, narrow ridges on flanks (12-14 per cm at 1 cm from apex), much finer and more numerous on posterior area. Hinge very similar to that of *S. subobesa* (Pl. 11a).

Otaian-Altonian; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type) and other Altonian localities in Oamaru district; Mt Harris; Bluecliffs, Otaio River. Common to very common at most localities.

Specimens of *Spissatella* from Trig Z, Otiake (Waitakian) are similar to *S. trailli* in shape and size but are more finely sculptured, particularly on the umbones. Some individuals have commarginal ridges persisting throughout growth, but most have sculpture becoming obsolete or reduced to growth lines distally. They are inferred to be conspecific with an undescribed species in which commarginal sculpture is almost completely obsolete, common in Waitakian off-shore siltstone in the Hakataramea Valley and the upper Tengawai River. *S. trailli* differs from *S. subobesa* (Pl. 11a) in its less elongate shape and in having coarser commarginal sculpture. *S. clifdenensis* (Altonian, Clifden) is somewhat smaller than *S. trailli* (length about 40 mm), is less elongate (length: height 1.23-1.33), has a more sharply defined umbonal ridge, and has finer commarginal sculpture (17-20 ridges per cm at 1 cm from apex). Another Altonian species, *S. scopalveus* (Target Gully Shellbed) differs from *S. trailli* in its more elongate shape (length: height 1.37-1.47), narrower posterior end and, most importantly, in having commarginal sculpture almost obsolete except on the umbones.

Spissatella is well represented in shelf and upper slope assemblages from Kaiatan to Altonian, and less so from Clifdenian to Tongaporutuan. Some species, including *S. subobesa* and *S. trailli*, are among the most common molluscs in their respective faunules. The genus also occurs in Oligocene rocks in Victoria, Australia (*S. maudensis* (Pritchard, 1903), Janjukian; Darragh 1965, p. 110-111).

Spissatella is closely similar to *Eucrassatella*, but the species assigned to *Spissatella* are typically smaller and

less strongly inflated than those of *Eucrassatella*, and have a less strongly convex ventral margin. In most species of *Spissatella* commarginal sculpture persists over the whole shell instead of being restricted to the umbonal region, although in some species (e.g. *S. scopalveus*, Altonian, Target Gully, Oamaru) it is obsolete on the adult. The two genera are very similar in hinge characters, although the right anterior cardinal tooth is typically better developed in *Spissatella* than in *Eucrassatella*.

Figured specimen (Pl. 18i, k): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.5.

Pl. 19 b,i. *Nemocardium (Varicardium) patulum* (Hutton, 1873) [*Cardium patulum* Hutton 1873b, p. 23; *Protocardia (Nemocardium) alata* Suter 1917, p. 78; *Protocardia patula*; *Nemocardium patulum*; *Varicardium patulum*]. Type species of *Varicardium* Marwick, 1944 (Cardiidae: Protocardiinae).

Moderately large for family (height 65-95 mm), robust, subequilateral, higher than long, strongly inflated; posterior area well defined, lunule not strongly differentiated. Anterior and median regions polished in well preserved shells, with commarginal sculpture of prominent rounded ridges and radial sculpture of more than 100 very fine radial lines (actually subsurface costellae that finely crenulate inner margins). Posterior area with about 30 low, rounded or flat-topped radial costae that bear minute tubercles on anterior edges on well-preserved young shells. Commarginal sculpture of growth lines that make the radial costae scaly distally. Hinge prominent, with strong anterior and posterior lateral teeth in each valve. Left hinge with prominent peg-like anterior cardinal tooth and a small posterior cardinal; right hinge with a small tubercular anterior cardinal attached to top of prominent triangular median cardinal. Adductor muscle scars large, ovate, subequal.

Waitakian (?); Otaian-Waiuan; "The Deans", Waipara (type locality of *C. patulum*—probably Mount Brown Formation, Weka Creek, Altonian?); *Neothyris* Shellbed, Weka Creek, Altonian (type locality of *P. alata*) and numerous localities throughout North and South Islands, where it is the most characteristic cardiid in shallow-water assemblages.

The poorly known *N. (Varicardium) serum* (Dunroonian, Castle Hill Basin) is very similar to *N. patulum*, apparently differing only in its smaller size (less than 65 mm in height) and its slightly less rounded shell—it may not be distinct.

Varicardium is very similar to *Nemocardium* (sensu stricto) but lacks the prominent nodules on the posterior area characteristic of the latter taxon. *Varicardium* is recorded from Kaiatan to Waiuan in New Zealand; the only local record of *Nemocardium* (sensu stricto) is from the Bortonian Stage (McCulloch's Bridge). The living tropical Indo-West Pacific species *Nemocardium bechei* (Reeve) is very similar to *N. patulum* and may be referable to *N. (Varicardium)*.

Figured specimen (Pl. 19b, i): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 1.

Pl. 19 d,e. *Hedecardium (Titanocardium) cantuariense* (Laws, 1933) [*Cardium (Trachycardium) cantuariense* Laws 1933, p. 317; *Hedecardium cantuariense*]. Type species of *Titanocardium* Maxwell, 1978 (Cardiidae: Protocardiinae).

Very large for family (length 75-105 mm), rather thin-shelled, highly inflated; posterior area well defined. Posterior end truncate, with a distinct siphonal gape. Lunule well defined. Anterior and median regions with radial sculpture of about 45 low, rounded or flat-topped costae, those near middle of shell with a shallow longitudinal groove distally, interspaces considerably wider anteriorly than in middle of shell. Posterior area with about 15 costae with narrow interspaces, more

subdued than those on rest of shell, and becoming obsolete near posterodorsal margin. Commarginal sculpture of weak growth lines. Hinge similar to that of *Hedecardium waitakiense* (Pl.13d,e).

Altonian; Southburn Sand, Sutherlands, Tengawai River (type); White Rock River; Ardgowan Shellbed, Oamaru.

Hedecardium cantuariense is not particularly common at any locality, but is conspicuous because of its large size. *H. (Titanocardium) greyi* (Otaian, Auckland) grows to a larger size than *H. cantuariense* (length up to 120 mm), has more widely spaced costae (particularly in the middle of the shell) and has a much narrower siphonal gape. *H. (Titanocardium) marwicki* (Lillburnian-Waiauian or Tongaporutuan, Clifden and Wairarapa) is more similar to *H. cantuariense* than is *H. greyi*, but differs in having a broader lunule and in having the radial costae in the middle of the shell triangular in section and lacking a longitudinal groove. The subgenus *Titanocardium* differs from *Hedecardium* (sensu stricto) in its much larger size and, more significantly, in having a distinct posterior gape.

Figured specimen (Pl. 19d, e): GS9700, J38/f9681, Sutherlands, Tengawai River, Altonian (NZGS) x 0.67.

Pl. 19 a,k. *Dosinia (Raina) bensoni* Marwick, 1927 [p. 587]. Type species of *Raina* Marwick, 1927 (Veneridae: Dosiniinae).

Moderately large for genus (length 65-85 mm), robust, moderately inflated; posterior area slightly flattened. Lunule relatively long, impressed or weakly pouting; escutcheon more prominent in left than in right valve. Commarginal sculpture on posterior area and towards anterior end of thin, lamellar ridges; central area somewhat polished on well preserved shells, sculpture reduced to shallow grooves with relatively broad, smooth interspaces, more numerous and more closely spaced near ventral margin. Ridges decreasing abruptly in strength on left escutcheon, but continuing virtually unchanged across right escutcheon. Left hinge with a prominent, rugose anterior lateral tooth, a thin anterior cardinal, a narrowly triangular, bifid median cardinal (anterior portion much the narrower) and a long, curved posterior cardinal. Right hinge with a rugose anterior lateral pit, a rather short, thin anterior cardinal tooth, a rugose, triangular median cardinal and a heavy, strongly grooved posterior cardinal. Pallial sinus rather variable in shape and depth, but always distinctly ascending, pointing towards upper part of anterior adductor muscle scar.

Altonian-Waiauian; Target Gully Shellbed, Oamaru, Altonian (type) and several localities in North Otago, Canterbury and Southland, in sandstone or shellbeds.

Dosinia bensoni is distinguished from other species of *D. (Raina)* primarily by the sculpture, i.e. commarginal grooves with relatively broad, smooth interspaces in the middle of the shell, passing into lamellar ridges towards the ends. *Dosinia (Raina)* is an endemic taxon with a recorded range of Duntroonian to Nukumaruan, and seems to have been restricted to relatively shallow waters (i.e. inner shelf zone). The main distinguishing character of the subgenus is that the right posterior cardinal tooth is considerably broader than the right median cardinal.

Figured specimen (Pl. 19a, k): GS9866, M34/f9146, "Neothyris shellbed", Weka Creek, North Canterbury, Altonian (NZGS) x 1.

Pl. 19 c,h. *Maorimactra acuminella* Finlay, 1930 [p. 53] (Mactridae: Mactrinae).

Small for family (length 11-15 mm), subtrigonal, inequilateral, strongly inflated; postero-umbonal ridge rounded, bounding a well defined, flattened posterior area. Commarginal sculpture rather variable, of relatively prominent, narrow, rounded ridges on posterior area and near anterodorsal margin, flanks with much finer ridges and some smooth areas, particularly proximally and anterior to umbonal ridge. Left hinge

with a single, prominent lamellar lateral tooth at each end, separated from dorsal margins by a long, deep groove, a small bifid median cardinal in the form of an inverted V, and a very short, curved, spur-like posterior cardinal attached to top of median cardinal. Right hinge with 2 lamellar lateral teeth at each end, the ventral one of each pair the stronger, a narrow, rather short anterior cardinal, and a much shorter posterior cardinal. External ligamental hollow very small, separated from prominent triangular resilifer by ridge. Pallial sinus moderately deep, broadly rounded.

Altonian; Southburn Sand, White Rock River (type); Sutherlands, Tengawai River (moderately common).

Maorimactra acuminella is very similar to the Opoitan-Recent *M. ordinaria* but more inequilateral, with a more pronounced postero-umbonal ridge and a more produced, narrower posterior end. Finlay (1930b, p. 53) referred *Maorimactra* specimens from Nukumarua (Nukumaruan) and Castlecliff (Castlecliffian) to *M. acuminella*, but most specimens from these much younger horizons are more like *M. ordinaria* than *M. acuminella* in shape; Finlay may have had specimens of a large, undescribed species that occurs in lower formations at Castlecliff.

Figured specimen (Pl. 19c, h): GS5897, J39/f6519, White Rock River, Canterbury, Altonian (NZGS) x 3.

Pl. 19 f. *Clavagella oamarutica* Maxwell, 1978 [p. 28-29] (Clavagellidae).

Size moderate for family (length probably up to 100 mm), anterior end of tube (sac) inflated, more so dorsoventrally than laterally, bearing numerous irregularly branching tubules and frill-like processes on anterior end and (on some shells) on part of right side. Rest of tube narrower, rather irregular, ovate in section, smooth, posterior end probably simple. Left valve subrectangular, attached to sac and visible on exterior, early portion with sculpture of radial rows of minute papillae, remainder with growth lines and numerous, fine, oblique wrinkles. Right valve free in interior, sculpture like that of left valve; hinge edentulous; pallial sinus moderately deep, narrowly triangular.

Altonian; Gee Greensand, Target Gully (type) (not uncommon); Awamoa Beach (rare); possibly also represented by specimens of Altonian to Waiauian age from Mokau, Taranaki, Ngahape, Wairarapa and Clifden, Southland. Specimens from the Chatton Formation, Shell Gully, Chatton (Duntroonian) may represent another species.

Clavagellids are among the most bizarre of all known bivalves, having one or both valves attached to the anterior end of a rigid tubular structure in the adult. Some species are adapted for burrowing in soft sediments, others for nestling in cracks or inside shells. The holotype of *C. oamarutica* may have lived in a subhorizontal position on or near the surface of the sediment, but other specimens seem to have nestled in the umbonal cavity of bivalves.

Figured specimen (Pl. 19f): holotype, GS9572, J41/f8040, Gee Greensand, c. 12 m below shellbed, Target Gully, Oamaru, Altonian (TM5458, NZGS) x 1.5.

Pl. 19 j. *Calliostoma (sensu lato) fragile* Finlay, 1923 [*C. suteri* var. *fragile* Finlay 1923, p. 102; *Venustus fragilis*; *Maurea fragilis*] (Trochidae: Calliostomatinae).

Rather small for subfamily (height 10-12 mm), trochiform, spire 0.6 total height, almost straight-sided throughout most of growth, then slightly concave (i.e. coeloconoid). Protoconch of little more than 1 whorl. Teleoconch of 6-7 almost straight-sided whorls with very weakly marked suture, last whorl with sharply angled periphery, base lightly convex with shallow central depression. Axial sculpture of low, narrow, prosocline costellae confined to first 4 or 5 whorls, finely reticulating spiral cords and forming small beads at intersections. Spiral sculpture commencing as 2 fine threads, with a 3rd appearing above and a 4th, just above suture, during growth; penultimate whorl with 4 narrow cords, the lowest noticeably stronger than others; some shells with

threads appearing between cords on last whorl. All spire spirals prominently beaded. Base with a narrow, moderately prominent cord near periphery with 1 or 2 weaker ones on either side, and 3 or 4 nodulose cords in middle, space between (about half diameter) smooth except for growth lines or bearing a few weak spirals. Aperture quadrate, nacreous within; columella strongly oblique, with a low denticle at base; inner lip with narrow nacreous band extending into axial depression.

Altonian; Ardgowan Shellbed, Oamaru (type); Target Gully Shellbed, Oamaru; Pukeuri (not uncommon).

Calliostoma fragile is distinguished from other mid-Cenozoic species of *Calliostoma* (sensu lato) by its slightly concave outline, its narrow spiral cords and the broad, smooth or weakly sculptured zone on the base.

Figured specimen (Pl. 19j): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 4.

Pl. 19 g. *Zetela awamoana* Laws, 1939a [p. 477; *Solariella (Zetela) awamoana*] (Trochidae: Solariellinae).

Small for family (height 4.5 mm), turbiniform, spire 0.6 total height. Protoconch smooth, of 1 whorl, terminated by a low, thin varix. Teleoconch whorls 3.5-4, obtusely angled adapically on early whorls, angulation gradually descending during growth and becoming obsolete on later whorls of most specimens. Last whorl with peribasal angulation; base gently convex with a broad, conical umbilicus. Axial sculpture commencing as narrow, well spaced costae reaching from suture to suture, becoming more numerous, thinner and more closely spaced, so that on later whorls it consists of imbricate lamellae forming small scales on spiral cords and subdued in interspaces; last whorl with about 75 such lamellae that persist across base and into umbilicus. Spiral sculpture commencing as 3 narrow, low cords—the uppermost on shoulder angulation—joined during growth by 2 or 3 other cords, tending to become subequal on last whorl; last whorl with additional cord of similar strength on peribasal angulation, and 6 or 7 narrow scaly cords between it and a heavy, more coarsely nodulose circumumbilical cord. Umbilicus with about 10 moderately strong, beaded cords within. Aperture subcircular, prosocline.

Altonian; Mount Harris Formation, Pukeuri (type) (moderately common); Awamo Creek (uncommon).

Zetela awamoana is very similar to the Recent *Z. textilis* (Murdoch and Suter, 1906) but has more prominent spiral sculpture, particularly on the base. *Z. praetextilis* (Dunroonian, Castle Hill Basin) has much weaker sculpture than either *Z. textilis* or *Z. awamoana*—in particular, the axial sculpture on the last whorl consists of little more than fine nodules on the spiral cords. *Z. textilis* is confined to the outer shelf and uppermost slope, and *Z. awamoana* may have had a similar habitat.

Figured specimen (Pl. 19g): GS9685, J41/f9499B, Pukeuri road-cutting, Oamaru, Altonian (NZGS) x 8.

Pl. 20 a. *Zeacolpus (Zeacolpus) pukeuriensis* Marwick, 1934 [p. 12] (Turritellidae).

Size moderate to large for family (height 45-115 mm), spire tall, slender. Protoconch turbiniform (1.5—nearly 2 whorls) or mamillate (2.5—nearly 3 whorls). Teleoconch of up to 18 whorls, early whorls strongly convex or medially angled, becoming slightly campanulate on about 9th whorl, adults typically with a rounded ridge abapically, giving whorls a frustate profile. B and C commencing at beginning of teleoconch, B remaining the stronger and medially angulating whorls until about 8th whorl when C rivals and eventually surpasses it, becoming flanked by 1 or more subsidiary cords on abapical ridge. A commencing very weakly on about 3rd whorl, not equalling B until 12th whorl or later. Subsidiary spirals becoming as strong as primaries on later whorls, which typically have 12 to 14 subequal, fine spirals. Outer lip sinus moderately deep, apex above middle of whorl.

Altonian-Lillburnian; Mount Harris Formation, Pukeuri, Oamaru, Altonian (type) (common) and other Altonian localities in North Otago and Canterbury, and several

localities in Southland and North Island. Most common in off-shore siltstone and fine sandstone.

Zeacolpus fyfei (Lillburnian-Waiauian, Gisborne district) is very similar to *Z. pukeuriensis* but has early and adolescent whorls more cylindrical and less frustate, and most specimens have a median zone of weaker sculpture. Along with *Z. lawsi* (Otaian-Altonian, Northland), these species form the “fyfei stock” of Marwick (1971a, p. 28), characterised by having frustate adult whorls with numerous sub-uniform spirals. *Z. awamoensis* (Altonian, widespread) occurs, apparently sympatrically, with *Z. pukeuriensis* at several localities; it is readily distinguished by having primary spirals A and B remaining much stronger than the subsidiaries, and in having campanulate adult whorls.

Figured specimen (Pl. 20a): GS9520, J41/f8029, Awamo Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 20 e. *Tropicolpus (Tropicolpus) abscisus* (Suter, 1917) [*Turritella (Haustator) concava* Hutton 1877b, p. 597 (not of Say, 1826, etc.); *T. (Colpospira) concava*; *T. (Zaria) abscisa* Suter 1917, p. 8; *T. albolapis* Finlay 1924a, p. 101 (new name for *T. concava* Hutton, preoccupied); *Zeacolpus albolapis*; *Tropicolpus albolapis*; *Zeacolpus abscisus*]. Type species (as *T. albolapis*) of *Tropicolpus* Marwick, 1931 (Turritellidae).

Large to very large for family (height 70-150 mm), robust. Protoconch mamillate, of 2.5 smooth whorls. Teleoconch of about 20 whorls, earliest whorls biangulate, quickly becoming strongly keeled below middle, keel soon becoming obsolete; subadult whorls concave, adult whorls subquadrate, telescoped, swollen adapically, gently concave below. B and C commencing at beginning of teleoconch, subequal at first, but C surpassing B on about 3rd whorl, B fading into background by about 6th, C by about 12th whorl. Cord A remaining insignificant throughout growth. Subadult and adult whorls with a broad, low cingulum at about 0.67 whorl height, and numerous fine, subuniform spirals below. Outer lip sinus moderately deep, asymmetrical, apex at or somewhat above middle, abapical limb becoming progressively more strongly convex during growth.

Altonian; “Oamaru” (type locality of *T. abscisa*—probably Mount Harris Formation, Old Rifle Butts, Cape Wanbrow); Southburn Sand, White Rock River (type locality of *T. concava*) and other localities in North Otago, Canterbury and southern Marlborough. Most common in shallow-water sandstone and shellbeds.

Tropicolpus abscisus is differentiated from other “giant” mid-Cenozoic turritellids by the submedially keeled early teleoconch whorls, by the more or less telescoped later whorls and by the tendency for the abapical limb of the sinus to become strongly convex in the adult. *T. milleri* (Altonian?, Clifdenian to Tongaporutuan, East Coast, North Island) is possibly conspecific, although it includes individuals with a very heavy adapical cingulum and strongly concave adult whorls.

Figured specimen (Pl. 20e): GS5591, J38/f9498, Sutherlands, Tengawai River, Canterbury, Altonian (NZGS; specimen figured by Marwick 1971a, pl. 8, fig. 11) x 1.

Pl. 20 i. *Sigapatella (Sigapatella) maccoyi* (Suter, 1917) [*Calyptraea (Sigapatella) maccoyi* Suter 1917, p. 9] (Calyptraeidae).

Size moderate for genus (diameter 15-25 mm), cap-shaped, apex strongly excentric, near margin; with internal septum and highly excentric umbilicus. Protoconch of about 1.5 smooth whorls. Teleoconch of 1.5-2 whorls, early part with fine spiral threads, later part with prominent, rather irregular cords, interrupted by growth ridges, mostly more or less spiral, but some divergent; 11-15 cords distally. Well preserved shells with an overlay of numerous very fine discontinuous spiral threads.

Duntroonian?, Altonian; Mount Harris Formation, Awamoa, Oamaru, Altonian (type) (rare); Target Gully Shellbed (moderately common); ? Whitewater Creek, Castle Hill Basin, Duntroonian.

Sigapatella subvaricosa (Waiheke Island, Otaian) is very similar to *S. maccoyi* and may not be distinct, but it seems to have spiral cords that are more discontinuous than those of *S. maccoyi*. An undescribed species from Lorne, North Otago (Kaiatan) has spiral rows of small tubercles and has a superficial resemblance to some species of *Haliotis*. Other New Zealand *Sigapatella* species are either devoid of spiral sculpture or have only fine threads.

Figured specimen (Pl. 20l): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 20 g,h. *Struthiolaria (Struthiolaria) calcar* Hutton, 1886 [*S. cincta* var. C Hutton 1873b, p.11; *S. calcar* Hutton 1886a, p.335; *S. subspinosa* Marwick 1924b, p.175; ?*S. prior* Finlay 1926b, p.228] (Struthiolariidae).

Rather small to moderate-sized for genus (height 25-55 mm), broadly ovate, spire gradate, about half total height. Protoconch depressed dome-shaped, of about 2.5 apparently smooth whorls, apex flattened. Teleoconch of 5-6.5 whorls, first 2 or 3 convex, then developing an angulation at about 0.6-0.7 whorl height that quickly becomes very prominent; some shells with a second, weaker angulation between shoulder and lower suture that becomes obsolete after a whorl or so. Last whorl with a prominent peribasal angulation, some shells with a weaker one a short distance below. Whorl sides convex or flat at first, strongly concave on adult; base flat or slightly concave, anterior end pointed. Spiral sculpture varying considerably in strength, commencing as 7 or 8 narrow, low, subequal cords, increasing steadily in number during growth, penultimate whorl with about 20-30 narrow cords, mostly subequal but including some noticeably weaker than others in some shells; some well preserved specimens with very fine interstitial threadlets. Last whorl with 15-25 similar spirals on base. Axial sculpture—apart from growth lines—commencing as numerous very small nodules on shoulder angulation, decreasing in number and increasing in strength during growth, penultimate whorl with 17-25, last whorl with 10-20 shoulder tubercles, in many shells becoming obsolete on last quarter-whorl. Tubercles sharp in some shells, bluntly triangular in others. Peribasal angle with more obscure nodules not corresponding in position or number to shoulder tubercles. Aperture ovate-trigonal, constricted anteriorly; columella twisted to right. Inner lip prominently calloused, less so in parietal region than below, callus not extending far above suture, strongly excavated over columella. Outer lip calloused to varying degree, prosocline and almost straight from suture to shoulder angle, slightly concave between whorl angles, strongly retracted from peribasal angulation to end of columella. Some specimens with a distinct, short spine at shoulder angle, its face shallowly grooved, but others lacking such a spine.

?Duntroonian, Waitakian-Clifdenian, possibly younger (Waiauan?); "Oamaru" (type locality of *S. calcar*—possibly Ardgowan Shellbed, Altonian, the locality of Marwick's neotype); Southburn Sand, White Rock River, Altonian (type locality of *S. subspinosa*) and numerous localities, particularly in South Island. The upper stratigraphic limit of *S. calcar* is uncertain—specimens from "Nissen no. 1 shellbed", Clifden (Waiauan) resemble Altonian shells in shape and sculpture, but are much larger (height 80-85 mm), a difference of doubtful taxonomic significance.

This is by far the most widely recorded and apparently the longest-ranging New Zealand struthiolariid, although the vast majority of records are under the name *S. subspinosa* rather than *S. calcar*. Marwick (1924b, p. 176) recognised the great similarity between these two nominal species but maintained that the presence of a spine (or "spur") on the outer lip of *S. calcar* warranted segregation from *S. subspinosa*, and this distinction has been accepted by all subsequent workers. However, large series of shells

show a complete gradation between those with a well developed spine and those without any trace of such a feature, and it is clear that it varies as much as other sculptural features in this highly variable species. Specimens with the spine seem to represent a shallow-water phenotype, as they occur mainly in shellbeds and in the Southburn Sand. With some reluctance, *S. subspinosa* is here regarded as a junior synonym of *S. calcar*. *S. prior* (Duntroonian, Waikaia, Southland) is probably another synonym of *S. calcar* (see Pl.15a), as the alleged differences between the two taxa are neither very important nor—as far as can be ascertained from the limited material available of *S. prior*—particularly constant. *S. lawsi* (Otaian, Waiheke Island) is similar to *S. calcar*, but grows to a much larger size (more than 125 mm in height), and has fewer but stronger peripheral tubercles (about seven per whorl on later whorls). Some individuals have a prominent spine-like extension to the outer lip at the periphery as in *S. calcar*.

Figured specimens (Pl. 20g, h): GS5517, J38/f6605, Tengawai River near Sutherlands, South Canterbury, Altonian (NZGS) x 1.5.

Pl. 20 b. *Struthiolaria (Callusaria) spinosa* Hector, 1886 [*S. spinosa* Hector 1886, p.51; *S. tuberculata* Hutton (in part, not of Hutton, 1873)] (Struthiolariidae).

Rather similar to *S. (Struthiolaria) calcar* (see above) but typically larger (height 45-70 mm) and stouter, and differing in sculptural and apertural details. The spines on the shoulder angle are considerably more prominent and usually fewer in number (8-12 on penultimate, 8-10 on last whorl) than in *S. calcar*, and the nodules or tubercles on the lower (peribasal) angulation are much more prominent than in any specimen of *S. calcar*, in some shells persisting right to the outer lip. The apertural callus is more heavily developed, with parietal callus spreading up to the shoulder angle of the previous whorl, and in some individuals, partly obscuring 1 or 2 tubercles. Some specimens have a well developed tongue-like extension to the outer edge of the inner lip callus, far more prominent than that noted on any specimen of *S. calcar*.

Altonian, Waiauan?; Altonian, Southburn Sand, White Rock River (type); Sutherlands; Ardgowan Shellbed, Oamaru; Tommy's Creek, Upper Waipara River. Most common in shallow-water sandstone and shellbeds, but a few specimens recorded from deeper-water siltstone.

Struthiolaria (Callusaria) callosa (Pl. 29d, e) has a much more heavily developed apertural callus than that of *S. spinosa*, particularly over the inner lip, with the parietal callus extending over the shoulder angle and, in some shells, up to the upper suture. Rare specimens of *Callusaria* from Waiauan beds in Southland (e.g. "Nissen no. 1 shellbed", Clifden) are more like *S. spinosa* than *S. callosa*, despite their stratigraphic position, suggesting that *S. spinosa* has a much longer stratigraphic range than the other records indicate.

The relationship of the very poorly known *S. (Callusaria) otaioica* (Bluecliffs, Otaio River, Otaian) to *S. spinosa* is uncertain; Laws (1935c, p. 41-42) distinguished his species on the basis of differences in shape and in the number of tubercles (12 on penultimate, 14 on last whorl in *S. otaioica*), but the importance of these differences must remain doubtful until additional material from Bluecliffs or a similar horizon becomes available.

Figured specimen (Pl. 20b): GS9700, J38/f9681, Sutherlands, Tengawai River, South Canterbury, Altonian (NZGS) x 1.

Pl. 20 c,d. *Struthiolaria (Callusaria) tuberculata* Hutton, 1873 [*S. tuberculata* Hutton 1873b, p.11; *S. spinosa* Hutton 1886a, p. 335 (not of Hector, 1886)] (Struthiolariidae).

Rather small for genus (height typically 35-40 mm but up to 50 mm). Protoconch not known. Teleoconch whorls with a pronounced subsutural fold, producing a relatively narrow, strongly concave sutural ramp, about 5-7 whorls on adult shells; peribasal angulation on last whorl typically projecting more strongly than shoulder angulation, area between angles almost flat. Spiral sculpture preserved on only a few unworn specimens, of fine threads; axial sculpture of prominent, sharp tubercles on shoulder angle and somewhat weaker ones, not corresponding in number or position to those above, on lower angulation; 10-12 shoulder tubercles on both penultimate and last whorls. Aperture moderately heavily callused; inner lip callus thickest near middle where it forms a tongue-shaped projection on some shells; parietal callus spreading above peribasal angulation, in some shells extending almost to shoulder angle. Outer lip with a broad, flat, rather low varix and a narrow but relatively deep posterior notch.

Altonian, "Broken River" (type—probably from Enys Formation, Porter River, Castle Hill Basin, between the limestone gorges, or from Whitewater Creek) (common at both localities). Not definitely recorded away from Castle Hill Basin.

Struthiolaria spinifera (Otaian or Altonian, Mt Harris) resembles *S. tuberculata* in sculpture and in having the peribasal angulation projecting more than the shoulder angle, but the holotype is considerably larger (height 60 mm) than the largest specimen of *S. tuberculata*, has a much less pronounced subsutural fold, and lacks the distinctive posterior notch in the outer lip. *S. spinifera* is known definitely only by the holotype and although it may be represented by very rare shells from Sutherlands and Ardgowan Shellbed, it is too poorly understood to tell if it is a recognisable species. The "*Struthiolaria* beds" in the Castle Hill Basin are of very shallow-water, probably

estuarine, facies whereas the Mount Harris Formation is a deeper-water, probably mid or outer shelf deposit, suggesting that distinct species should be expected in these formations. *S. tuberculata* is effectively distinguished from other species by its relatively small size, prominent subsutural fold, strongly tubercular sculpture, projecting peribasal angulation and distinct posterior notch.

Figured specimen (Pl. 20c, d): GS14484, K34/f9510, "*Struthiolaria* beds", Porter River, Castle Hill Basin, Canterbury, Altonian (NZGS) x 1.5.

Pl. 20 i. *Tanea consortis* (Finlay, 1924) [*Natica consortis* Finlay 1924b, p. 451; *Cochlis socius* Finlay 1927b, p. 499 (invalid new name for *N. consortis*); *Tanea social*] (Naticidae: Naticinae).

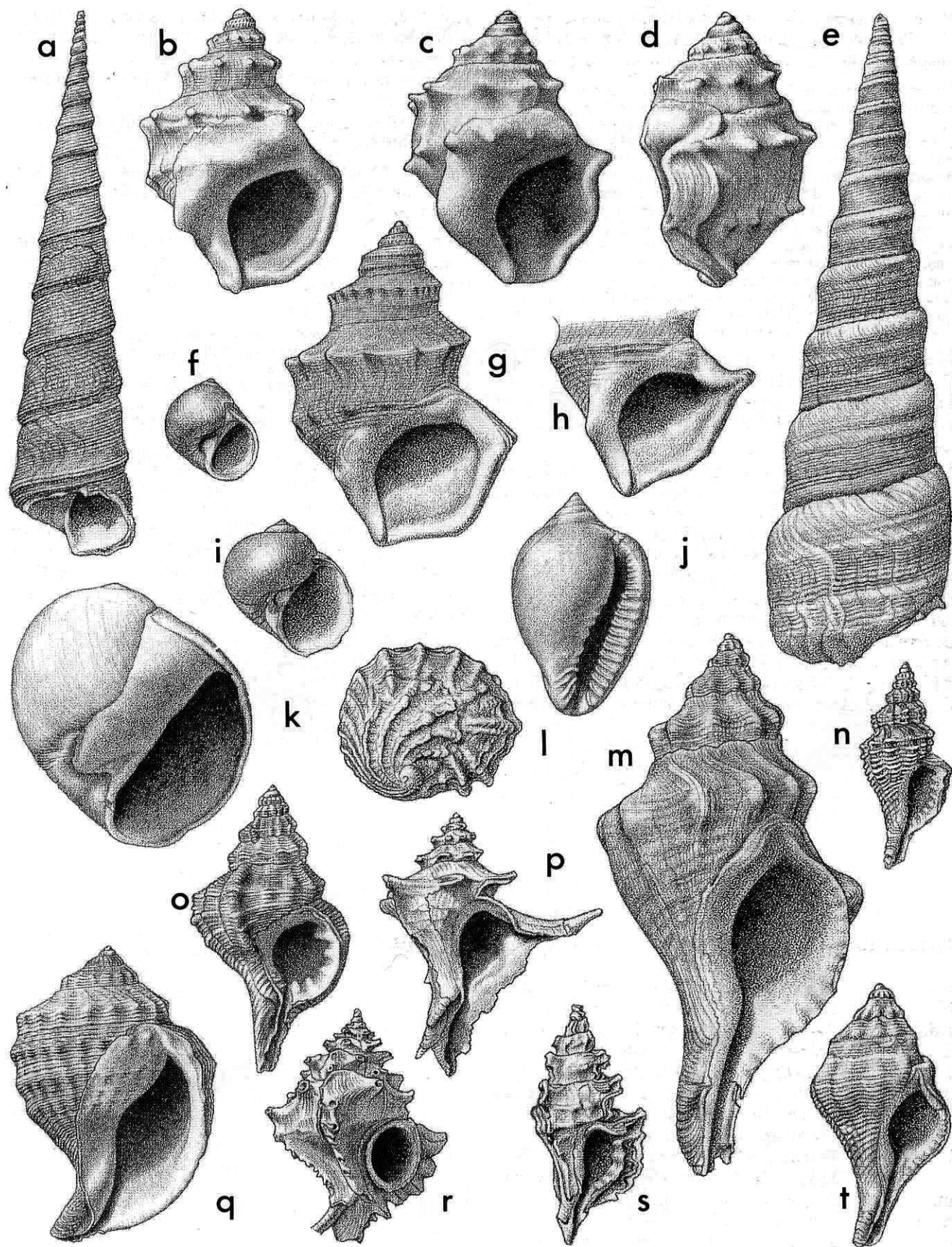
Small for genus (height 8-11 mm), globose, spire slightly gradate, 0.25-0.3 total height. Protoconch moderately large, depressed, of about 2.5 smooth whorls. Teleoconch of 2.5-3 whorls, strongly convex except adapically where they are distinctly flattened and turned in towards suture, forming a sutural shelf; last whorl capacious, with a moderately wide umbilicus. No sculpture apart from weak growth lines and feeble spiral ridges, surface polished in well preserved shells. Umbilicus with a moderately large, smooth funicle. Aperture ovate, inner lip shallowly grooved along its length to take operculum; parietal callus thin. Outer lip prosocline, inclined at about 20° from vertical, almost straight except near suture where it is slightly retracted.

Altonian-Opoitian; Mount Harris Formation, Pukeuri road cutting, Oamaru, Altonian (type) and other Altonian North Otago localities; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour, Otaian-Altonian; Kaawa Creek, Opoitian.

Another Altonian species, *T. sublata* (Marwick, 1924) (White Rock River; Sutherlands) differs from *T. consortis* in its noticeably narrower shape and its higher spire. Both species are much smaller than *T. zelandica* (Nukumarian

Plate 20 Temperate Early Miocene (Otaian-Altonian) Mollusca (5).

- a. *Zeacolpus (Zeacolpus) pukeuriensis* Marwick, x 1.
- b. *Struthiolaria (Callusaria) spinosa* Hector, x 1.
- c,d. *Struthiolaria (Callusaria) tuberculata* Hutton, x 1.5.
- e. *Tropicolpus (Tropicolpus) abscisus* (Suter), x 1.
- f. *Taniella (Taniella) notocenica* (Finlay), x 2.
- g,h. *Struthiolaria (Struthiolaria) calcar* Hutton, x 1.5.
- i. *Tanea consortis* (Finlay), x 2.
- j. *Proterato neozelanica* (Suter), x 2.
- k. *Polinices (Polinices) huttoni* Ihering, x 1.
- l. *Sigapatella (Sigapatella) maccayi* (Suter), x 1.5.
- m. *Penion marwicki* (Finlay), x 0.67.
- n. *Xymene* n.sp.(?), x 3.
- o. *Sassia (Sassia) maoria* (Finlay), x 1.5.
- p. *Poirieria delli* Maxwell, x 1.5.
- q. *Galeodea (Galeodea) apodemetes* Marwick, x 1.5.
- r. *Typhis (Typhis) hebetatus* Hutton, x 1.5.
- s. *Prototyphis (Prototyphis) awamoanus* (Finlay), x 4.
- t. "*Vesanula*" *tegens* (Hutton), x 2.



Recent) and have a relatively smaller funicle. The earliest member of the genus, *T. praeconsors* (Bortonian-Kaiatan, Waihao River), is smaller than *T. consors* (height seven mm) and has a narrow infra-umbilical ridge as well as a minute funicle.

Finlay (1927b, p. 499) claimed that the epithet "*consors*" was an error for "*consors*", even though the former name appears no fewer than nine times in the original paper, and as the name *Natica consors* was used by Dall in 1909, he thought a replacement name was needed for *N. consors* Finlay. Finlay's emendation is here regarded as unjustified — if he intended the epithet to be an adjective then "*consors*" is correct ("*consors*" is the masculine form); if on the other hand he was using the epithet as a noun then there is no conflict between "*consors*" (a brother) and "*consors*" (a sister). Under the 1985 Code of Zoological Nomenclature (Article 57f) these names are clearly not homonyms, and the name *consors* should not have been replaced.

Figured specimen (Pl. 20i): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 2.

Pl. 20 f. *Taniella (Taniella) notocenica* (Finlay, 1924) [*Natica notocenica* Finlay 1924b, p. 450; *Cochlis notocenica*; *Tanea notocenica*]. Type species of *Taniella* Finlay and Marwick, 1937 (Naticidae: Naticinae).

Rather small for family (height 7–12 mm), ovate, solid; spire low, conical, 0.15 total height. Protoconch depressed, of 2.5 smooth whorls with distinctly impressed suture. Teleoconch of 1.5–2.5 almost flush whorls, with only feebly impressed suture on spire, base with moderately wide umbilicus. No sculpture except for weak growth lines, well preserved shells polished. Umbilicus largely filled by prominent, smooth funicle of variable development but invariably separated from parietal region by deep groove or chink. Aperture semilunular, inner lip almost straight; parietal callus moderately thick. Outer lip thin, almost straight, inclined at about 20° from vertical.

Dunroonian-Opoitian; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type) and other Altonian localities near Oamaru, and numerous localities in North and South Islands.

Taniella notocenica is readily distinguished from *Tanea consors* (see above), with which it occurs at many localities, by its ovate shape with almost flush spire whorls and its large funicle. *T. notocenica* has a very long stratigraphic range; its presumed successor, *T. planisuturalis* (Pl. 41n), differs in its larger size and in having the funicle more widely separated from the umbilical wall. Finlay (1924b, p. 450) considered *T. notocenica* to extend down to the Kaiatan (McCulloch's Bridge) but specimens from that locality are considered to belong in a distinct, undescribed species; they are on the whole broader in relation to height than *T. notocenica*, have a smaller funicle, and have a shallower notch separating the funicle from the parietal callus.

T. notocenica occurs in a wide range of lithofacies and seems to have had a considerable bathymetric range (inner shelf to uppermost bathyal zone). A deeper-water habitat (upper bathyal zone) seems to have been favoured by such species as *T. motutaraensis* (Altonian, Motutara, Auckland), *T. mima* (Clifdenian-Waiuan, Westland) and *T. poliniformis* (Tongaporutuan, Wairarapa); these species differ from *T. notocenica* in having a tuberculate rather than a smooth funicle, and in having the umbilicus more or less completely filled.

Figured specimen (Pl. 20f): GS9500, J41/f8028,

excavation for Oamaru Borough Council septic tank, south Oamaru, Altonian (NZGS) x 2.

Pl. 20 k. *Polinices (Polinices) huttoni* Ihering, 1907 [*Natica solida* "Sowerby" of Hutton 1873b, p. 9 (not of G.B. Sowerby I, 1846, nor of Blainville, 1825); *Natica (Neverita) gibbosa* Hutton 1886a, p. 334 (not of Lea, 1833) (new name for *Natica solida* Sowerby of Hutton, 1873, preoccupied); *Polinices huttoni* Ihering 1907, p. 154 (new name for *Natica gibbosa* Hutton, 1886, preoccupied)] (Naticidae, Polinicinae).

Size moderate to very large for genus (height 30–65 mm), subglobose, ovate or subcylindrical; spire low, broadly conical, c. 0.1 total height. Protoconch low, of about 2.5 very weakly inflated, smooth, low whorls, not clearly differentiated from teleoconch. Teleoconch of 3–4 rapidly expanding whorls, spire whorls gently convex, last whorl typically somewhat flattened on sides, base convex. Well preserved shells with fine spiral grooves and weak ridges, otherwise smooth except for growth lines. Aperture large, semilunular, inner lip almost straight, heavily callused; parietal callus thick, spreading to a varying degree into umbilicus, almost completely filling it in some individuals, but leaving a shallow hollow or a chink in others. Outer (left) edge of callus almost straight in a few shells, but usually somewhat concave or obtusely angled, some shells with a short triangular lobe near middle. A short, shallow groove running obliquely from near base of umbilical callus towards aperture. Outer lip gently convex, rather thin and so damaged on most specimens.

Altonian-Lillburnian, possibly younger; "Broken River", Altonian? (type locality of *N. gibbosa* and *P. huttoni*—probably basal shellbed, Enys Formation, but precise locality unknown) and from very numerous localities in North and South Islands, in shallow-water sandstone or shellbeds. Very common at some localities (e.g. Sutherlands). The stratigraphic range is very imperfectly known because of the difficulty of confidently identifying fossil *Polinices* when only one or two indifferently preserved specimens are available.

No fewer than 19 species of *Polinices*, ranging in age from Wangaloan to Recent, have been described from New Zealand, and their relationships are for the most part poorly understood. *P. huttoni* seems to be characterised by its relatively large size, its low spire, its weak spiral sculpture, its heavy callus that almost fills the umbilicus, and its tendency for the sides of the last whorl to be flattened (although this is often noticeable on only large shells). *P. mucronatus* (?Lillburnian, Tongaporutuan) seems to be closely related to *P. huttoni*, differing in its smaller size (height about 30 mm), in having callus filling the umbilicus to a greater extent (though this is not consistent), and in having a deep groove separating the abapical end of the callus from the inner lip margin. The status of *P. intracrassus* (?Lillburnian-Tongaporutuan, "Castle Point", Wairarapa—probably really from the Mangapakeha Valley, west of the Cretaceous "taipos", east of Masterton) is unclear—the lectotype is a bizarre shell with a flattened apex, a minute spire, which is almost involute, and an exceptionally heavy parietal callus. It is much broader from left to right (in apertural view) than from front to back. Similar shells occur in the Lillburnian (e.g. the one figured by Marwick 1931, pl. 8, fig. 148 as *P. huttoni*) and Waiuan (Lower Waipara Gorge) where they accompany more or less typical specimens of *P. huttoni*. They may therefore merely represent an extreme morphotype in the *P. huttoni* population, but it must be stressed that none of the numerous specimens of *Polinices* available for study from Altonian localities (e.g. White Rock River; Sutherlands) even begin to approach the

extreme form of *P. intracrassus*, and few or none seem to occur in post-Waianan rocks.

Polinices is represented in the Recent New Zealand fauna by *P. tawhitirahia* Powell, 1965 (Northland, also Norfolk Island), but there are no records from the Nukumaruan or Castlecliffian, suggesting either that the genus was at that time confined to northernmost New Zealand (where no sediments of this age are known—the more probable alternative) or that the genus became extinct here and then arrived again recently. Most overseas records of *Polinices* are from subtropical or tropical regions, where it crawls buried in sand in shallow water (e.g., in sheltered intertidal sand flats) and is a predator on other molluscs.

Figured specimen (Pl. 20k): GS5592, J39/f6479, White Rock River, Altonian (NZGS) x 1.

Pl. 20 j. *Proterato neozelanica* (Suter, 1917) [*Erato neozelanica* Suter 1917, p. 12; *Lachryma* (*Proterato*) *neozelanica*]. Type species of *Proterato* Schilder, 1927 (Triviidae: Eratoinae).

Rather large for subfamily (height 12–20 mm), pear-shaped; spire low, conical, 0.15 total height, apex flattened. Whorls covered by thin callus, which almost totally obscures sutures except in abraded shells. Callus apparently absent from narrow irregular zone in middle of abapertural (dorsal) side. Protoconch planorboid, probably of about 2 whorls; teleoconch of about 4 or 5 whorls, last whorl large, weakly excavated. No sculpture, shell smooth and polished. Aperture narrow, inner and outer lips almost parallel. Base of inner lip with a strongly projecting, oblique ridge, which bifurcates at entrance to aperture, and another, less prominent one (also bifurcating in some shells) above. Posterior to these ridges is a narrow, concave gap, followed by 8–11 low denticles decreasing in strength posteriorly. Outer lip with a broad, rounded varix, leading face somewhat flattened, bearing 13–17 narrow, transverse lirae.

Waitakian-Altonian; Target Gully Shellbed, Oamaru, Altonian (type) and other Altonian localities near Oamaru; Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike; Mount Harris Formation, Bluecliffs, Otaio River; Mt Horrible, Pareora River; Coral Point, Kaipara Harbour. Uncommon or rare at all localities.

Proterato neozelanica is one of the largest New Zealand eratoines and is exceeded in size only by some species of *Willungia*, particularly *W. maoria* (Pl. 24e). Apart from its size, *P. neozelanica* is distinguished from other eratoines by its relatively elevated, conical spire and its prominent inner lip denticles, and in having a distinct gap between these denticles and the terminal apertural ridges. *P. waiouensis* (Altonian-Lillburnian, Clifden) is very similar to *P. neozelanica*, but is somewhat more slender and has stronger denticles at the posterior end of the inner lip. *P. pliocenica* (Opoitian-Waipipian) reaches a similar size to *P. neozelanica*. It seems to differ from *P. neozelanica* in its last whorl being taller and narrower, but is known by very few specimens.

Eratoines are mesogastropods and are therefore only very distantly related to the superficially similar marginellids (which are neogastropods). Eratoines differ from marginellids in having a planorboid rather than a bulbous or mamillate protoconch (although this feature is usually obscured by spire callus in both groups) and in lacking columellar plaits. Although apparently extinct in New Zealand, the subfamily has a good fossil record from at least Mangaorapan to Waipipian. The records indicate that most species lived in shallow waters (inner to middle shelf) with a few extending down into the upper bathyal zone.

Figured specimen (Pl. 20j): GS11154, J39/f26, Pareora River, foot of Mt Horrible, Otaian (NZGS) x 2.

Pl. 20 q. *Galeodea* (*Galeodea*) *apodemetes* Marwick, 1934 [p. 12; "*Galeodea senex* (Hutton)" of authors] (Cassidae: Cassinae).

Size moderate for genus (height 35–50 mm), broadly pyriform, spire 0.25–0.3 total height. Protoconch naticiform, of about 1.5 smooth whorls. Teleoconch whorls 4–5, shouldered at or near middle on spire, sutural ramp broad, almost flat; last whorl with 2 or 3 additional angulations, base excavated, with a strongly twisted neck. Axial sculpture of tubercles or nodules on angulations, not agreeing with those on other angulations in number or position, those on shoulder angle less numerous and more prominent than those below; 13–15 shoulder tubercles per whorl. Spiral sculpture of numerous narrow cords with occasional interstitial threads, covering virtually all of teleoconch. Aperture pyriform with a narrow siphonal canal that in complete shells is strongly twisted to left and away from aperture. Inner lip prominently callused, expanded freely over columella, sculpture on last whorl showing through on parietal region, otherwise smooth. Outer lip with a narrow, rounded varix, which does not extend onto canal, leading edge finely crenulate, smooth within except for a tubercle near adapical end in some shells.

Duntroonian-Altonian; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type) and other Altonian localities in Oamaru district; Otekaike Limestone, Sister's Creek, Hakataramea Valley; Mount Harris Formation, Dyer's Run, Waihao Valley; Southburn Sand, Tengawai River near Sutherlands.

Galeodea apodemetes is by far the most widely recorded and therefore best-known fossil species of *Galeodea* (sensu stricto) from New Zealand. It is readily distinguished from *G. modesta* (Pl. 6l) by its coarser spiral sculpture and in having the inner and outer lips almost completely smooth. *G. triganaceae* (Waipipian-Recent) is much closer but differs in having a less thickened outer lip and in having two rather than only one row of nodules visible on spire whorls. An undescribed species from Tongaporutuan localities in North Canterbury also seems to be closely related to *G. apodemetes*, differing in having considerably coarser spiral sculpture, particularly on the whorl angles.

The rather limited available evidence suggests that *Galeodea* (sensu stricto) has undergone some restriction in habitat in New Zealand during the Cenozoic. The Bortonian *G. modesta* is recorded from shallow water (inner or mid shelf) assemblages, and the contemporary *G. geniculosa* (Hampden) from deeper water (outer shelf or upper slope) facies. *G. apodemetes* seems to have been most common in the mid or outer shelf region but also to have extended into shallower waters and into the upper bathyal zone. After the Altonian the record of the genus becomes very patchy. An undescribed species (with an armoured aperture and therefore unlike *G. apodemetes*) is present in the Slip Point Siltstone (Clifdenian) at Clifden, and another undescribed species is recorded from the Tongaporutuan of Kaiwara Valley, North Canterbury, associated with upper bathyal molluscs. The extant *G. triganaceae* is typically bathyal in distribution, although a few specimens (including the type material) are from mid-shelf depths. Fossil records of *G. triganaceae* are from the Whenuataru Tuff on Pitt Island (Waipipian) (? outer shelf) and from Palliser Bay (Mangapanian) and Oaro, Marlborough (Nukumaruan) in both cases associated with diverse upper bathyal faunules (Beu 1967a, p. 100; 1979, p. 91).

Figured specimen (Pl. 20q): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.5.

Pl. 20 o. *Sassia* (*Sassia*) *maoria* (Finlay, 1924) [*Austrotriton maorium* Finlay 1924b, p. 453; *A. maorium* var. *insignitum* Finlay 1924b, p. 454; *Austrosassia maoria*; *A. insignita*] (Ranellidae: Cymatiinae).

Small for genus (height 25-37 mm), with moderately tall, weakly stepped spire (a little less than half total height in well preserved specimens with long canal). Protoconch as in *S. parkinsonia* (Pl. 48f), turbiniform, of 2.5 smooth whorls. Teleoconch whorls 4-5, shouldered near middle on spire, last whorl with prominent peribasal angulation, base convex, rapidly contracted to moderately long neck. Low, narrow varices with hollowed back (abapertural) faces at each 0.67 whorl down whole teleoconch; varices retracting to suture rather than crossing it. Sculpture of 2 major spiral cords on spire whorls and 2 more on base of last whorl, low, narrow and widely spaced, bearing low nodules (particularly on uppermost cord) where they cross the low, rounded axial costae; remainder of surface (including spaces between primary cords) closely sculptured with low, narrow, irregularly gemmate spiral threads and faint growth ridges. Aperture small, subcircular with long to moderately long, straight, weakly left-deflected siphonal canal; outer lip flared, bearing 5 prominent nodules on inner edge; inner lip narrowly flared with low parietal callus and a few ridges on base of columella.

Duntroonian-Altonian; Target Gully Shellbed, Oamaru, Altonian (type locality of both *A. maorium* and its "variety" *insignitum*), and many localities in North Otago, Canterbury and Southland.

Sassia maoria is the most common New Zealand Oligocene and Early Miocene ranellid, recognisable by its relatively short spire, its almost circular aperture, and its relatively long canal. The varices do not clasp the preceding whorl, as they do in *S. pahaoensis* (Clifdenian-Tongaporutuan), which succeeds *S. maoria* at Clifden. The *S. maoria*-*S. parkinsonia* species group is discussed under *S. parkinsonia*, below.

Figured specimen (Pl. 20o): GS11283, J39/f9500C, Bluecliffs, Otaio River, Otaian (NZGS) x 1.5.

Pl. 20 p. *Poirieria delli* Maxwell, 1971 [p. 771-773] (Muricidae: Muricinae).

Moderately large for genus (height 30-40 mm), biconic, spire about 0.3 total height. Protoconch mamillate, of 2 smooth whorls. Teleoconch of 5-6 whorls, shouldered well below middle on spire, in some shells shoulder almost immersed in suture; last whorl broadly excavated, with a moderately long neck. Axial sculpture of lamellar varices, very low except on periphery where they are folded to form prominent, almost horizontal, open triangular spines; varices extending across base of last whorl onto fasciole; 5 or 6 varices per whorl. Spiral sculpture of very weak threads on base. Aperture pyriform with moderately long, open siphonal canal; columella gently concave, inner lip moderately callused. Outer lip thin, weakly reflected, terminal spine very long in many shells, front face bent back at about 40°. Fasciole prominent, narrow, with a deep, narrow pseudumbilicus between it and inner lip.

Waitakian?; Altonian; Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type); Ardgowan Shellbed; Southburn Sand, Tengawai River near Sutherlands; Mount Brown Formation, Weka Creek; Brother's Stream and Sister's Creek, Hakataramea Valley? Uncommon or rare at all localities.

Poirieria delli is readily distinguished from *P. zelandica* (Pl. 48k) and *P. primigena* (Duntroonian-Opoitian) by its low spire and its low shoulder, and by the absence of variceal spines other than the peripheral spine. *P. denticulifera* (Pl. 8g) is much smaller than *P. delli* and has a conical protoconch, a single additional variceal spine and a denticulate outer lip.

Figured specimen (Pl. 20p): holotype, GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (TM4925, NZGS) x 1.5.

Pl. 20 n. *Xymene* n. sp. (?) (Muricidae: Trophoninae).

Small for family (height 9-14 mm), fusiform, spire slightly less than half total height. Protoconch conical, of 2.5 smooth convex whorls. Teleoconch of 5-5.5 whorls, shouldered at or near middle on spire, with 2 less prominent angulations between shoulder and lower suture; last whorl excavated, base convex, neck moderately long, straight, slightly left-deflected. Axial sculpture commencing as narrow costellae, on later whorls consisting of prominent raised costae of rounded or broadly triangular section with broad, concave interspaces, reaching from suture to suture on spire whorls, dying out on base or upper part of neck of last whorl; later whorls typically with 1 or 2 previous varices retained; 9 or 10 costae (including varices) on penultimate whorl. Other axial sculpture of growth ridges of variable development, weak on some shells, forming scaly lamellae on others, particularly on axial costae. Spiral sculpture commencing as 2 or 3 cords, 1 on shoulder angle, the other 2 below, penultimate whorl with 3 subequal, rather prominent cords on sides, some shells with a 4th margining lower suture, and 1-3 weaker cords on sutural ramp. Last whorl with 11-13 additional cords, becoming obsolete on neck. Aperture ovate-triangular, columella slightly concave, bent to left just above inception of moderately long, narrow, weakly notched siphonal canal. Inner lip moderately callused; outer lip angled at periphery, with a heavy varix, inner face with a shallow channel at shoulder angle and 6-7 narrow lirae below.

Otaian; Mount Harris Formation, Bluecliffs, Otaio River; Mt Horrible, Pareora River (common).

The taxonomy of Oligocene and Early Miocene *Xymene* is in an unsatisfactory state. Ponder (1972a, p. 480-481) identified the Otaian shells and very similar shells from Awamoa Creek and other North Otago Altonian localities as *X. lepidus*, but the holotype (from Target Gully Shellbed) differs from the Otaian species in its relatively broad shell and in having evenly convex teleoconch whorls and a rounded aperture. It seems unlikely to be conspecific with the species described here, which is much more like *X. minutissimus* in shape, but not in size. Specimens of *X. minutissimus* from the Southburn Sand at White Rock River (type locality) and from Sutherlands are indeed minute (height 2.7-4.7 mm), have a much smaller protoconch than the Otaian shells and have less prominent axial sculpture with costae becoming obsolete on the last whorl of some shells. Ponder (1972a, p. 482, 484) recorded *X. minutissimus* from several other localities, including Pukeuri where he noted that it seemed to intergrade with "*lepidus*". The large shells from Awamoa Creek and Ardowan Shellbed resemble the Otaian shells in most respects but typically have only two spiral cords on the sides of the penultimate whorl (although an additional cord may appear at a later stage of growth), and only five lirae on the inside of the outer lip. They are probably conspecific with shells from Target Gully Shellbed assigned by Ponder (1972a, p. 490) to *X. chattonensis*. The latter species (described from Shell Gully, Chatton, Duntroonian) is poorly known, and its relationship to the Altonian shells must remain uncertain until more material is available.

Figured specimen (Pl. 20n): GS11283, J39/f9500c, Bluecliffs, Otaio River, Otaian (NZGS) x 3.

Pl. 20 t. "*Vesanula*" *tegens* (Hutton, 1877) [*Fusus tegens* Hutton 1877b, p. 594; *Fusinus tegens*; *Fusinus congestus* Suter 1917, p. 21-22] (Muricidae: Trophoninae?).

Size moderate for family (height 15-20 mm), fusiform, spire 0.3 total height. Protoconch small, mamillate, of about 2.5 strongly convex, smooth whorls. Teleoconch of 5-7 whorls, convex at first then becoming strongly shouldered at or below middle with sutural ramp almost flat, last 2 whorls or so strongly clasping, riding up to obscure shoulder angle of preceding whorl, sutural ramp concave, periphery rounded. Last whorl excavated, base convex, neck moderately long. Axial sculpture

commencing as narrow, opisthocyrt costellae reaching from suture to suture, but becoming obsolete on sutural ramp as shoulder develops, forming short, hollow spines on shoulder angle and extending down to lower suture. Last whorl of adult shells with about 10 broad, rounded, rather low folds with broadly concave interspaces, extending down onto base. Spiral sculpture on juvenile shells of 8-10 low, rounded cords on base and neck, other spirals appearing on ramp and sides on 5th whorl or so, adult shells covered with numerous narrow cords with interspaces of similar width. Aperture ovate, outer lip angled at periphery and bearing about 6 weak denticles within in subadult shells, rounded and smooth within but with finely crenulate leading edge in adult. Inner lip callused, columella concave, bent to left at inception of siphonal canal, which is long and slender in subadult shells, but relatively much shorter in adults.

Altonian; Southburn Sand, White Rock River (type locality of both *F. tegens* and *F. congestus*); Sutherlands (not uncommon).

Despite the rather unusual nature of the adult shell, this species seems to be closely related to *Vesanula chaskanon* (Altonian, Ardgowan and Target Gully Shellbeds), the type species of *Vesanula* Finlay, 1926. The protoconch, teleoconch whorl shape and sculpture are rather similar in subadult shells of both species—although *V. tegens* is rather more slender and has a longer siphonal canal—but whereas *V. chaskanon* retains much the same whorl profile (i.e. a strong peripheral angulation) and type of sculpture in the adult shell, *V. tegens* changes drastically and ends up resembling a buccinid. *Vesanula chaskanon* is similar to some species of *Xymene*, and *Vesanula* is probably not worth recognising as a distinct genus. *Pagodula* Monterosato, 1884 seems an appropriate location for *Zeatrophon waitemataensis* (Otaian, Waiheke Island)—referred to *Vesanula* by Powell (1938, p. 374)—and for *V. delli* (Mangapanian, Palliser Bay) and for *Pagodula vegrandis* (Altonian, Oamaru district), which was included in *Vesanula* by Finlay (1926c, p. 426). However, *Columbarium maorum* ("Pukeuri" but actually Kaiatan, McCulloch's Bridge) belongs in *Cochlespira* (*Tahusyrix*) (Turridae) (see Pl.8q), and not in *Vesanula* where it was placed by Finlay (1926c, p.426).

Figured specimen (Pl. 20t): GS9700, J38/f9681, Sutherlands, Tengawai River, Altonian (NZGS) x 2.

Pl. 20 s. *Pterotyphis* (*Prototyphis*) *awamoanus* (Finlay, 1930) [*Pteronotus* (*Pterochelus*) *awamoanus* Finlay 1930b, p. 77; *Pterochelus awamoanus*] (Muricidae: Muricinae?).

Small for family (height 10-17 mm), fusiform, spire half total height. Protoconch mamillate, of about 1.25 smooth whorls, rounded in most specimens, but flattened on top in a few. Teleoconch whorls 5, broadly angled near middle on spire; last whorl with weaker angulation appearing out of suture or somewhat above, broadly excavated below with moderately long neck. First whorl with 5 low, lamellar varices, later whorls with 3 prominent varices, which are more or less aligned across whorls, folded into prominent, open, upwardly curved spines on ramp and into a much smaller open spine below, just above suture on spire. Other axial sculpture of small nodules on upper angulation, 3 or 4 between each pair of varices. Spiral sculpture of a low cord margining lower suture on spire, emerging on last whorl to mark the lower angulation, accompanied by another, of similar strength or weaker, on base. Aperture ovate, columella slightly concave above, bent to left below to form slightly curved, open siphonal canal. Inner lip moderately callused, slightly detached over columella. Outer lip slightly reflected, bearing 5 prominent denticles within; terminal varix thin, frilled by 4 short, open spines below the prominent shoulder spine.

Altonian; Target Gully Shellbed, Oamaru (type); Ardgowan Shellbed, Oamaru; Awamoa Creek (uncommon).

Pterotyphis awamoanus is closely similar to *P. angasi eos* (Recent, Northland) but much smaller and has less prominent spiral sculpture and fewer variceal spines (only

one other than the shoulder spine exposed on spire whorls, in contrast to two exposed on *P. angasi eos*). *P. angasi powelli* (Castlecliffian; Pl.48i) has a non-denticulate outer lip. *P. allani* (Waitakian-Otaian, South Canterbury) differs from *P. awamoanus* in its larger size and its more prominent spiral sculpture, in having the shoulder spine almost horizontal, and in having a non-denticulate outer lip.

Pterotyphis (*Prototyphis*) has a rather puzzling stratigraphic distribution. Although it seems to have been rather widespread in New Zealand—though not necessarily common—from at least Bortonian to Altonian, there is only one record of the subgenus (Waipipian, Waipipi) from then until the Nukumaruan. This possibly indicates that it was absent from the New Zealand region during the Middle Miocene to early Pliocene and that the late Cenozoic records result from a new dispersal to New Zealand, but it seems more likely that for some reason it underwent a severe habitat restriction (presumably to rocky environments, both intertidally and in deeper water) and its later fossil record results from the relatively good late Cenozoic preservation of rocky environments.

Figured specimen (Pl. 20s): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 4.

Pl. 20 r. *Typhis* (*Typhis*) *hebetatus* Hutton, 1877b [p. 594; "*T. maccoyi*" of authors (not of Tenison-Woods, 1876)] (Muricidae: Typhinae).

Size moderate for genus (height 25-35 mm), biconic, spire about half total height. Protoconch mamillate, of 1.5 smooth whorls. Teleoconch of about 6 whorls, rather indistinctly angled near middle on spire; last whorl excavated with a moderately long neck. Varices of narrowly triangular section, not present on sutural ramp, extending across base of last whorl onto upper part of siphonal canal, terminal varix bearing 6 backwards-curved hollow triangular spines, the topmost considerably larger than the others and typically the only one exposed on spire whorls; 5 varices on last whorl. Between each pair of varices a prominent, straight tube bent sharply backwards at 50-60°, the last one opening into aperture. Spiral sculpture of feeble, irregular threads between varices. Aperture ovate, peristome continuous, raised; siphonal canal flattened in apertural plane, closed; previous 2 canals retained on well preserved shells.

Waitakian-Altonian; Mount Harris Formation, Mt Harris, Altonian (type); Awamoa Creek; Target Gully Shellbed; Ardgowan Shellbed; Bluecliffs, Otaio River; Mt Horrible, Pareora River; Brother's Stream, Hakataramea Valley; upper Tengawai River. All records are from moderately deep-water (mid-shelf to upper bathyal) assemblages.

Typhis adventus (Duntroonian-Otaian, South Canterbury and North Otago) is similar, but is more slender and has two variceal spines (rather than only one) exposed on spire whorls. *T. aculeatus* (Altonian-Lillburnian, Clifden) has much more prominent and more nearly radial variceal spines than *T. hebetatus*.

Typhis (sensu stricto) has a recorded range of Bortonian to Waiauan, and possibly to Tongaporutuan, in New Zealand.

Figured specimen (Pl. 20r): GS11283, J39/f9500C, Bluecliffs, Otaio River, Otaian (NZGS) x 1.5.

Pl. 21 e. *Exilia dalli* Suter, 1907a [p. 209; *Zexilia dalli*] (Turbinellidae: Ptychactinae?).

Size moderate for genus (height 15-20 mm), narrowly fusiform, spire half total height. Protoconch mamillate, of about 2 whorls with weak axial costellae on last quarter whorl or so, otherwise smooth. Teleoconch of 7-8 whorls, those on spire weakly concave on adapical half, convex below; last whorl with long, slender, straight neck. Axial sculpture of narrow, opisthocline, opisthocyrt costae with somewhat wider interspaces, reaching from suture to suture on spire whorls, scarcely

extending onto base of last whorl, and becoming obsolete on last whorl on some shells; 15-19 costae per whorl. Spiral sculpture absent from first whorl or so on spire, rest of shell with numerous narrow, rounded or flat-topped cords. Aperture pyriform with a long, narrow, open siphonal canal; columella almost straight or distinctly twisted. Inner lip smooth, outer lip thin, slightly flexuous.

Waitakian-Otaian; "White Rock, Pareora River" (type—almost certainly not from the Southburn Sand at White Rock River (Altonian), but from the Mount Harris Formation at Pareora River, foot of Mt Horrible (Otaian), where it is common); Bluecliffs, Otaio River; Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike; Brother's Stream, Hakataramea Valley.

Exilia dalli is smaller than *E. waihaoensis* (Pl. 8s) and differs in having a mamillate protoconch of only two whorls rather than a dome-shaped one of three whorls.

Figured specimen (Pl. 21e): GS11154, J39/f26, Pareora River, foot of Mt Horrible, South Canterbury, Otaian (NZGS) x 3.

Pl. 21 h. *Coluzea dentata* (Hutton, 1877) [*Fusus dentatus* Hutton 1877b, p. 594; *Fusinus spiralis dentatus*] Type species of *Coluzea* Finlay in Allan, 1926 (Turbinellidae: Columbariinae).

Moderately large to large for genus (height 45-120 mm), broadly fusiform; spire pagodiform, about 0.4 total height. Protoconch mamillate, of about 2.5 whorls, initial whorl bulbous, deviated, last 1.5 whorls angled near middle, last whorl narrower than preceding whorl, with 1 or 2 weak axial costellae near end. Teleoconch of 9-10 whorls, sharply angled at or below middle on spire, sutural ramp broad, almost flat, whorl sides sloping inwards; last whorl with well developed peribasal angulation, excavated below with a very long, straight, slender neck. Axial sculpture on first 5 whorls or so of low, rounded folds with much broader interspaces, reaching more or less from suture to suture and forming triangular serrations on peripheral keel; during growth, folds tending to become obsolete on ramp and sides, but peripheral serrations becoming more prominent, more strongly vertically compressed, and more rounded; mature shells with 12-16 serrations on penultimate and last whorl. (On a very large shell (original length c. 120 mm) from Awamoa Creek, axial sculpture on last 3 whorls is reduced to growth ridges and numerous small, irregular peripheral serrations). Spiral sculpture commencing at beginning of teleoconch as a narrow peripheral cord, accompanied by a weaker one between it and lower suture, and 2 or 3 on ramp. A narrow cord margining lower suture appears at about same stage. During growth an additional cord may appear on sides and another on ramp, but basic spiral sculptural plan remains much the same. Adult shells with some very fine interstitial threads. Supramargining cord emerging on last whorl as peribasal angulation, accompanied by about 14 narrower cords on base and neck. Aperture ovate, columella straight; siphonal canal very long and slender, usually straight, but slightly recurved in largest shell seen. Inner lip thinly callused, outer lip thin, smooth within.

Otaian-Altonian, Tongaporutuan?; Mount Harris Formation, Mt Harris, South Canterbury, Otaian or Altonian (type) and other Otaian or Altonian localities in North Otago and South Canterbury; Blind River, Marlborough (?); Kaiwara River, North Canterbury (?); Hurupi Stream, Palliser Bay (?).

Coluzea dentata is always uncommon or rare and difficult to collect in a reasonably complete condition, so its variation and relationship to other species is not well understood. The three Tongaporutuan shells are very similar to Otaian and Altonian specimens in most respects, but all have more numerous spiral cords on the base than typical *C. dentata*. The absence of records of *Coluzea* of this kind from the intervening Southland Series makes it difficult to know if this difference is taxonomically significant.

C. dentata seems to be closely related to *C. macrior* (Altonian, Ardgowan and Target Gully Shellbeds) and *C. paucispinosa* (Waitakian, Otiake). According to Finlay (1930e, p. 269), *C. macrior* differs from *C. dentata* (with which it occurs at both localities) in its more slender shape, more rounded periphery and much weaker peripheral serrations. Although it may seem unlikely that there were two, possibly sympatric, species of *Coluzea* in the North Otago area during the Altonian, the limited available material does seem to bear out Finlay's contention that *C. macrior* is a distinct species. *C. paucispinosa* is poorly known, but it seems to differ from *C. dentata* in having a smaller and much less strongly angled protoconch, finer spiral sculpture, more numerous spirals on the base and neck, and fewer peripheral serrations (only nine to 11 per whorl). It may also be significant that available specimens are much smaller than *C. dentata* (height only 18-30 mm). *Coluzea* from another Waitakian locality (Brother's Stream, Hakataramea Valley—probably of deeper-water facies than Trig Z)—are more like *C. dentata* in overall size, protoconch size and spiral sculpture, but have larger and more strongly compressed peripheral serrations, and have a more prominent peribasal keel which is also serrated by the axial folds.

Coluzea is recorded from Mangaorapan to Recent in New Zealand, from the Middle to Upper Eocene of the Paris Basin and as extant species from southern Africa (Darragh 1969, p. 106-109) and the eastern Indian Ocean (Harasewych 1986). We agree with Harasewych (1983) that a position in the Turbinellidae seems the most reasonable one for Columbariinae.

Figured specimen (Pl. 21h): Mt Harris, South Canterbury, Otaian or Altonian (NZGS, from an early collection) x 1.

Pl. 21 b. *Buccinulum protensum* Powell, 1929 [*B. (Evarnula) protensum* Powell 1929, p. 74] (Buccinidae).

Size moderate for genus (height 20 mm), broadly fusiform, spire 0.4 total height. Protoconch narrowly dome-shaped, of a little more than 2 smooth whorls. Teleoconch of about 5 whorls, subangled near middle on spire; last whorl excavated, with long, curved neck. Axial sculpture of prominent rounded costae reaching from suture to suture on early whorls but obsolete on ramp on later whorls, and largely confined to periphery on last whorl, in some shells becoming obsolete on last quarter-whorl; 8-11 costae per whorl. Spiral sculpture of low, narrow cords with interstitial threads. Aperture ovate, siphonal canal long, open, bent to left and away from aperture. Inner lip callused, with small parietal tubercle and another at upper end of siphonal canal. Outer lip with thin leading edge, thickened behind by rounded varix, and bearing 9-13 narrow lirae within.

Altonian; Mount Harris Formation, Old Rifle Butts, Cape Wanbrow (type); Pukeuri; excavation for Oamaru Borough Council septic tank, South Oamaru (moderately common).

Buccinulum protensum is possibly only a variant of the highly variable *B. compactum* (Altonian, Target Gully Shellbed) but is distinguished from it and from other mid-Cenozoic species by its slender shape and its relatively long siphonal canal, by the persistence of axial costae onto the last whorl, and by its relatively weakly armoured aperture. *B. longicolle* (Altonian, Clifden) was synonymised with *B. protensum* by Ponder (1971b, p. 276-277) but although the two species are similar in shape, *B. longicolle* consistently has a more strongly armoured aperture with three to five additional tubercles on the columella, and we regard it as a distinct species.

Figured specimen (Pl. 21b): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 2.

Pl. 20 m. *Penion marwicki* (Finlay, 1930) [*Verconella marwicki* Finlay 1930b, p. 67-68] (Buccinidae).

Size moderate to large for genus (height typically 85-120 mm, but a few specimens up to 160 mm), solid, broadly fusiform, spire 0.3-0.4 total height. Protoconch tall, conical, of 3.5 strongly convex, smooth whorls. Teleoconch of 6-8 whorls, strongly convex at first then becoming bluntly but very prominently shouldered below middle, sutural ramp strongly concave, on most specimens extending up to just below periphery of previous whorl; last whorl weakly subangled on base, strongly excavated below with a long, curved neck. Axial sculpture commencing as heavy, rounded costae reaching from suture to suture, but soon becoming obsolete on ramp and forming very prominent, distant, rounded nodules on periphery; costae dying out on upper part of base of last whorl; 8-10 on penultimate whorl. Spiral sculpture most prominent on first 5 whorls or so, of numerous narrow, closely spaced cords, on most specimens broader, lower and less distinct on later whorls, last whorl typically with a noticeably stronger cord on basal subangulation, slightly thickened where it crosses lower ends of axial costae. Aperture large, ovate, columella concave above, twisted to left below to form long, open, weakly notched siphonal canal. Inner lip thickly callused in adult shells; outer lip weakly crenulate.

Altonian; Mount Harris Formation, Mt Harris (type) and many other localities in North Otago and South Canterbury, most commonly in shallow-water sandstone or shellbeds.

Penion marwicki is distinguished from related species by its very strong, knob-like peripheral tubercles, which persist throughout growth, and its relatively subdued adult spiral sculpture. *P. finlayi* (Otaian, Bluecliffs, Otaio River and Tengawai River) is similar, but has a lower, more conic spire, more strongly clasping whorls (the sutural ramp extending up to the periphery of the previous whorl in most shells), and considerably stronger spiral sculpture, particularly on the base of the last whorl. The highly variable *P. sulcatus* (Pl. 49a) may be closely related to *P. marwicki*, but those forms with prominent, persistent peripheral nodules differ at sight from *P. marwicki* in having much stronger adult spiral sculpture.

Penion has a recorded range of Wangaloan (*P. proavitus*) to Recent in New Zealand, and although the genus has been recorded from Bortonian, Duntroonian and Waitakian rocks it was not until the Otaian or Altonian that it became relatively widespread and eventually, one of the most characteristic gastropod genera in the New Zealand Cenozoic. The genus is represented in the Australian fauna by five species, ranging in age from Early Miocene to Recent (Ponder 1973). It is very similar to the widespread Northern Hemisphere genus *Kelletia* Fischer, 1884—differences between the two taxa (listed by Ponder 1973, table 1) are relatively minor and may not justify generic separation.

Figured specimen (Pl. 20m): GS5177, J38/f9526, Tengawai River near Sutherlands, South Canterbury, Altonian (NZGS) x 0.67.

Pl. 21 k. *Austrofusus (Austrofusus) spiniferus* (Finlay and McDowall, 1923) [*Aethocola spinifera* Finlay and McDowall 1923, p. 113-114] (Buccinidae).

Moderately large for genus (height 40-55 mm), broadly bucciniform, spire 0.4-0.6 total height. Protoconch narrowly conical, of about 3 whorls, last half whorl with axial costellae, rest smooth. Teleoconch of 6-7 whorls, sharply shouldered at or below middle on spire, sutural ramp broad, steep, almost flat, sides sloping inwards. Last whorl with prominent peribasal angulation, space between it and shoulder angle

concave; base almost flat, neck short, strongly twisted to left. Axial sculpture of prominent rounded costae reaching virtually from suture to suture on earliest whorls, but almost obsolete on ramp on later whorls and extending only a short distance below lower keel on last whorl, interspaces broadly concave. Costae slightly vertically compressed and subspinose on keels; 11-14 per whorl. Spiral sculpture of narrow cords with occasional interstitial threads, over whole surface except fasciole. Aperture ovate, columella concave above, twisted to left below to form short, strongly notched siphonal canal with prominent fasciole. Inner lip moderately callused; outer lip thin, finely lirate within.

Altonian; Ardgowan Shellbed, Oamaru (type); Target Gully Shellbed; Awamoa Creek; Southburn Sand, White Rock River; Sutherlands; basal shellbed, Enys Formation, junction of Porter and Thomas River, Castle Hill Basin.

Austrofusus spiniferus is distinguished from most other species of *Austrofusus* by its relatively large size, its broad shell and its strongly twisted neck. *A. precursor* (Duntroonian, Chatton and Wharekuri) is most similar, but differs in having much stronger spiral sculpture, particularly on the base. *A. magnificus* (Pl. 25a) (Altonian-Lillburnian, Clifden) is also closely related, but has the axial costae much more compressed and hence, more sharply spinose, on the keels.

Figured specimen (Pl. 21k): GS9700, J38/f9681, Ardgowan Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 21 j. *Austrofusus (Neocola) apudalpha* Finlay, 1926b [p. 235] (Buccinidae).

Size moderate for genus (height 25-40 mm), bucciniform, spire 0.4-0.5 total height. Protoconch conical, of 4.5 convex whorls, last quarter whorl with a few opisthocyrt costellae, remainder smooth. Teleoconch of 6-7 whorls, convex at first but soon becoming angled near middle, sutural ramp almost flat on early whorls, distinctly concave with a weak subsutural swelling on later whorls; base weakly subangled, neck moderately long, twisted. Axial sculpture commencing as narrow costae reaching from suture to suture, gradually increasing in strength except on ramp where they eventually become obsolete; on adult whorls consisting of prominent, broadly rounded costae with concave interspaces of similar or greater width, dying out on upper part of base on early portion of last whorl, but reduced to little more than low nodules on shoulder angulation on latter half of last whorl on many shells; penultimate whorl with 10-12 costae. Other axial sculpture of very numerous fine growth ridges. Spiral sculpture commencing as 5 or 6 fine cords, additional spirals appearing by intercalation during growth and tending to become as strong as primaries on later whorls; penultimate whorl with 12-16 subequal, low, narrow cords with much wider interspaces, some with interstitial threads and exceedingly fine threadlets. Last whorl with about 15 additional cords (some with interstitial threads) on base and neck, 3 or 4 of them on lower base noticeably coarser than the others. Aperture ovate, columella strongly inclined to right but almost straight above, strongly twisted to left and away from aperture below; siphonal canal moderately long, notched with narrow, prominently raised fasciole. Inner lip thinly callused; outer lip thin, prosocline, almost straight except for a shallow indentation near abapical end.

Waitakian-Otaian; Otekaike Limestone, Trig Z, Otiake, Waitakian (type); Mount Harris Formation, Bluecliffs, Otaio River; Mt Horrible, Pareora River; Tengawai River near Clelland's Bridge. Uncommon at Trig Z, but common to very common at other localities.

Austrofusus apudalpha is readily distinguished from *A. (Neocola) alpha* and its presumed relatives (Pl. 25b-d) by its broader shell and its longer siphonal canal, and by lacking a continuous ridge along the outer edge of the fasciole. The basal spiral cords are much less strongly differentiated than in either *A. (Neocola) beta* or *A. (Neocola) gamma*, but are comparable with those of some specimens of *A. (Neocola) alpha*. *A. (Neocola) flexuosus* (Pl. 25g) has a similar siphonal canal to *A. apudalpha* but differs in its much more slender shape and in having

axial sculpture becoming obsolete for a short distance on the spire. A closely similar species occurring in the Ardgowan and Target Gully Shellbeds, Oamaru (Altonian) differs from *A. apudalpha* in its larger size (height 35-50 mm), broader shell and coarser spiral sculpture. For further comments on *Neocola* see under *A. (Neocola) alpha*, *beta* and *gamma* (below).

Figured specimen (Pl. 21j): Bluecliffs, Otaio River, Otaian (Canterbury Museum) x 1.5.

Pl. 21 m. *Nassicola finlayi* nom. nov. [*Neptunaea (Sipho) costatus* Hutton 1877b, p. 594 (not of Link, 1807); *Siphonalia costata*; *Aethocola costata*; *Nassicola contracta* Finlay of Finlay 1930a, p.43 (in part, not of Finlay 1926b)]. Type species (as *N. costata*) of *Nassicola* Finlay, 1926 (Buccinidae).

Size moderate for subfamily (height 30-35 mm), cominelliform, spire about 0.4 total height. Protoconch narrowly conical, of 3 lightly convex whorls, last quarter whorl with a few weak opisthocline axial costellae and a fine spiral thread margining lower suture, otherwise smooth. Teleoconch of 5-6 whorls, early whorls convex, later whorls becoming bluntly shouldered near middle through development of a concave sutural ramp, periphery well rounded; last whorl gently and evenly convex below periphery, neck short and strongly twisted. Axial sculpture of well spaced, prominent, rounded costae, reaching from suture to suture on early whorls but becoming obsolete on ramp on later whorls, and extending down onto upper part of base on last whorl, in some shells reduced to large peripheral nodules on last half whorl; 9-12 costae on penultimate whorl. Spiral sculpture commencing as about 4 thin cords, additional cords appearing during growth, later whorls covered with narrow, low cords with considerably wider interspaces, those on ramp noticeably narrower than those below, some cords with interstitial threads. Aperture ovate, columella almost straight above, sharply twisted to left and away from aperture below to form short, strongly notched siphonal canal. Fasciole prominent, of squarish section, margined above by a sharp ridge, below by a more rounded one. Inner lip quite thickly callused in mature shells, callus extending to end of siphonal canal; outer

lip thin, prosocline, almost straight except for shallow indentation near lower end, leading edge finely crenulate, bearing narrow lirae within.

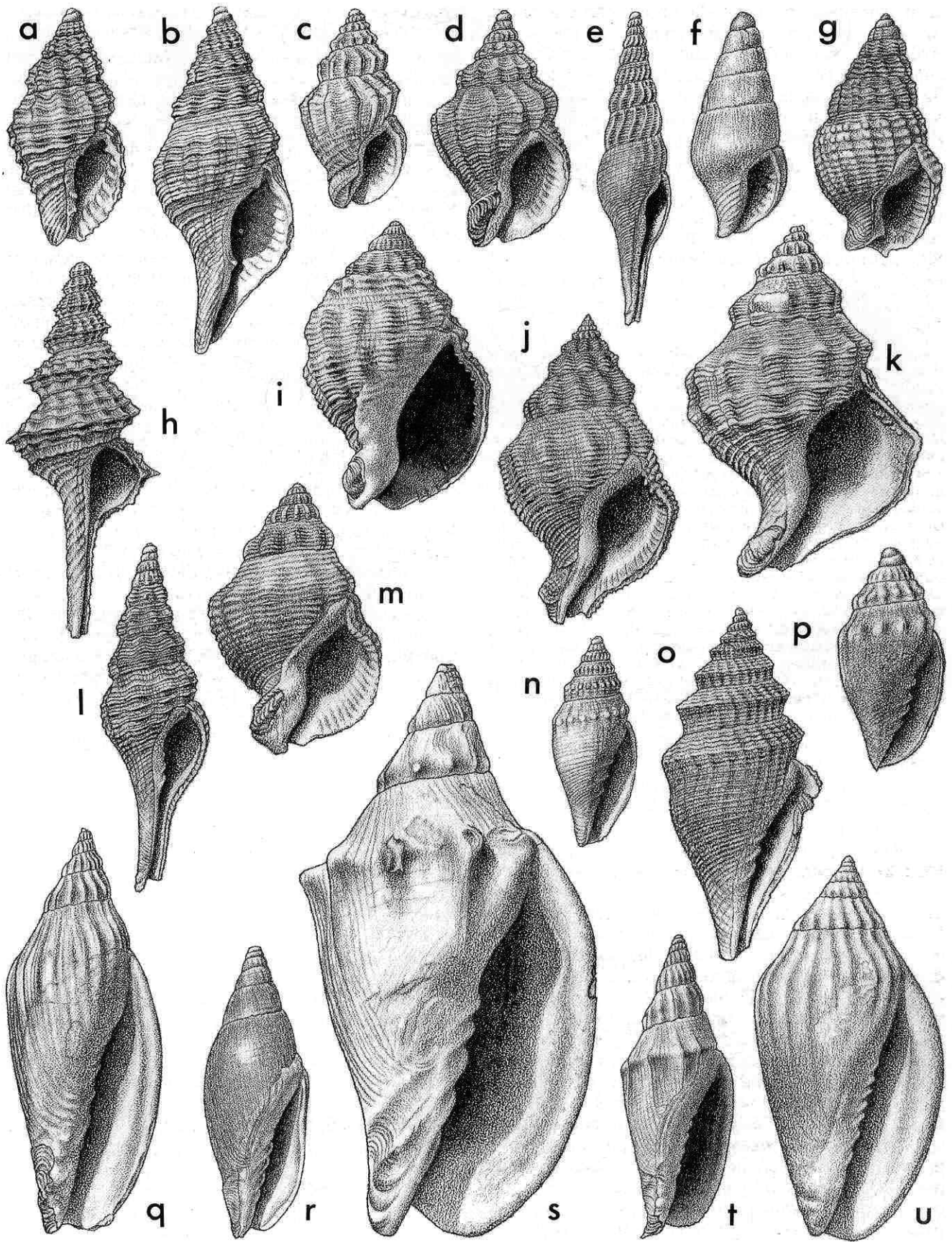
Altonian; Mount Harris Formation, Mt Harris (type) and several other localities in North Otago and South Canterbury, mostly in shallow-water sandstone and shellbeds.

Nassicola finlayi is superficially similar to *N. contracta* (Lillburnian-Waiauian, Clifden) but is distinguished by its broader and lower spire, its less well defined shoulder angulation, and in lacking a basal subangulation, so that the last whorl is convex from periphery to neck rather than slightly but distinctly flattened on the sides.

Finlay (1926b, p. 236) originally accepted *N. costata* as a distinct species, but later (Finlay 1930a, p.43), when he discovered that Hutton's name is preoccupied, considered it to be not worth distinguishing from *N. contracta*, and accordingly did not propose a replacement name. The differences between the North Otago and South Canterbury *Nassicola* on the one hand, and Clifden shells on the other, are rather subtle but apparently constant, and we therefore propose the replacement name *N. finlayi* for the preoccupied *Neptunaea costatus* Hutton, 1877. It is interesting to note that *Nassicola* from Altonian localities in North Canterbury (e.g. Weka Creek and Tommy's Creek) are more like *N. contracta* than *N. finlayi*, possibly suggesting that these species were warm-water (*N. contracta*) and cool-water (*N. finlayi*) forms respectively. The status of other Miocene nominal species of *Nassicola* is less clear, however; both *N. nassa* (Altonian, Clifden) and *N. speighti* (Waiauian, Burnt Hill, North Canterbury) have a similar whorl profile to *N. contracta* and seem to differ in only minor sculptural details. *N. cingulifer* (Clifdenian, Muddy Creek, Gisborne) differs markedly from other *Nassicola* species

Plate 21 Temperate Early Miocene (Otaian-Altonian) Mollusca (6).

- a. *Cantharus (Zeapollia) acuticingulatus* (Suter), x 4.
- b. *Buccinulum protensum* Powell, x 2.
- c. *Cominella (Procominula) pukeuriensis* (Finlay), x 2.5.
- d. *Egotistica scirrhoma* Marwick, x 1.5.
- e. *Exilia dalli* Suter, x 3.
- f. *Zemitrella haroldi* Laws, x 8.
- g. *Nassarius (Hima) socialis* (Hutton), x 5.
- h. *Coluzea dentata* (Hutton), x 1.
- i. *Zelandiella subnodosa* (Hutton), x 1.5.
- j. *Austrofusus (Neocola) apudalpha* Finlay, x 1.5.
- k. *Austrofusus (Austrofusus) spiniferus* (Finlay and McDowall), x 1.5.
- l. "*Pleia*" *otaioensis* Finlay, x 2.
- m. *Nassicola finlayi* Beu and Maxwell, nom.nov., x 1.5.
- n. *Proximitra apicalis* (Hutton), x 3.
- o. *Proximitra rutidoloma* (Suter), x 2.
- p. *Peculator (Parvimitra) pukeuriensis* (Finlay), x 6.
- q. *Spinomelon parki* (Suter), x 0.67.
- r. *Teremelon tumidior* (Finlay), x 1.5.
- s. *Alcithoe (Alcithoe) turrita* (Suter), x 1.
- t. *Alcithoe (Leporemax) lepida* Marwick, x 1.
- u. *Pachymelon amoriaformis* (Marwick), x 1.



by its small size (height 19 mm), its pronounced subsutural fold and its less strongly projecting fasciole. Its protoconch is unknown, and it may be a species of *Cominella* rather than of *Nassicola*.

Nassicola is an endemic genus with a range of Wangaloan (*N. subflurida*) to Waipipian (*N. ultima*; Pl. 37 m). Although originally classed as a subgenus of *Austrofusus*, it differs sufficiently (particularly in having a relatively short siphonal canal and a squarish fasciole) to warrant generic rank (Finlay 1930a, p. 43; Beu 1973b, p. 324).

Figured specimen (Pl. 21m): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 1.5.

Pl. 21 d. *Egotistica scirrhoma* Marwick, 1934 [p. 17].
Type species of *Egotistica* Marwick, 1934 (Buccinidae).

Rather small for subfamily (height 23–30 mm), cominelliform, spire half total height. Protoconch relatively large, mamillate, of 1.5 convex whorls, a few weak axial costellae near end, otherwise smooth. Teleoconch of 5 whorls, first whorl convex, later whorls prominently angled at or near middle, sutural ramp slightly concave; last whorl evenly convex from periphery to the short but rather thick, twisted neck. Axial sculpture of prominent, rounded costae with broad, concave interspaces, reaching from suture to suture at first but then becoming obsolete on upper part of ramp, extending across base of last whorl; 11–13 costae on penultimate whorl. Spiral sculpture commencing as 4 or 5 narrow, low cords, other spirals appearing by intercalation during growth, later whorls covered with prominent, crisp cords, most with interstitial threads, those on ramp mostly somewhat weaker than those below. Spirals finely crenulated by numerous growth lines. Aperture rather small, ovate, columella almost straight above, strongly twisted to left below, with a low, oblique ridge on twist. Siphonal canal short, strongly notched; fasciole prominent, of squarish section, margined above by a sharp ridge, below by a slightly less prominent ridge. Inner lip rather thickly callused, almost to end of canal; outer lip thin, weakly sigmoid, with a shallow indentation near anterior end, and bearing fine lirae within.

Otaian; Mount Harris Formation, Bluecliffs, Otaio River (type); Mt Horrible, Pareora River (rare).

Egotistica was proposed by Marwick (1934, p. 16) for buccinids with the teleoconch characters of *Austrofusus* (sensu lato), but having a large, mamillate protoconch like that of *Cominella* rather than the small, conical protoconch characteristic of *Austrofusus*. In fact, the short siphonal canal and the prominent, squarish fasciole set *Egotistica* apart from *Austrofusus* (sensu stricto) and its subgenus *Neocola*, and suggest closer relationship to *Nassicola* (see above). Beu (1973b, p. 324) suggested that on the basis of its aperture, siphonal canal and fasciole, *Nassicola* could be more closely related to *Cominella* than to *Austrofusus*. *Egotistica* has a mamillate protoconch, and in this respect it is even more similar to *Cominella* and its relatives. However, in both *Nassicola* and *Egotistica*, but particularly in the former genus, the fasciole projects more strongly above the profile of the last whorl than in typical *Cominella*. On present evidence it is difficult to decide whether *Egotistica* is indeed closely related to *Cominella*, or if their similarity results from convergence. Besides the two Otaian occurrences, *Egotistica* is recorded from the Mount Harris Formation at upper Tengawai River (Waitakian), and at Old Rifle Butts, Cape Wanbrow (Altonian), and from Muddy Creek, Gisborne district (Clifdenian; Marwick 1934, p. 17). All occurrences are in moderately deep-water (outer shelf or upper bathyal) siltstone.

Figured specimen (Pl. 21d): Bluecliffs, Otaio River, Otaian (Canterbury Museum) x 1.5.

Pl. 21 i. *Zelandiella subnodosa* (Hutton, 1877) [*Cominella*

subnodosa Hutton 1877b, p. 596; *Siphonalia subnodosa*; *Austrofusus* (*Zelandiella*) *subnodosa*]. Type species of *Zelandiella* Finlay, 1926 (Buccinidae).

Size moderate for subfamily (height 30–40 mm), cominelliform, spire conical, low, 0.35–0.4 total height. Protoconch mamillate, of about 3.5 convex whorls, last 0.4 whorl with opisthocyrt costellae, remainder smooth. Teleoconch of about 6 whorls, early whorls convex, later whorls angled just above suture, sutural ramp concave with a prominent subsutural fold, strongly clasping previous whorl. Last whorl with second angulation on base, convex below to short, thick, twisted neck. Axial sculpture commencing as rounded costae reaching virtually from suture to suture, but on later whorls restricted to rounded nodules on shoulder angle and subsutural fold, and on last whorl on basal angulation as well; 11–13 nodules on penultimate whorl. Spiral sculpture of narrow, low cords, typically subequal, but a few basal cords noticeably stronger than others in some shells. Aperture large, columella almost straight above, twisted to left below; siphonal canal short, twisted, strongly notched; fasciole prominent, squarish, upper edge margined by a sharp ridge, lower edge also bounded by a ridge, but in many specimens obscured by inner lip callus. Inner lip callus well developed, spreading laterally over columella and base, typically closely attached to shell but outer edge detached or even deflected in a few shells. Outer lip thin, in well preserved shells finely lirate within and having a shallow indentation near anterior end.

Altonian; Southburn Sand, White Rock River (type) (common); Sutherlands (common); Ardgowan Shellbed (rare).

Two species of *Zelandiella* are recorded from the Double Corner Shellbeds, Lower Waipara Gorge (Waiauan)—one is the highly distinctive *Z. fatua* (Pl. 30c, e), the other is very similar to *Z. subnodosa* but differs in being lower-spired, and in having more subdued teleoconch sculpture. The differences are not constant, however, and may not be taxonomically significant. *Z. calcarata* (Lillburnian-Tongaporutuan, widespread) is very similar to *Z. subnodosa* in shape and sculpture but differs in having a tongue-like or nodular protrusion on the outer edge of the columellar callus. An undescribed species from the Clifdenian of Karamea district has a similar columellar process but differs from *Z. calcarata* in its smaller size, its more slender shape and its much crisper sculpture. It closely resembles *Austrofusus* (*Neocola*) *beta* (Pl. 25c) in sculpture, but has the protoconch, inner lip callus and fasciole of *Zelandiella*.

Zelandiella is first definitely recorded from the Whaingaroan (*Z. robinsoni*; The Cliffs, Nelson) and ranges up to the Opoitian (*Z. propenodosa*; Kaawa Creek). Finlay and Marwick (1937, p. 77–78) described two species of *Zelandiella*—each based on a very imperfect specimen—from Boulder Hill, Dunedin (Wangaloan), but neither is a very convincing member of the genus. On the other hand, some late Cenozoic buccinids previously referred to *Zelandiella* (i.e. *Austrofusus allani* (Opoitian-Waipipian); *Purpura conoidea* (Kapitean) and *Z. pliocenica* (Opoitian-Mangapanian; Pl. 37d)) lack the prominent inner lip callus and the strongly projecting, squarish-sectioned fasciole of typical species of the genus, and are here referred to *Austrofusus* (*Austrofusus*).

Zelandiella seems to have been confined to shallow waters, and may have occupied the niche now taken by some species of *Cominella* (i.e. as scavengers and/or predators). The genus may not be endemic—it is very similar to, and possibly identical with *Austrocominella* Ihering, 1907 (Cenozoic, Patagonia).

Figured specimen (Pl. 21i): GS165, J39/f6470, White Rock River, South Canterbury, Altonian (NZGS) x 1.5.

Pl. 21 c. *Cominella* (*Procominula*) *pukeuriensis* (Finlay,

1926) [*Cominula (Procominula) pukeuriensis* Finlay 1926b, p. 242] (Buccinidae).

Small for genus (height 12-15 mm), elongate-ovate, spire 0.55-0.6 total height. Protoconch depressed-mamillate, of about 1.5 whorls, smooth or with a few weak axial costellae near end. Teleoconch of 4.5-5 whorls, convex at first but gradually becoming broadly angled near middle, sutural ramp slightly concave with a weak subsutural swelling. Last whorl gradually contracted to a short, ill-defined neck. Axial sculpture of prominent, narrow costae of rounded-triangular section with broad interspaces, reaching from suture to suture at first but then becoming obsolete on upper part of ramp, extending onto base of last whorl; 10-12 costae on penultimate whorl. Spiral sculpture of weak threads with narrow interspaces, 4 or 5 on base considerably stronger than others. Aperture ovate, columella almost straight and subvertical above, twisted to left below; siphonal canal short, twisted, strongly notched; fasciole not projecting, bounded above by sharp ridge. Inner lip moderately callused; outer lip thin, with 5 or 6 weak denticles within.

Altonian; Mount Harris Formation, Pukeuri road cutting, Oamaru (type); Awamoa Creek; Old Rifle Butts, Cape Wanbrow; Target Gully Shellbed, Oamaru. Common at Pukeuri, less so at other localities.

Cominella pukeuriensis is distinguished from *C. (Procominula) denselirata* (Pl. 15j) by its taller spire (slightly more than half the total height, rather than less) and in having several basal spirals stronger than the others. *C. (Procominula) pulchra* (Otaian, Bluecliffs and Pareora River) has spiral sculpture of prominent, crisp cords.

Figured specimen (Pl. 21c): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 2.5.

Pl. 21 a. *Cantharus (Zeapollia) acuticingulatus* (Suter, 1917) [*Tritonidea acuticingulata* Suter 1917, p. 35; *Zeapollia acuticingulata*]. Type species of *Zeapollia* Finlay, 1926 (Buccinidae).

Small for family (height 9-13 mm), ovate, spire about half total height. Protoconch mamillate, of 1 smooth whorl. Teleoconch of 4-4.5 whorls, spire whorls convex, last whorl weakly excavated, contracted gradually to short, ill-defined neck. Axial sculpture of prominent, rounded, prosocline costae with interspaces of similar or greater width, reaching from suture to suture on spire, and onto lower part of base of last whorl; 10 or 11 costae on penultimate whorl. Spiral sculpture commencing at beginning of teleoconch as 2 cords, 1 near middle, the other between it and lower suture, and 1 or 2 much weaker spirals on upper half. Cords prominent on later whorls, the 2 anterior ones remaining stronger than those above, joined on last whorl by a peribasal cord of similar strength (visible above suture on penultimate whorl on some shells) and 4 or 5 prominent cords on base, and 4 or 5 much weaker, crowded ones on neck. Some shells with interstitial threads as well. Spirals noticeably thickened where they cross axial costae, particularly on lower part of base where they are distinctly nodulose. Aperture ovate, columella slightly concave and subvertical above, strongly twisted to left below, with a low ridge on twist. Siphonal canal short, strongly notched; fasciole low, rounded. Inner lip moderately callused, with a prominent denticle or ridge immediately above the one on the columellar twist, and 2 weaker parietal denticles, some shells with an additional, oblique ridge on upper part of columella. Outer lip thickened externally by a broad, rounded varix, and bearing 5-7 prominent denticles within.

Altonian, Target Gully Shellbed, Oamaru (type) (abundant); not recorded elsewhere.

Cantharus acuticingulatus is readily distinguished from other New Zealand buccinids by its small size, its prominent axial and spiral sculpture, its relatively strongly armoured aperture and its short siphonal canal. An undescribed species from the Slip Point Siltstone, Clifden (Clifdenian) differs from *C. (Zeapollia) acuticingulatus* in its more slender shell, and in having less prominent axial costae, but more prominent secondary spiral sculpture. *Zeapollia* is represented in Australia by *C. (Zeapollia) purpuroides* (Johnston, 1880) (Longfordian (basal

Miocene), Table Cape, Tasmania) (Finlay 1926c, p. 418). Finlay also referred the extant *Tritonidea colensoi* Suter, 1908 to *Zeapollia*, but it was regarded as a subspecies of *Buccinulum vittatum* by Ponder (1971b, p. 262) and certainly belongs in *Buccinulum*.

Figured specimen (Pl. 21a): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 4.

Pl. 21 g. *Nassarius (Hima) socialis* (Hutton, 1886) [*Nassa (Uzita) compta* Hutton 1877b, p. 596 (not of A. Adams, 1851); *Nassa socialis* Hutton 1886a, p. 333 (new name for *Nassa compta* Hutton, 1877, preoccupied); *Alectrion socialis*; *Hima (Mirua) socialis*; *Nassarius (Hima) tatei socialis*]. Type species of *Mirua* Marwick, 1931, now regarded as a synonym of *Hima* Leach, 1852 (Cernohorsky 1981a, p. 175) (Nassariidae).

Small for family (height 4.5-8 mm), ovate, spire 0.55-0.6 total height. Protoconch broadly conical, of 3 whorls, last half whorl with weak spiral threads, soon followed by a few weak, almost straight axial costellae, remainder smooth. Teleoconch of 4-5 whorls, evenly convex or weakly angled at about 0.67 whorl height on spire, base of last whorl convex, neck short, thick. Axial sculpture of prominent rounded, prosocline costae, typically with much wider interspaces, reaching from suture to suture on spire, and onto base on last whorl, in many shells persisting almost to neck; 9-18 (mean 11) costae on penultimate whorl. Spiral sculpture highly variable, penultimate whorl with 3-5 low, narrow, rounded or flattened cords on sides and 1-3 weaker ones on ramp; some shells with the occasional interstitial thread. Last whorl with 7-10 additional cords on base, and 4-7 much weaker and more crowded ones on neck. Cord marking shoulder angle (where present) typically slightly nodulose where it crosses axial costae, other cords usually crossing costae unchanged or with slight thickening. Aperture ovate, columella straight with a narrow ridge at base, bounded above by a shallow groove; siphonal canal short, strongly notched. Inner lip moderately callused, with a small parietal ridge. Outer lip angled at anterior end, thickened externally by a heavy, rounded varix, and bearing 7 or 8 lirae within.

Otaian-Altonian; Southburn Sand, White Rock River, South Canterbury, Altonian (type) and other localities in North Otago and South Canterbury, often occurring in great numbers.

Like the other two species of *Nassarius (Hima)* described from New Zealand, i.e. *N. (Hima) separabilis* (Otaian-Altonian, Pakaurangi Point) and *N. (Hima) karoroensis* (Waiauian, Greymouth), *N. (Hima) socialis* varies greatly in shape, spire height and teleoconch sculpture. Cernohorsky (1981a, p. 177-178) was unable to detect any consistent differences in teleoconch characters between *N. socialis* and *N. separabilis* and considered them to be conspecific. Maxwell (1988a, p. 52), however, has shown that these species, and *N. karoroensis*, can be differentiated on the basis of protoconch characters. *N. socialis* has a relatively small protoconch (maximum diameter 0.85-1.10 mm (mean 0.9 mm) compared with 1.15-1.45 mm (mean 1.35 mm) for *N. separabilis* and 1.10-1.40 mm (mean 1.25 mm) for *N. karoroensis*), in which spiral sculpture appears slightly before the almost straight axial costellae. In *N. separabilis* axial sculpture in the form of distant, opisthocyrt costellae appears well before the spirals, and the lower suture on the last whorl or so is margined by a narrow cord, which is absent from *N. socialis*. Spiral sculpture is weakly developed—in present at all—in *N. karoroensis*, which has one or two straight axial costellae like those in *N. socialis*, and lacks a margining cord. There are also some, less reliable differences in teleoconch characters—*N. separabilis* tends to have more evenly convex whorls than the other species, and to have more numerous, more closely spaced spiral

cords with less tendency to become thickened where they cross the costae. The number of axial costae per whorl varies greatly in all three species but *N. socialis* tends to have considerably fewer (9-18 on penultimate whorl (mean 11)) than *N. separabilis* (10-26 (mean 15)) or *N. karoroensis* (12-23 (mean 15)).

Nassarius (*Hima*) has a recorded range of Otaian to Tongaporutuan in New Zealand and is recorded from a wide range of lithofacies indicating depths ranging from the inner shelf to the upper bathyal zone. The subgenus is represented in southern Australia by the extant *N. (Hima) mobilis* (Hedley and May, 1908) and by *N. (Hima) tatei* Tenison-Woods, 1879 (described from Muddy Creek, Victoria (Balcombian) but recorded widely from other Neogene localities by Cernohorsky (1981a, p. 177-178)). Cernohorsky (1981a, p. 177-178) classed *N. socialis* as a subspecies of *N. tatei*, but topotypes of the latter species have a protoconch like that of *N. separabilis* (i.e. with a margining cord on the last whorl).

Figured specimen (Pl. 21g): GS165, J39/f6470, White Rock River, South Canterbury, Altonian (NZGS) x 5.

Pl. 21 f. *Zemitrella haroldi* Laws, 1935 [p. 40-41] (Columbellidae).

Rather small for family (height 5-5.5 mm), elongate-ovate, spire narrowly conical, 0.6 total height. Protoconch mamillate, of about 2 smooth, weakly convex whorls. Teleoconch of 4 whorls, spire whorls weakly convex; last whorl with rounded or subangled periphery, excavated below; sutures distinctly impressed. Spire whorls devoid of sculpture except for very feeble spiral striae; neck of last whorl with about 8 low cords. Aperture rather small, pyriform; columella twisted to left near middle to form a short, slightly oblique, unnotched siphonal canal. Outer lip with a low, broad, rounded varix, bearing about 4 narrow lirae within.

Altonian; Mount Harris Formation, Pukeuri road cutting, Oamaru (type); Awamoa Creek; Old Rifle Butts, Cape Wanbrow; excavation for Oamaru Borough Council septic tank, South Oamaru. Moderately common at Pukeuri, uncommon at other localities.

Zemitrella haroldi is distinguished from other species of *Zemitrella* by its almost straight-sided spire, its subangled periphery and its relatively prominent outer lip lirae. Although the modern New Zealand columbellid fauna is quite diverse (about 50 named species-group taxa) there are remarkably few records of the family prior to the Pliocene, suggesting either that its diversification has taken place relatively recently, or that one of its main habitats (intertidal to shallow subtidal algae on rocky shores) has a poor fossil record. *Zemitrella* itself is first recorded definitely from the Duntroonian, *Z. mackayi* (Bortonian-Kaiatan) being only provisionally referred there.

Figured specimen (Pl. 21f): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 8.

Pl. 21 i. "*Pleia*" *otaioensis* Finlay, 1930b [p. 60-61] (Fascioliidae).

Size moderate for family (height 30-38 mm), fusiform, spire about half total height. Protoconch mamillate, apparently of about 1.5 smooth whorls, but incompletely known. Teleoconch of 6-7 whorls, narrowly concave adapically, strongly convex below, last whorl broadly excavated, base convex, neck long and narrow. Axial sculpture of prominent, broad, rounded costae with concave interspaces, reaching from lower edge of subsutural concave zone to lower suture on spire, and extending onto base of last whorl; 7-9 costae on penultimate whorl. Spiral sculpture of prominent, low, narrow cords, 7 or 8 (some with interstitial threads) on penultimate whorl, 2 or 3 on ramp somewhat weaker than those below. Numerous additional cords appearing on base and neck, those

on neck crowded and rather indistinct. Spirals crossing costae with little or no change. Aperture pyriform, constricted adapically by prominent parietal tubercle; columella almost straight, only weakly twisted, with a plait of variable strength on or slightly above twist, some shells with a second plait above. Inner lip moderately callused, outer lip thin, weakly flexuous, edge finely crenulate, some shells with 7-9 narrow lirae within. Siphonal canal long, narrow, almost straight.

Waitakian?, Otaian; Mount Harris Formation, Bluecliffs, Otaio River, Otaian (type); Mt Horrible, Pareora River; "The Peaks", Waihao Valley; ?upper Tengawai River (rare to uncommon).

"*Pleia*" *cryptocarinata* (Mangapanian-Recent) has a less slender shell and more strongly convex teleoconch whorls, and lacks the strong parietal tubercle of "*P.*" *otaioensis*. Neither *P. otaioensis* nor *P. cryptocarinata* seem to be very closely related to the type species of *Pleia* Finlay, 1930 (*Fasciolaria decipiens* Tate, 1888; Balcombian, Victoria), which is much larger than either of the New Zealand species (height 55 mm), has distinctly shouldered teleoconch whorls, and has a recurved siphonal canal, and so resembles *Latirus* much more than the New Zealand species Finlay referred to *Pleia*. However, in the absence of a more appropriate location for the New Zealand species they are provisionally retained in *Pleia*.

"*Pleia*" *otaioensis* probably had a similar habitat to *P. cryptocarinata*, i.e. on level bottoms in the upper bathyal zone.

Figured specimen (Pl. 21i): GS11154, J39/f26, foot of Mt Horrible, Pareora River, South Canterbury, Otaian (NZGS) x 2.

Pl. 21 o. *Proximitra rutidoloma* (Suter, 1917) [*Vexillum* (*Costellaria*) *rutidolomum* Suter 1917, p. 29; *Mitra* (*Cancilla*) *armorica* Suter 1917, p. 27; *Proximitra armorica*; *P. attractoides armorica*]. Type species of *Proximitra* Finlay, 1926 (Volutomitridae).

Large for genus (height 25-35 mm), elongate-ovate to fusiform, spire 0.4-0.45 total height. Protoconch mamillate, of 1.5 whorls, smooth except for a few very weak axial costellae near end in some shells. Teleoconch of 6-7 whorls of highly variable shape, some shells with weak subangulation at about 0.75 whorl height, and straight or gently convex sides ("*armorica*" type), others more or less prominently shouldered at 0.5-0.67 whorl height, the extreme forms with a strongly projecting rim-like keel and concave sides. Last whorl with rounded peribasal subangulation, excavated below with moderately long neck. Axial sculpture highly variable, in some shells—particularly those with only weakly shouldered whorls—consisting of weak costellae on early whorls but becoming obsolete or reduced to growth ridges on later whorls; other shells—typically with prominently shouldered whorls—with relatively prominent costae persisting throughout growth and extending virtually from suture to suture on spire and down to peribasal subangulation on last whorl; in still other shells becoming restricted to rather crude, angular tubercles on shoulder angle on last whorl. Spiral sculpture commencing as 4 or 5 very weak cords, others appearing during growth, so that later whorls are covered with numerous subequal, narrow, low, flat-topped or rounded cords, some with interstitial threads, those on ramp (where present) typically more widely spaced than those below. Aperture narrow, elongate, siphonal canal barely differentiated; columella long, oblique, straight, bearing 4 plaits, 3 of them prominent and subequal, the other (abapical) much weaker and often barely visible in apertural view. Inner lip thinly callused; outer lip thin, weakly flexuous, smooth within.

Otaian-Altonian; Mount Harris Formation, Bluecliffs, Otaio River, Otaian (type localities of both *V. rutidolomum* and *M. armorica*); Mt Horrible, Pareora River; Ardgowan Shellbed; Target Gully Shellbed. Moderately common at all localities.

Proximitra rutidoloma is distinguished from other New Zealand *Proximitra* species mainly by its large size. As noted in the description this is a highly variable species.

Most specimens from Bluecliffs and Pareora River (Otaian) have strongly shouldered teleoconch whorls, typically with a rim-like periphery, and have distinct axial sculpture on the adult whorls, and so resemble the type of *V. rutidoloma*; only a few individuals resemble the type of *M. armorica* in having a slender shell with only weakly subangled teleoconch whorls and subobsolete axial sculpture. Some shells, however, are intermediate in whorl shape and sculpture, and there can be little doubt that only one, highly variable species is involved. Although *M. armorica* has page precedence over *V. rutidoloma*, we (as first revisers) select the latter name as the name to be used for the species named both *Vexillum rutidoloma* and *Mitra armorica* by Suter (1917), because it is based on the more common morphotype at Bluecliffs, and because it is the nominated type species of the genus.

Proximitra specimens from Waitakian localities in North Otago and South Canterbury (e.g. Trig Z, Otiake; Brother's Stream, Hakataramea Valley; upper Tengawai River) have the slender fusiform shape of the "*armorica*" morphotype but are much more weakly sculptured and probably represent a distinct species. Specimens from the two North Otago Altonian localities (Ardgowan; Target Gully), on the other hand, have distinctly shouldered teleoconch whorls and relatively well developed axial sculpture and are referable to *P. rutidoloma*, although none have the peripheral keel as strongly projecting as in Otaian shells.

Cernohorsky (1970a, p. 136) classed *Proximitra "armorica"* as a subspecies of *P. attractoides* (Tate, 1889) (Balcombian, Victoria), but despite a certain similarity in teleoconch shape and sculpture, *P. attractoides* differs from New Zealand shells in having a narrowly dome-shaped protoconch of 2.5 smooth whorls, and is not considered to be conspecific.

Figured specimen (Pl. 21o): GS11283, J39/f9500C, Bluecliffs, Otaio River, South Canterbury, Otaian (NZGS) x 2.

Pl. 21 n. *Proximitra apicalis* (Hutton, 1873) [*Mitra apicalis* Hutton 1873b, p. 7; *Vexillum apicale*; *Proximitra tumens* Finlay 1930b, p. 62] (Volutomitridae).

Size moderate for genus (height 9-17 mm), biconic to fusiform, spire 0.37-0.5 total height. Protoconch mamillate, of 1.5 whorls, smooth except for feeble spiral grooves and axial costellae near end. Teleoconch of 4-5.5 whorls, a subsutural concavity developing at a very early stage, gradually producing a well defined shoulder; angulation at or slightly above middle on spire whorls of some shells, but much lower down on others, sutural ramp flat to gently concave. Last whorl broadly and shallowly excavated, neck not well differentiated. Axial sculpture on earliest part of teleoconch of narrow, low costellae reaching from suture to suture, but soon becoming obsolete on ramp, and on later whorls, restricted to low, rounded peripheral tubercles with little or no axial prolongation, typically becoming less distinct on last whorl, and in some shells obsolete near outer lip; 14-24 tubercles on penultimate whorl. Spiral sculpture subdued, of very low, rounded or flattened cords with linear interspaces. Aperture similar to that of *P. rutidoloma* (see above), anterior plait much weaker than others and close to the one above.

Altonian; Mount Harris Formation, Awamoa, Oamaru (type locality of *M. apicalis*); Pukeuri road cutting, Oamaru (type locality of *P. tumens*); Old Rifle Butts, Cape Wanbrow; All Day Bay; excavation for Oamaru Borough Council septic tank, south Oamaru. Moderately common at all localities.

Finlay (1930b, p. 62) claimed that *Proximitra tumens* could be distinguished from *P. apicalis* by its more

inflated shell, its lower spire (and hence greater spire angle) and its more numerous shoulder nodules (17-21 as against 14-15), although both he and Cernohorsky (1970a, p. 134) conceded that it might only be an extreme morphotype of *P. apicalis*. Examination of a series of shells from the localities listed above, however, shows that there is no consistent correlation between number of tubercles per whorl and either relative spire height or relative width, although—as might be expected—there are usually fewer nodules on the slender than on the broad shells. *P. tumens* is therefore here synonymised with *P. apicalis*. Cernohorsky (1970a, p. 133) synonymised *P. partinoda* (Otaian, Bluecliffs and Pareora River) with *P. apicalis*, but the former species is considerably smaller than *P. apicalis* (height 9-10 mm) and consistently has the shoulder tubercles obsolete over much or all of the last whorl of adult shells, and we regard it as a distinct species. *P. enysi* (Dunroonian, widespread) differs from *P. apicalis* in having much coarser axial sculpture (in the nature of distinct costae rather than nodules).

Figured specimen (Pl. 21n): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 3.

Pl. 21 p. *Peculator (Parvimitra) pukeuriensis* (Finlay, 1930) [*Parvimitra pukeuriensis* Finlay 1930b, p. 63; *Proximitra (Parvimitra) pukeuriensis*; *Parvimitra scopi* Finlay 1930b, p. 64; *Parvimitra ponsatanae* Finlay 1930b, p. 64]. Type species of *Parvimitra* Finlay, 1930 (Volutomitridae).

Rather small for family (height 6-9 mm), elongate-ovate to biconic, spire 0.3-0.4 total height. Protoconch mamillate, of about 1.25 smooth whorls, not sharply distinguished from teleoconch. Teleoconch of 3.5-4 whorls, typically becoming shouldered at an early stage of growth; angulation well marked in most shells—though becoming less distinct on later part of last whorl of most shells—but very weak in some shells; situated at or slightly below middle on spire whorls of most shells, but much lower in others, sutural ramp almost flat or with weak subsutural swelling. Last whorl elongate, weakly excavated, neck short. Axial sculpture highly variable, almost completely obsolete in some shells but consisting of small, rounded peripheral tubercles on most shells, typically obsolete on ramp, but extending down to lower suture on spire whorls on most shells, in many shells becoming obsolete near outer lip on last whorl; 9-22 nodules on penultimate whorl. Spiral sculpture subdued, almost completely obsolete on some shells, but more obvious on others, consisting of feeble striae that on most shells are most conspicuous on shoulder angulation or on neck. Aperture narrow, elongate; siphonal canal short, weakly differentiated; columella oblique, almost straight, with 4 plaits, the anterior one noticeably stronger than the others. Outer lip thin, smooth within.

Altonian; Mount Harris Formation, Oamaru; Pukeuri road cutting (type locality of *P. pukeuriensis*); Target Gully Shellbed (type locality of *P. scopi*); Ardgowan Shellbed (type locality of *P. ponsatanae*); Awamoa Creek; Old Rifle Butts. Particularly common at Pukeuri, less so elsewhere.

Peculator (Parvimitra) pukeuriensis differs from *P. (Parvimitra) plicatellus* (Pl. 8j) in being somewhat thicker-shelled, in typically having more strongly shouldered teleoconch whorls, and in being more weakly spirally sculptured. *P. (Parvimitra) paucinoda* (Otaian, Bluecliffs and Pareora River) is larger than *P. pukeuriensis* (height 7-12 mm), has more prominent spiral sculpture, and typically has a strongly projecting peripheral keel. Small specimens of *Proximitra apicalis* (see above) may be distinguished from *P. pukeuriensis* by the larger protoconch, the stronger spiral sculpture, and the relatively much weaker anterior columellar plait of *P. apicalis*.

Figured specimen (Pl. 21p): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 6.

Pl. 22 h. *Amalda (Baryspira) robusta* (Marwick, 1924) [*Ancillaria pseudaustralis* var. Tate" of Suter (not of Tate, 1889); "*Ancillaria papillata* Tate" of Suter (not of Tate, 1889); *Ancilla (Baryspira) robusta* Marwick 1924e, p. 322; *Baryspira robusta*; *B. (Gemaspira) robusta*]. Type species of *Gemaspira* Olson, 1956, synonymised with *Baryspira* by Beu (1970a) (Olividae: Ancillinae).

Large for subgenus (height 35-65 mm), elongate-ovate, spire conic, about 0.3 total height, apex pointed or narrowly rounded, apical whorls obscured by heavy spire callus. Periphery of last whorl rounded, sides straight or slightly convex except for weak subangulation at edge of fasciole. Sculpture, apart from growth lines, of weak spiral grooves and rows of small, rather obscure pits around periphery of last whorl. Aperture capacious, some shells with a short, shallow, slightly curved groove (posterior siphonal groove) extending from posterior end. Anterior notch deep, fasciole bounded by low, rounded ridge, covered by smooth callus that extends up to edge of depressed band. Columella moderately long, straight or weakly concave, subvertical, with 4-8 very weak plaits or grooves. Some shells with a prominent, sharp, oblique external ridge extending from near anterior end of columella, typically accompanied by a slightly weaker, parallel one above, neither entering aperture. Parietal callus very prominent, spreading from outer lip up to, or nearly to apex and for 180° or more around upper part of last whorl; thickness highly variable, polished on well preserved shells. Callus extending along columella to anterior notch.

Duntroonian-Altonian; Mount Harris Formation, Mt Harris, South Canterbury, Otaian or Altonian (type); Ardgowan Shellbed; Southburn Sand, Tengawai River, near Sutherlands; Mount Harris Formation, Bluecliffs, Otaio River; Otekaike Limestone, Trig Z, Otiake; Chatton Formation, Shell Gully, Chatton. Moderately common in shallow-water sandstone, less common in siltstone.

Amalda robusta is readily distinguished from most other species of *Amalda (Baryspira)* by its large size, its pointed or narrowly rounded apex, its prominent, spreading parietal callus, and its almost straight columella. *A. (Baryspira) platycephala* (Otaian, Waiheke Island) differs from typical specimens of *A. robusta* in its smaller size (height c. 30 mm), its more rounded apex, and its more strongly concave columella. Olson (1956, p. 16) recorded *A. platycephala* from the Mount Harris Formation at Tengawai River from a lower horizon (Otaian) than that of typical *A. robusta*—these specimens are considerably larger than topotypes of *A. platycephala* (height c. 50 mm) but most have a more rounded apex and a more concave columella than typical *A. robusta*. Their identity is uncertain, but they may represent a variant of *A. robusta* rather than *A. platycephala*.

Figured specimen (Pl. 22h): GS5177, J38/f9526, Tengawai River near Sutherlands, South Canterbury, Altonian (NZGS) x 1.

Pl. 22 g. *Amalda (Alocospira) hebera* (Hutton, 1873) [*Ancillaria hebera* Hutton 1873b, p. 6; *Baryspira (Alocospira) hebera*] (Olividae: Ancillinae).

Rather small for genus (height 17-30 mm), elongate-ovate or bullet-shaped, spire narrowly rounded, 0.4-0.5 total height, apex covered by spire callus. Last whorl slightly excavated apically, sides flat or gently convex to edge of fasciole, then contracted to relatively broad anterior end. Sculpture, apart from growth lines, of spiral grooves on spire callus, more obvious on some shells than on others. Aperture elongate, narrow, constricted posteriorly; anterior notch moderately deep, fasciole covered with callus to edge of depressed band. Columella subvertical, straight or slightly concave with 2-5 weak plaits or grooves that in most shells do not extend within aperture. Parietal callus not very prominent nor extending far laterally, outer edge almost straight to concave from top of columella to base of spire callus, then bent back and concave to top of spire, forming a broadly open V.

Waitakian?, Altonian; Mount Harris Formation, Awamoa, Oamaru, Altonian (type); Target Gully Shellbed; Mt Harris; Southburn Sand, White Rock River; Sutherlands.

Olson (1956, p. 22) recorded *Amalda hebera* from Wharekuri Greensand (Duntroonian) at two localities and from several Waitakian localities, including Trig Z, Otiake, the type locality of *Amalda (Alocospira) cuppedita*. The latter species was distinguished from *A. hebera* primarily on the basis of its more elongate and tapering spire and on differences in the shape of the parietal callus margin. In *A. hebera* the edge of the callus is usually distinctly concave and sweeps away from the aperture up to the spire callus, whereas in *A. cuppedita* it is almost straight and vertical from the top of the columella to the spire callus. Most specimens of *Alocospira* from Trig Z (and from Campbell Park School—also Waitakian) have a pointed spire (usually with a papillate apex) and have a parietal callus like that described for *A. cuppedita*, but a few have a rounded spire and a parietal callus like that of typical *A. hebera*. As it seems unlikely that there were two sympatric species of *Alocospira* during the Waitakian we must either expand the diagnosis of *A. hebera* to include *A. cuppedita* or accept that *A. cuppedita* includes a few individuals convergent with, or presaging *A. hebera*. The latter course is adopted here, at least until such time as more Waitakian material is available for study. *A. electa* (Duntroonian, Chatton) is also very similar to *A. hebera*, but in the few known specimens the margin of the parietal callus is convex rather than concave on the spire, thus giving it a sigmoidal outline. *A. (Alocospira) subhebera* (Tongaporutuan; Opoitian-Waipipian ?) differs from *A. hebera* in being still more smoothly bullet-shaped, without spiral grooves on the spire callus; it is doubtfully distinct from *A. paeroa* (Opoitian, southern Hawke's Bay).

The subgenus *Alocospira* has a recorded range of Kaiatan to Waipipian in New Zealand and is also present in the Australian Cenozoic and Recent faunas (the type species, *A. papillata* (Tate, 1889) (Kalimnan, Victoria) is very similar to *A. hebera*). *Alocospira* is recorded from a wide range of lithofacies, indicating a wide bathymetric distribution from shallow waters (inner shelf equivalent) down to the upper bathyal zone. Presumably, like modern *Amalda* species, the fossil species were carnivores, crawling just below the sediment surface on soft substrates.

Figured specimen (Pl. 22g): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 21 r. *Teremelon tumidior* (Finlay, 1926) [*Scaphella tumidior* Finlay 1926b, p. 250; *Waihaoia (Teremelon) tumidior*; *W. (Teremelon) awamoaensis* Marwick 1926a, p. 280]. Type species of *Teremelon* Marwick, 1926 (Volutidae: Zidoninae).

Small for subfamily (height 33-48 mm), fusiform, spire 0.4 total height. Protoconch prominent, mamillate, of about 1.5 squat whorls, smooth or with weak spiral ridges. Teleoconch of 4.5-5 whorls, spire whorls gently convex, last whorl somewhat more inflated, elongate, only weakly excavated. Axial sculpture absent or confined to thin distant costellae on first 1 or 2 whorls. Spiral sculpture of very fine striae, and on some shells weak ridges as well. Shell otherwise smooth and polished. Aperture narrow, constricted posteriorly; anterior notch moderately deep, asymmetrical, fasciole weakly differentiated, not protruding. Columella oblique, almost straight, with 4 or 5 low plaits. Inner lip moderately callused posteriorly, but with only a thin glaze below. Outer lip thin, slightly indented near posterior end.

Duntroonian-Altonian; Otekaike Limestone, Trig Z,

Otiake, Waitakian (type locality of *S. tumidior*); Mount Harris Formation, Awamoa Creek, Oamaru, Altonian (type locality of *W. awamoaensis*); Old Rifle Butts; Ardgowan Shellbed; excavation for Oamaru Borough Council septic tank, South Oamaru; Wharekuri Greensand, Wharekuri.

As there seem to be no important differences between specimens of *Teremelon* from Trig Z, Otiake and Wharekuri on one hand, and those from the Altonian localities listed above on the other, *T. awamoaensis* is here regarded as a synonym of *T. tumidior*. Another Altonian species (*T. cognata*; Target Gully Shellbed) differs from *T. tumidior* in its larger size (height 55 mm) and its somewhat more prominent axial sculpture (persisting onto the third whorl), and in having a symmetrical anterior notch. *T. elegantissima* (Altonian, Weka Pass) is a much more slender and higher-spined species than either *T. tumidior* or *T. cognata*.

Species of *Teremelon* are smaller than most of the other New Zealand members of the subfamily Zidoninae, lack axial sculpture entirely or have it confined to the early whorls, have a moderately deep anterior notch, and have a weakly differentiated fasciole. The oldest known member of the genus (and the oldest New Zealand volute) is from the Red Bluff Tuff (Teurian) of Pitt Island. (*Paleopsephes neozelanica* (Wangaloan, Boulder Hill)—formerly included in the Volutidae—is here referred to the Turbinellidae Ptychactractinae). The extant species *T. knoxi* (Tongaporutuan-Recent) is confined to the upper bathyal zone, but at least some of the extinct species ranged into shallow (inner or mid-shelf) waters.

Figured specimen (Pl. 21r): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 1.5.

Pl. 21 u. *Pachymelon amoriaformis* (Marwick, 1926) [*Waihaoia (Pachymelon) amoriaformis* Marwick 1926a, p. 282]. Type species of *Pachymelon* Marwick, 1926 (Volutidae: Zidoninae).

Size moderate for subfamily (height 66-75 mm), broadly fusiform, rather solid. Protoconch prominent, bulbous, of about 2.5 smooth whorls, apex bluntly pointed. Teleoconch of 4-4.5 whorls, convex at first, later bluntly shouldered with broad, concave sutural ramp; last whorl gradually contracted, unexcavated. Axial sculpture of low, rounded costae reaching from suture to suture on spire but becoming obsolete on ramp on penultimate whorl of some shells, and absent from part or all of last whorl; 17-27 costae per whorl. Aperture constricted posteriorly; anterior notch broad and shallow, fasciole inconspicuous. Columella oblique, almost straight, with 6-8 narrow plaits. Outer lip convex, thickened within.

Altonian; Target Gully Shellbed, Oamaru (type); Ardgowan Shellbed; Awamoa Creek; Mt Harris. Rare at all localities.

Pachymelon amoriaformis is readily distinguished from other Early Miocene volutes by its rather solid shell, its very shallow anterior notch, and its exceptionally numerous columellar plaits. Several other fossil and extant volutes have been assigned to *Pachymelon*, but none closely resemble *P. amoriaformis*, and all are here referred to *Alcihoe* (in part following the action of Dell (1978) who transferred modern *Pachymelon* species to *Alcihoe*), pending a much-needed revision of the New Zealand members of the family.

Figured specimen (Pl. 21u): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 21 q. *Spinomelon parki* (Suter, 1907) [*Lapparia parki* Suter 1907a, p. 207; *Lapparia corrugata* "(Hutton)" of Suter 1914, p. 27 (in part—not *Voluta (Lyria) corrugata* Hutton 1873b, p. 7, a *nomen dubium* not now used); *Cymbiola (Miomelon) corrugata* "(Hutton)" of Suter 1917, p. 87 (in part); *Spinomelon otaioensis* Laws 1932, p. 193; *S. evelynae* Laws 1933, p. 326]. Type species of *Spinomelon* Marwick, 1926 (Volutidae: Zidoninae).

Moderately large for subfamily (height 105-135 mm), fusiform, spire 0.3-0.4 total height. Protoconch highly variable, mamillate to cylindrical, of 2-3 whorls with feeble spiral ridges, those with 2 whorls having a prominent apical spike, those with 3 with a very bulbous initial whorl. Teleoconch of 5-6 whorls, typically weakly shouldered near middle on spire with gently concave sutural ramp and convex sides, but more distinctly shouldered on some shells, particularly on last whorl. Last whorl contracted gradually with little or no excavation. Axial sculpture of distant, rounded costae reaching from suture to suture on early whorls, but becoming obsolete on ramp on later whorls, and extending onto upper part of base of last whorl, distinctly tubercular on shoulder on those shells with a definite angulation; 12-15 costae on penultimate whorl. Aperture large, constricted to a prominent channel posteriorly; anterior notch moderately deep, fasciole distinct, depressed in some shells, slightly projecting in others. Columella with 5 prominent plaits, the lowest usually much weaker than the others, some shells with a 6th, weak plait at posterior end. Inner lip with thin callus smear spreading well onto last whorl; outer lip broadly convex, thickened internally, in some specimens weakly reflected.

Otaian-Altonian; "Lower Gorge of Pareora River" (type locality of *L. parki*—probably Mount Harris Formation, foot of Mt Horrible, Otaian); Bluecliffs, Otaio River, Otaian (type locality of *S. otaioensis* and *S. evelynae*); Mt Harris; Dyer's Run, Waihao Valley; Awamoa Beach; Ardgowan Shellbed.

The holotype of *Lapparia parki* is a juvenile shell consisting of the protoconch and only two teleoconch whorls, but it compares closely with larger shells from its probable type locality and with numerous specimens (including adults) from coeval beds at Bluecliffs, Otaio River, the type locality of *Spinomelon otaioensis* and *S. evelynae*. *S. otaioensis* was alleged to differ from *S. parki* in having angulated whorls with a strongly concave sutural ramp, and in having sharply nodulated axial costae, whereas *S. evelynae* was supposed to have a more slender shell and a higher spire than *S. parki*. However, the reasonably large series of specimens now available for study shows that *S. parki* varies considerably in shell form, relative spire height and whorl shape, and that the holotypes of Laws' species fall well within the observed range of variation of *S. parki*. *S. speighti* (Otaian or Altonian, Mt Harris) is probably another synonym of *S. parki*; Marwick (1926a, p. 284) distinguished it on the basis of its supposedly broader shape and in having more strongly angled teleoconch whorls with strongly tubercular axial costae, but these differences are unlikely to be important in view of the variability noted in Bluecliffs shells. Marwick (1926a, p. 284-285) described a second species of *Spinomelon*, *S. mira*, from the foot of Mt Horrible, Pareora River. It differs from *S. parki* in having only very fine axial sculpture on the spire whorls but quite prominent costae on the last whorl, and in having a distinctly concave zone below the shoulder angle on the last whorl. Similar specimens have been collected from Bluecliffs, lower Tengawai River, Awamoa Creek and Ardgowan Shellbed and indicate that this is a distinct species rather than a variant of *S. parki*. Even more distinctive is *S. benitens* (type locality Trig Z, Otiake (Waitakian), also recorded from Awamoa Creek and

Target Gully Shellbed)—this has axial sculpture confined to the first three or four whorls, a very shallow anterior notch, and an inconspicuous fasciole.

Species of *Spinomelon* and *Alcithoe* (sensu stricto) are of similar adult size, and some closely resemble one another in sculpture. The protoconch of *Spinomelon*, however, usually has an apical spike (although this is not present in a few individuals where the normally deciduous initial whorl has not been shed), but *Alcithoe* lacks such a spike. In addition species of *Spinomelon* typically have a shallower anterior notch and a less prominent fasciole than *Alcithoe*. *Spinomelon* is first recorded from the Duntroonian, although the typically Eocene genus *Waihaoia* is very similar and may not be distinct. The genus is best-represented in faunules of Waitakian to Altonian age, particularly in North Otago and South Canterbury—thereafter it has a very poor fossil record but seems to have persisted until the Mangapanian.

Figured specimen (Pl. 21q): Mt Harris, South Canterbury, Otaian-Altonian (hypotype of Marwick 1926a, pl.62, fig. 8) (NZGS) x 0.67.

Pl. 21 s. *Alcithoe (Alcithoe) turrita* (Suter, 1917) [*Fulgoraria (Alcithoe) arabica* var. *turrita* Suter 1917, p. 39; *F. (Alcithoe) turrita*; *Spinomelon turrita*; *Alcithoe familiaris* Marwick 1926a, p. 291-292] (Volutidae: Zidoninae).

Moderately large for subfamily (height 80-120 mm), biconic to fusiform, spire 0.3-0.45 total height. Protoconch not known. Teleoconch of about 6 whorls, early whorls apparently lightly convex, later whorls becoming increasingly more strongly shouldered (at 0.2-0.5 whorl height on spire), sutural ramp flat or concave. Last whorl weakly excavated, contracted gradually to relatively broad anterior end. Axial sculpture commencing as narrow costae reaching from suture to suture but gradually becoming tubercular on shoulder angle and obsolete on ramp; last whorl with 7-11 strong, laterally compressed tubercles with broad interspaces, in some shells restricted to periphery, in others extending anteriorly as low costae. Aperture rather large; anterior notch deep, fasciole prominent, bordered above by thin, sharp ridge, below by a more prominent but more rounded ridge. Columella almost straight except anteriorly where it is broadly twisted to right, in well preserved shells extending further anteriorly than outer lip; with 4 or 5 plaits, the lowermost and—in shells with 5 plaits, the topmost—considerably weaker than the others. Inner lip callus moderately thick at posterior end in some shells, a thin glaze below. Outer lip only slightly thickened and weakly reflected, broadly angled at periphery.

Otaian-Altonian; Mount Harris Formation, Bluecliffs, Otaio River, Otaian (type locality of *F. turrita*); Mt Harris, South Canterbury, Altonian (type locality of *A. familiaris*); Dyer's Run, Waihao Valley; Ardgowan Shellbed; ? basal shellbed, Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin.

Alcithoe turrita is very similar in shape and sculpture to some of the more strongly sculptured forms of *A. arabica* (Pl. 49d), but differs in having a much thinner inner lip callus. In *A. arabica* the callus is particularly thick over the columella and obscures the lower margin of the fasciole, and in many shells it forms a projecting plate or collar over the neck. Although none of the specimens of *A. turrita* retain the protoconch, its great similarity to *A. arabica* makes assignment to *Alcithoe* almost certain. *A. turrita* is very rare at Bluecliffs, so little is known of the range of variation there, but apart from its relatively slender shape and tall spire, the holotype is very similar to specimens of *A. familiaris* from Ardgowan. In view of the considerable variation in such characters as shape and spire height in other species of *Alcithoe*, the differences between *A. familiaris* and *A. turrita* are here considered not to be taxonomically significant.

The taxonomy of *Alcithoe* is in a highly unsatisfactory state, but there can be little doubt that there are far more available names than there are recognisable taxa in the genus. Marwick (1926a) described no fewer than 12 nominal species of *Alcithoe* (sensu lato) (in addition to *A. turrita*) from the Otaian or Altonian of North Otago and Canterbury, and Laws (1932, p. 194) described an additional Altonian species. Of these 14 "species", eight are assignable to *Alcithoe* (sensu stricto), the others to the subgenus *A. (Leporemax)* (see below). *A. familiaris* is here synonymised with *A. turrita*; a preliminary analysis of the remaining nominal species of *Alcithoe* (sensu stricto) suggests that only one taxon is involved, and for this we (as first revisers) select the name *A. cylindrica* Marwick (1926a, p.290) (type locality, Target Gully Shellbed). Synonyms are *A. wekaensis* (Weka Creek), *A. compressa* (Target Gully Shellbed), *A. armigera* (Ardgowan Shellbed), *A. robusta* (Mt Harris) and *A. sequax* (Mt Harris) (all of Marwick 1926a). *A. cylindrica* is readily distinguished from *A. turrita* by its much more robust shell, its thicker inner lip callus, its very thick outer lip, its more constricted aperture, its less prominent fasciole, and its thicker, more closely spaced columellar plaits.

Alcithoe (Alcithoe) is first recorded—somewhat doubtfully—from the Duntroonian (see Pl.15m), and is the most characteristic New Zealand Cenozoic volute taxon from Altonian onwards, although it is not recorded from warm-water Early and Middle Miocene faunules from Southland or Northland. The origin of the taxon is uncertain and it is possible that it is polyphyletic. The strong peripheral tubercles, deep anterior notch and prominent, ridge-margined fasciole of *A. turrita* may indicate derivation from a species of *Mauira*, but *A. cylindrica* with its less tubercular sculpture and less prominent, more rounded fasciole could have evolved from *Spinomelon*.

Figured specimen (Pl. 21s): GS11174, J41/f8237, shellbed on Fallon's property, Ardgowan, Oamaru, Altonian (NZGS) x 1.

Pl. 21 t. *Alcithoe (Leporemax) lepida* Marwick, 1926 [*Alcithoe lepida* Marwick 1926a, p.296; *Alcithoe reflexa* Marwick 1926a, p.296-7; *Alcithoe neglecta* Marwick 1926a, p.298; *Alcithoe separabilis* Laws 1932, p.194; *Leporemax lepidus*; *Leporemax neglectus*] (Volutidae: Zidoninae).

Size small to moderate for subfamily (height 50-80 mm), fusiform, spire 0.35-0.4 total height. Protoconch mamillate, of 2 squat whorls with feeble spiral threads. Teleoconch of 5-6 whorls, first whorl lightly convex, later whorls broadly angled at or near middle on spire, sutural ramp flat or gently concave; last whorl unexcavated or broadly and shallowly excavated. Axial sculpture of narrow, low costae reaching from suture to suture on first 2 or 3 whorls but becoming obsolete on ramp, and in most shells restricted to peripheral nodules or tubercles with little or no anterior extension on later whorls, but in a few shells becoming obsolete; 12-15 nodules on penultimate whorl. Spiral sculpture retained on well-preserved shells as feeble threads or grooves. Aperture narrow, constricted posteriorly; anterior notch broad, moderately deep, fasciole almost flush. Columella almost straight, somewhat padded near middle in some shells, bearing 5 or 6 narrow plaits, the anteriormost considerably weaker than the others. Inner lip callus a thin smear in some shells, but much thicker in others. Outer lip slightly thickened, extending almost up to peripheral angulation, only weakly reflected in most shells.

Otaian-Altonian; Ardgowan Shellbed, Oamaru, Altonian

(type locality of *A. lepida* and *A. separabilis*); Pukeuri, Oamaru, Altonian (type locality of *A. reflexa*); Target Gully Shellbed, Oamaru, Altonian (type locality of *A. neglecta*); Awamoa Creek; Old Rifle Butts, Cape Wanbrow; Bluecliffs, Otaio River; Weka Creek.

The holotype of *Alcithoe reflexa* differs from typical *A. lepida* in having much weaker axial sculpture on spire whorls, and a more conspicuously reflected outer lip, but these differences are unlikely to be taxonomically significant. The holotype of *A. neglecta* is smaller, more robust and lower-spined than most specimens of *A. lepida*, but it closely resembles the latter in protoconch size, whorl shape, sculpture and columellar plaits and is not considered to be a distinct taxon. *A. separabilis* was distinguished from *A. lepida* on the basis of several minor differences, including its larger size and concave sutural ramp, but none are sufficiently compelling to warrant its taxonomic separation. *A. (Leporemax) scopi* (Target Gully Shellbed, Oamaru, Altonian; also Awamoa Creek), however, does seem to be a different species, distinguished from *A. lepida* by its normally much larger protoconch (although protoconch size varies considerably in both species), its less strongly shouldered teleoconch whorls, by having less conspicuous axial sculpture on adult whorls (typically costae rather than peripheral nodules) and in having a narrower anterior notch. *A. (Leporemax) finlayi* (Target Gully Shellbed, Oamaru, Altonian) also seems to be distinct—it differs from both *A. lepida* and *A. scopi* in being consistently tall-spined (although some specimens of *A. lepida* are equally tall-spined), in having a very shallow anterior notch and a thin outer lip, and in having only four columellar plaits. As first revisers we select the name *Alcithoe lepida* for the species named *A. lepida*, *A. reflexa* and *A. neglecta* by Marwick (1926a).

Leporemax includes volutes resembling *Alcithoe* (sensu stricto) in general appearance but of considerably smaller size and rather more slender shape. Although treated as a full genus by some workers it is probably more appropriately classed as a subgenus of *Alcithoe*. The earliest record of *Leporemax* is Waitakian (Brother's Stream, Hakataramea Valley).

Figured specimen (Pl. 21t): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 1.

Pl. 22 b. *Protoginella (Protoginella) conica* (Harris, 1897) [*Marginella (Glabella) conica* Harris 1897, p. 88-89] (Marginellidae).

Size moderate for family (height 4.8-7.5 mm), strombiform, spire conic, 0.25-0.3 total height. Sutures largely obscured by callus, teleoconch of about 3 whorls, bluntly shouldered near middle on spire, sutural ramp slightly concave; last whorl shallowly excavated anteriorly. Surface polished, no sculpture. Aperture narrow, elongate; anterior end truncate or slightly convex, no notch or sinus. Inner lip callus thin, spreading across much of ventral face of last whorl, around top of aperture and behind outer lip, but in many specimens difficult to distinguish from rest of shell. Columella with 4 prominent plaits, the lowest bordering the short siphonal spout. Outer lip with shallow sinus between suture and prominent shoulder angle, thickened externally, inner edge prominently denticulate.

Altonian; Mount Harris Formation, Awamoa, Oamaru (type) and other localities in Oamaru district, at most localities common or abundant and occurring with the similar-sized *Deviginella harrisi* (see below).

Protoginella conica is readily distinguished from other

New Zealand marginellids by its biconic shell with a prominently shouldered and denticulate outer lip, and its prominent columellar plaits. *Protoginella* (sensu stricto) ranges from at least Kaiatan to Waiauian, and possibly to Opoitian in New Zealand. The type species (*P. valida* (Watson, 1886) (northern Australia) lives in shallow waters, but all of the New Zealand records are from mid-shelf to upper bathyal faunules.

Figured specimen (Pl. 22b): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 4.

Pl. 22 a. *Deviginella(?) harrisi* (Cossmann, 1899) [*Marginella (Glabella) ovata* Harris 1897, p.88 (not of Lea, 1833); *Marginella harrisi* Cossmann 1899, p.88 (new name for *M. ovata* Harris, preoccupied); *M. (Kogomea) harrisi*; *Phyloginella harrisi*] (Marginellidae).

Size moderate for family (height 4-7 mm), ovate, spire low, rounded-conic, 0.1-0.15 total height. Sutures largely obscured by callus, weakly impressed; teleoconch of about 2.5-3 whorls, spire whorls very gently convex; last whorl convex, with well rounded periphery, on some shells feebly excavated anteriorly. Surface polished, no sculpture. Aperture narrow, anterior end truncate or slightly convex, no notch or sinus. Inner lip callus thin, very difficult to discern in most shells, spreading around top of aperture and apparently along back of outer lip. Columella with 4 prominent plaits, the anteriormost bordering the short siphonal spout. Outer lip swinging forwards slightly at posterior end forming a shallow sinus; thickened externally, somewhat bevelled, inner edge smooth or weakly denticulate.

Waitakian-Altonian; Mount Harris Formation, Awamoa, Oamaru, Altonian (type) and other Altonian localities in Oamaru district; Otekaike Limestone, Trig Z, Otiake; Campbell Park School, Otekaike Valley, common or abundant at most localities.

Deviginella (?) harrisi is easily distinguished from *Protoginella conica*, with which it occurs at many localities, by its ovate shape, its rounded periphery and its narrower aperture. *Deviginella (?) coxi* (Waipipian, Pitt Island) is very similar but differs in being more strongly convex and in having a less elongate last whorl.

Figured specimen (Pl. 22a): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 6.

Pl. 22 v. *Conilithes wollastoni* Maxwell, 1978 [*Conus ornatus* Hutton 1873b, p.10 (not of Michelotti, 1847); *Hemiconus trilli* ("Hutton") of Finlay 1924a, p.105 (in part not *Conus trilli* Hutton 1873b, p.10, not of A. Adams, 1855, = *Conus huttoni* Tate 1890, p.189, = *Conospira bimutata* Finlay 1924d, p.498); *Conospira huttoni* ("Tate") of Olson in Gage 1957, p.126 (in part not *Conus huttoni* Tate, 1890); *Conilithes wollastoni* Maxwell 1978, p.42-43 (new name for *Conus ornatus* Hutton, 1873, preoccupied); *Hemiconus ornatus*] (Conidae).

Rather small to moderate-sized for family (height 20-45 mm), biconic, spire 0.25-0.3 total height. Protoconch narrowly conical, of about 4 smooth whorls. Teleoconch of 8-9 whorls, angled below middle on spire, some shells with angulation just above suture, sutural ramp flat or slightly concave; last whorl straight or weakly excavated. Axial sculpture typically of small, squarish, opisthocline nodules on periphery, extending a short distance anteriorly but obsolete on ramp; 23-29 nodules on penultimate whorl. Some shells with nodules confined to first 4 whorls or so. Sutural ramp with thin, arcuate growth ridges. Spiral sculpture on spire whorls of 2-4 narrow cords on periphery and a few weak threads on ramp; last whorl with 11-14 well defined narrow grooves on anterior half or less, remainder smooth except for 1 or 2 weakly defined grooves on some shells. Aperture narrow, rectangular with inner and outer lips almost parallel and straight. Outer lip thin with shallow, arcuate sinus on ramp.

Altonian; Mount Harris Formation, Awamoa (type—probably from the former beach outcrop at the mouth of Awamoa Creek where it seems to have been very abundant) and other localities in North Otago and South Canterbury.

Conilithes wollastoni is the best-known New Zealand cone. It has long been identified as *Conus* (or *Conospirus*) *huttoni*, but the type specimen of that species (the only one known) has only weak nodules on the early teleoconch whorls, and has distinct spiral grooves over the whole of the last whorl below the periphery. *C. rivertonensis* (Altonian, Southland) is more slender and higher-spined than *C. wollastoni*, and has the shoulder angle situated higher up on later whorls. *C. oliveri* (Clifdenian, Gisborne district) is similar in shape to *C. wollastoni*, but has a larger and more narrowly conical protoconch.

Figured specimen (Pl. 22v): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 2.

Pl. 22 u. *Zeacuminia biplex* (Hutton, 1885) [*Terebra biplex* Hutton 1885b, p. 327] (Terebridae).

Size moderate for genus (height 20-30 mm), turriculate, spire elevated. Protoconch narrowly conical, of about 5 convex whorls, last quarter-whorl with narrow opisthocyrt costellae, remainder smooth. Teleoconch of 8-10 whorls, early whorls narrowly concave posteriorly, convex below; later whorls swollen at both ends, flat or slightly concave between; last whorl with prominently angled periphery, convex base and short neck. Axial sculpture of narrow, sharp-crested costae that are more prominent

on swellings than between, and are typically nodular on peribasal angulation. Costae reaching from suture to suture on spire, but scarcely extending onto base; 12-16 costae on penultimate whorl. Spiral sculpture apparently absent from early whorls, consisting on later whorls of numerous closely spaced threads over whole surface. Aperture with short, notched siphonal canal; fasciole prominent, ridge-margined. Columella vertical posteriorly, twisted to left below. Outer lip broadly and shallowly concave between suture and periphery, almost straight below.

Otaian; "Pareora" (type—probably from Mount Harris Formation, foot of Mt Horrible, Pareora River); Bluecliffs, Otaio River, moderately common.

Zeacuminia biplex is distinguished from other species of *Zeacuminia* by having a prominent subsutural swelling and a slightly less prominent suprasutural swelling, and in having relatively few, sharp-crested axial costae that are considerably stronger on swellings than in between. *Z. planitas* (Opoitian-early Nukumaruan; Pl. 37z) is closest, but the costae become obsolete between the swellings on adult whorls, leaving two rows of prominent nodules.

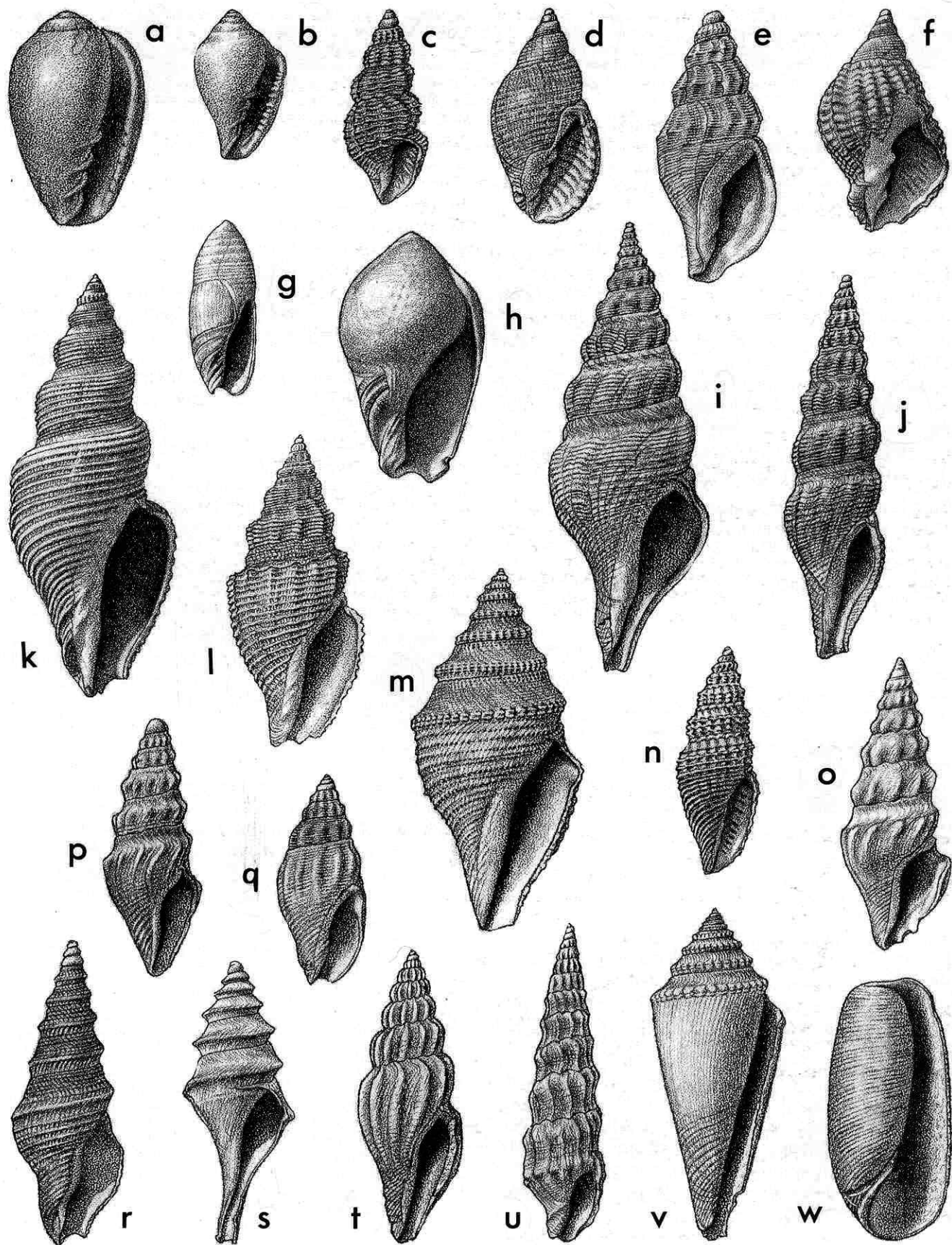
Figured specimen (Pl. 22u): Bluecliffs, Otaio River, Otaian (Canterbury Museum) x 2.

Pl. 22 l. *Austrotoma lawsi* Powell, 1942 [p. 75] (Turridae: Pseudotominae).

Size moderate for genus (height 25-40 mm), biconic, spire half total height. Protoconch of 4.5 whorls, last whorl with spiral cords, crossed on last quarter-whorl by axial costellae. Teleoconch of 5-6 whorls, shouldered at or above middle on spire; sutural ramp concave, with prominent subsutural fold; last whorl broadly excavated, neck short

Plate 22 Temperate Early Miocene (Otaian-Altonian) Mollusca (7).

- a. *Deviginella(?) harrisi* (Cossmann), x 6.
- b. *Protoginella (Protoginella) conica* (Harris), x 4.
- c. *Inglisella pukeuriensis* (Suter), x 6.
- d. *Aphera scopalveus* Finlay, x 2.
- e. *Turehua lividorupis* Beu and Maxwell, x 4.
- f. *Maorivetia brevirostris* (Hutton), x 1.
- g. *Amalda (Alocospira) hebera* (Hutton), x 1.5.
- h. *Amalda (Baryspira) robusta* (Marwick), x 1.
- i. *Comitas fusiformis* (Hutton), x 1.5.
- j. *Inquisitor awamoaensis* (Hutton), x 3.
- k. *Austrotoma nervosa* Powell, x 1.5.
- l. *Austrotoma lawsi* Powell, x 1.5.
- m. *Bathytoma (Bathytoma) haasti* (Hutton), x 2.
- n. *Vexithara nodosolirata* (Suter), x 4.
- o. *Austroclavus marshalli* Powell, x 5.
- p. *Mauidrillia costifer* (Suter), x 8.
- q. *Rugobela tenuilirata* (Suter), x 4.
- r. *Tomopleura (Tomopleura) transenna* (Suter), x 5.3.
- s. *Parasyrinx (Parasyrinx) alta* (Harris), x 3.
- t. *Neoguraleus (Fusiguraleus) flexicostatus* Powell, x 4.
- u. *Zeacuminia biplex* (Hutton), x 2.
- v. *Conilithes wollastoni* Maxwell, x 2.
- w. *Kaitoa haroldi* Marwick, x 3.



and broad. Axial sculpture of narrow-crested costae extending from shoulder angle to lower suture on spire whorls and onto base on last whorl, in some shells becoming obsolete on later part of last whorl; 13-15 costae per whorl. Spiral sculpture of fine threads on ramp, one typically stronger than others on sub sutural fold; and narrow, rather crisp cords—some with interstitial threads—below, last whorl with 13-18 cords. Numerous growth lines weakly granulate the spiral cords and reticulate the threads. Aperture elongate, subrectangular; columella weakly twisted to left to form short, strongly notched siphonal canal; fasciole ridge-margined, more conspicuous on some shells than on others. Outer lip thin, with a shallow, arcuate sinus on ramp, well preserved shells with finely crenulate inner margin.

Otaian; Mount Harris Formation, Bluecliffs, Otaio River (type); foot of Mt Horrible, Pareora River; lower Tengawai River, moderately common. Powell's (1942, p.75) record of this species from Awamoa Creek (Altonian) is based on a specimen of *A. minor*.

Austrotoma lawsi seems to be most closely related to *A. clifdenica* (Pl. 26e), but differs in having definite costae rather than only peripheral nodules on later whorls, and in having more numerous spiral cords on the last whorl.

Figured specimen (Pl. 22l): GS11283, J39/f9500C, Bluecliffs, Otaio River, South Canterbury, Otaian (NZGS) x 1.5.

Pl. 22 k. *Austrotoma nervosa* Powell, 1942 [p. 76] (Turridae: Pseudotominae).

Size moderate for genus (height 35-55 mm), fusiform, spire about half total height. Protoconch as in *A. lawsi* (see above). Teleoconch of 5-6 whorls, shouldered well above middle on spire; sutural ramp strongly concave, subsutural fold weakly developed on early whorls, obsolete on later whorls; last whorl weakly excavated. Axial sculpture, apart from growth lines, confined to first 2 or 3 whorls, consisting of narrow costae extending from shoulder angle to lower suture. Spiral sculpture of fine threads on ramp, and low, flattened cords below, 16-20 on last whorl. Spaces between cords smooth or with a single weak thread. Aperture more elongate than in *A. lawsi* but otherwise similar.

Altonian; Mount Harris Formation, Mt Harris (type); Awamoa Creek; Old Rifle Butts; Dyer's Run, Waihao Valley; Ardgowan Shellbed; Mokau Formation, North Taranaki. Rather uncommon at all localities.

The tall spire, slender shape, early obsolescence of axial costae, and relatively simple spiral sculpture effectively distinguish *Austrotoma nervosa* from most of its congeners. Its closest relative (and probable ancestor) is *A. finlayi* (Waitakian-Otaian, Auckland, North Otago), which differs in having axial costae persisting to a much later stage of growth (on to the penultimate whorl in some shells).

Figured specimen (Pl. 22k): GS12324, J41/f198, Old Rifle Butts, Cape Wanbrow, Oamaru, Altonian (NZGS) x 1.5.

Pl. 22 i. *Comitas fusiformis* (Hutton, 1877) [*Pleurotoma trailli* Hutton 1873b, p.4 (not of Hutton 1873a); *Drillia fusiformis* Hutton 1877b, p. 595; *Surcula huttoni* Suter 1914, p. 28 (new name for *P. trailli* Hutton 1873b, preoccupied); *Surcula oamarutica* Suter 1917, p. 51; *Turricula oamarutica*; *Comitas oamarutica*]. Type species (as *Surcula oamarutica*) of *Comitas* Finlay, 1926 (Turridae: Turrinae).

Size moderate for genus (height 30-60 mm), fusiform, spire 0.5-0.6 total height. Protoconch mamillate, of about 1.5 smooth whorls, last whorl prominently keeled on some shells, evenly convex on others. Teleoconch of 7-9 whorls, shouldered at or above middle on spire, sutural ramp concave with a low subsutural swelling (more pronounced in some shells than in others), sides strongly convex. Last whorl with rounded periphery, strongly excavated below, neck moderately long, almost

straight. Axial sculpture of prominent, opisthocline, rounded costae reaching from lower part of ramp to lower suture on spire, not extending onto base of last whorl; 10-13 costae per whorl. Spiral sculpture rather variable, of weak threads (on a few specimens obsolete) on ramp and considerably stronger cords below, extending over base and neck of last whorl. Aperture pyriform, columella straight or weakly twisted below; siphonal canal moderately long, unnotched. Outer lip thin, anal sinus narrowly U-shaped with apex somewhat above middle of ramp.

Duntroonian-Altonian; Mount Harris Formation, Mt Harris, South Canterbury, Otaian or Altonian (type locality of *D. fusiformis*); Awamoa, Oamaru, Altonian (type locality of *P. trailli*); "Oamaru" (probably Old Rifle Butts, Cape Wanbrow, Altonian—type locality of *S. oamarutica*), and numerous localities in North Otago and Canterbury (including Weka Pass). Particularly common in off-shore siltstone of Mount Harris Formation, less so in the shallower-water Southburn Sand.

Comitas fusiformis is very similar to *C. onokeana* (Mangapanian-Nukumaruan; Recent?), but differs in its rather less slender shape (although shape varies considerably in *C. fusiformis*), in having less distinctly shouldered teleoconch whorls, and in having more strongly convex whorl sides. *Comitas*—which is first recorded from the Duntroonian—is one of the most characteristic New Zealand Neogene turrid genera, particularly in mid- to outer shelf and upper bathyal faunules. Powell (1966, p. 29; 1969, p. 262-291) has referred numerous modern Indo-Pacific turrids (mostly of bathyal habitat) to *Comitas*, but many are probably not congeneric with the New Zealand species.

Cernohorsky (1987, p.130) claimed that *Comitas fusiformis* should be known as *C. huttoni*, as *Surcula huttoni* Suter was a replacement name (the replacement having been published before 1961) for the secondary homonym *Drillia fusiformis* Hutton. However, this is incorrect, as Suter (1914, p.28) made it quite clear that he was proposing *Surcula huttoni* for *Pleurotoma trailli* Hutton, 1873b (June), as it is preoccupied by *P. trailli* Hutton, 1873a (May). As *Drillia fusiformis* Hutton, 1877 is a much earlier name for this species than *Surcula huttoni* Suter, 1914, it is the valid name.

Figured specimen (Pl. 22i): holotype of *Surcula oamarutica* Suter, ? Old Rifle Butts, Cape Wanbrow, Oamaru, Altonian (TM6853, NZGS) x 1.5.

Pl. 22 s. *Parasyrinx (Parasyrinx) alta* (Harris, 1897) [*Pleurotoma pagoda* Hutton 1873b, p.5 (not of Reeve, 1845); *Pleurotoma alta* Harris 1897, p.45 (new name for *Pleurotoma pagoda* Hutton, 1873, preoccupied); *Turris (Leucosyrinx) altus*]. Type species of *Parasyrinx* Finlay, 1924 (Turridae: Turrinae).

Rather small for subfamily (height 20-25 mm), fusiform-biconic, spire pagodiform, 0.4 total height. Protoconch mamillate, of 1.5 smooth, convex whorls. Teleoconch of 5 or 6 whorls, sharply keeled at or below middle on spire, sutural ramp broad, almost flat, steep, sides sloping inwards. Last whorl with weak peribasal subangulation, strongly excavated below. No sculpture except for feeble spirals on neck of some shells. Aperture pyriform, columella almost straight, siphonal canal moderately long and narrow. Outer lip thin; anal sinus deeply arcuate, apex below middle of sutural ramp.

Altonian; Awamoa, Oamaru (type) and other localities in Mount Harris Formation, Oamaru district, moderately common at most localities.

Parasyrinx alta is distinguished from *P. subalta* (Pl. 15q) primarily by the total or near-total absence of spiral

sculpture. A superficially similar, undescribed species occurring in the Mount Harris Formation at Bluecliffs, Otaio River and Pareora River (Otaian) differs from *P. alta* in having a more sharply projecting peripheral keel, a more prominent peribasal angulation, and distinct spiral sculpture on the base and neck. The Duntroonian-Waitakian *P. subalta* (Pl.15q) is described above. *Parasyrinx* (sensu stricto) ranges from Duntroonian to Altonian and its subgenus *P. (Lirasyrinx)* from Kaiatan to Duntroonian (possibly Waitakian). Hickman (1976, p. 62-70) has referred several Paleogene turrids from the northwestern USA to *Parasyrinx* (sensu lato).

Figured specimen (Pl. 22s): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 3.

Pl. 22 j. *Inquisitor awamoensis* (Hutton, 1873) [*Pleurotoma awamoensis* Hutton 1873b, p. 4; *Drillia awamoensis*; *Pseudoinquisitor problematicus* Powell 1942, p. 96; *Inquisitor (Pseudoinquisitor) problematicus*]. •Type species (as *P. problematicus*) of *Pseudoinquisitor* Powell, 1942 (Turridae: Crassispirinae).

Size moderate for genus (height 20-30 mm), narrowly fusiform, spire 0.7 total height. Protoconch mamillate, of 1.5 smooth, convex whorls. Teleoconch of 8-9 whorls, weakly shouldered at about 0.7 whorl height on spire; sutural ramp concave with pronounced subsutural fold, sides strongly convex. Last whorl shallowly excavated. Axial sculpture of prominent, rounded opisthocline costae with concave interspaces, reaching from lower part of ramp to lower suture on spire, dying out on upper part of base of last whorl; 10-13 costae on penultimate whorl. Spiral sculpture on ramp of subdued threads, typically with 1 or 2 somewhat stronger cords on subsutural fold; whorl sides with much stronger, low, rounded cords, 5 or 6 on penultimate whorl, some with interstitial threads; last whorl with about 20 additional, similar cords on base and neck. Aperture narrow, columella gently convex, siphonal canal short, shallowly notched. Inner lip with parietal callus pad, narrowly and more thinly callused below. Outer lip thin, with deep but rather narrow anal sinus on ramp, convex below except for shallow stromboid notch near anterior end.

Altonian; "Awamoa", Oamaru (probably former outcrops of Mount Harris Formation, on beach at mouth of Awamoa Creek—type locality of *P. awamoensis*); Pukeuri road cutting, Oamaru (type locality of *P. problematicus*) (common); Old Rifle Butts; excavation for Oamaru Borough Council septic tank, South Oamaru (common).

Powell (1942, p. 93-94) noted that two superficially similar turrids, differing mainly in protoconch characters, are present in Altonian beds in the Oamaru district. One of these, with a conical protoconch, he identified as *Inquisitor awamoensis*; the other, with a mamillate protoconch, he named *Pseudoinquisitor problematicus*, and selected it as the type species of his new genus *Pseudoinquisitor*. He later synonymised *Pseudoinquisitor* with *Inquisitor* but continued to recognise *I. problematicus* as a distinct species (Powell 1966, p. 79-80). Unfortunately, the type specimen of *Pleurotoma awamoensis* has a mamillate protoconch so *P. problematicus* becomes a synonym of *Inquisitor awamoensis*, leaving the other *Inquisitor* (which occurs in the Mount Harris Formation at Awamoa Creek (not the same locality as Awamoa Beach), Target Gully Shellbed and Mt Harris) without a name. Quite apart from the protoconch, this unnamed species differs from *I. awamoensis* in having considerably finer spiral sculpture, a character that also distinguishes it from *I.*

komiticus (Otaian-Altonian, Pakaurangi Point, Kaipara Harbour).

Inquisitor includes slender, fusiform turrids with a distinct subsutural fold, a concave sutural ramp, axial sculpture of prominent costae below the ramp, a parietal callus pad, and a U-shaped anal sinus on the ramp. In New Zealand it is doubtfully recorded from the Wangaloan and Kaiatan, and more definitely from Waitakian to Tongaporutuan. Extant species occur in the Indo-Pacific.

Figured specimen (Pl. 22j): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 3.

Pl. 22 o. *Austroclavus marshalli* Powell, 1942 [p. 120] (Turridae: Drillinae).

Rather small for subfamily (height 8-10.5 mm), narrowly fusiform, spire 0.6 total height. Protoconch narrowly conical, of about 5 whorls, smooth except for a narrow cord margining lower suture. Teleoconch of 5-6 whorls, bluntly shouldered somewhat above middle on spire, sutural ramp concave, sides convex; last whorl weakly excavated. Axial sculpture of prominent, rounded opisthocline costae reaching from shoulder angle to lower suture on spire, typically becoming shorter on last whorl, forming little more than peripheral tubercles in some shells; 9 or 10 on penultimate whorl. Last whorl with rounded varix some distance (up to quarter of a whorl) behind outer lip. Spiral sculpture restricted to 7 or 8 narrow cords on neck, rest of shell glossy. Aperture small, ovate; columella gently convex, siphonal canal short, shallowly notched. Inner lip with well developed parietal callus pad, narrowly callused below. Outer lip with deep, subtubular anal sinus, convex below except for shallow stromboid notch near anterior end.

Otaian-Altonian; Mount Harris Formation, Pukeuri road cutting, Oamaru, Altonian (type); Awamoa Creek; Ardgowan Shellbed; Target Gully Shellbed; Bluecliffs, Otaio River; foot of Mt Horrible, Pareora River; uncommon at all localities.

Austroclavus marshalli is easily distinguished from *A. tenuispiralis* (Pl.26k) by its smaller size, its more rounded teleoconch whorls, by not having the axial costae sharply truncate at the shoulder, and by having spiral sculpture restricted to the neck.

Figured specimen (Pl. 22o): GS9520, J41/f8029, Awamoa Creek, Oamaru, Altonian (NZGS) x 5.

Pl. 22 m. *Bathytoma (Bathytoma) haasti* (Hutton, 1877) [*Clavatulula haasti* Hutton 1877b, p.595] (Turridae: Borsoniinae).

Size moderate for genus (height 30-55 mm), biconic, spire 0.45-0.5 total height. Protoconch conical, of 3.5 convex whorls, last 0.8 whorl with opisthocyrt costellae, remainder smooth. Teleoconch of 7-8 whorls, prominently shouldered at, or more typically below, middle on spire; sutural ramp concave with slight subsutural swelling, whorl sides sloping sharply inwards. Last whorl excavated, with short neck. Axial sculpture of numerous, narrow, straight or slightly arcuate tubercles with considerably wider interspaces, on narrow peripheral band; some shells with more numerous, short, prosocline ridges on subsutural swelling as well; growth ridges numerous, moderately prominent. Penultimate whorl with about 30-50 peripheral tubercles. Spiral sculpture complex, penultimate whorl with 2 or 3 narrow, rounded cords on peripheral tubercles, and numerous finer cords and threads on ramp, 2 or 3 on subsutural swelling typically stronger than others. Base and upper part of neck with 10-15 narrow, well spaced cords, as strong as or stronger than peripheral cords, the uppermost exposed on penultimate whorl of some shells, with 1-3 threads between each pair. Lower part of neck with closely spaced, narrow cords. Most, if not all, spirals finely nodulose. Aperture elongate, columella weakly twisted near middle, some shells with a low fold on twist; siphonal canal short, shallowly notched. Outer lip thin, with broadly V-shaped anal sinus, its apex rounded, on peripheral band.

Otaian-Altonian; Mount Harris Formation, Mt Harris,

South Canterbury, Otaian or Altonian (type); Bluecliffs, Otaio River; foot of Mt Horrible, Pareora River; Southburn Sand, Sutherlands; Ardgowan Shellbed, Oamaru; Awamoa Creek; Otahu Formation, Clifden. Considerably more common at South Canterbury than at North Otago localities.

Bathytoma haasti belongs to a different species group from *B. bartrumi* (Pl. 26j) and *B. finlayi* (Altonian-Lillburnian, Clifden), differing from them in having finer, more rounded peripheral tubercles, and finer, more numerous spiral cords. A closely related species from Waitakian siltstone (Mount Harris Formation) in the upper Tengawai River differs from typical *B. haasti* in having a more slender shell and considerably finer and more numerous spiral cords on the last whorl. It may be conspecific with the poorly known *B. hokianga* (Otaian, Hokianga Harbour area, Northland).

B. haasti is remarkably similar to the type species of *Bathytoma*, *B. cataphracta* (Brocchi, 1814) (Pliocene, Europe), differing mainly in rather minor sculptural characters and in having a less pronounced columellar fold. *Bathytoma* (sensu stricto) ranges from Waitakian (possibly Duntroonian) to Tongaporutuan in New Zealand, and the subgenus *B. (Micantapex)*—which differs only in having a paucispiral protoconch—from Clifdenian to Recent.

Bathytoma (sensu stricto) is most characteristic of moderately deep-water (outer shelf or upper bathyal) assemblages, but *B. haasti* is common in the shallow-water Southburn Sand at Sutherlands, and *B. finlayi* is not uncommon in shallow-water units at Clifden.

Figured specimen (Pl. 22m): GS5177, J38/f9526, Tengawai River near Sutherlands, South Canterbury, Altonian (NZGS) x 2.

Pl. 22 p. *Mauidrillia costifer* (Suter, 1917) [*Drillia (Crassispira) costifer* Suter 1917, p. 48] (Turridae: Borsoniinae).

Small for subfamily (height 7-8 mm), narrowly fusiform, spire 0.6 total height. Protoconch mamillate, of 1.5 smooth whorls. Teleoconch of about 5 whorls, shouldered near middle on spire; sutural ramp concave, some shells with weak subsutural swelling; last whorl weakly excavated. Axial sculpture of narrow, opisthocline costae with much broader interspaces, reaching from shoulder angle to lower suture on spire, typically obsolete on ramp, but represented by small nodules just below suture on some shells. Costae weaker on last whorl of most specimens, scarcely extending onto base, reduced to short peripheral nodules on some shells; 12-15 costae on penultimate whorl. Spiral sculpture weak, obsolete on spire of some shells, typically discernible only on base and particularly on neck of last whorl, consisting of low, narrow cords. Aperture narrow; siphonal canal only weakly differentiated, shallowly notched. Inner lip thinly callused, no parietal callus pad. Outer lip thin, with shallow U-shaped anal sinus, its apex near middle of ramp.

Altonian; Mount Harris Formation, Pukeuri road cutting, Oamaru (type); Awamoa Creek, moderately common.

Mauidrillia costifer is distinguished from other species of the genus by its prominently angled whorls, its relatively prominent axial costae and its weak spiral sculpture. *Mauidrillia* ranges from Duntroonian to Tongaporutuan (possibly to Waipipian) in New Zealand, and from Late Eocene to Miocene in Australia. The genus was particularly speciose in the Early Miocene; eight species have been described from Otaian and Altonian beds in North Otago and South Canterbury. Considerable care

is needed when trying to identify these small turrids, particularly as two or more species occur together at some localities (e.g. Pukeuri and Awamoa Creek) (see Powell 1942, p. 85-87). Although some species (e.g. the Duntroonian *M. cinctuta*) seem to have lived in a shallow-water habitat, most records of *Mauidrillia* are from mid to outer shelf faunules, and a few are from upper bathyal assemblages. *Mauidrillia* has long been assigned to the subfamily Clavinae (= Drilliinae) but the absence of a parietal callus pad, and the general resemblance (except for the absence of columellar plaits) to some species of *Borsonia* indicate referral to the Borsoniinae (Maxwell 1988a, p. 63).

Figured specimen (Pl. 22p): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 8.

Pl. 22 r. *Tomopleura (Tomopleura) transenna* (Suter, 1917) [*Leucosyrinx alta transenna* Suter 1917, p. 44; *Phenatoma (Cryptomella) transenna*]. Type species of *Cryptomella* Finlay, 1924, synonymised with *Tomopleura* Casey, 1904 by Powell (1942, p. 110) (Turridae: Borsoniinae).

Small for subfamily (height 8-11 mm), narrowly biconic, spire pagodiform, 0.6 total height. Protoconch narrowly conical, of 4.5 whorls, a weak subangulation appearing at about a quarter whorl height on 3rd whorl, gradually becoming more marked, last whorl with well developed keel somewhat below middle, and weak opisthocyrt costellae on ramp on last quarter-whorl. Teleoconch of 5-6 whorls, sharply keeled at about 0.4 whorl height on spire, sutural ramp broad, steep, slightly concave, whorl sides sloping inwards. Last whorl with peribasal angulation or subangulation, strongly excavated below, neck short. Spiral sculpture commencing as a prominent, rounded, smooth cord on periphery, accompanied by a much weaker one margining lower suture and another just below upper suture on most specimens. Additional spirals appearing during growth, penultimate whorl with 3-5 narrow cords or threads on ramp, 1 or 2 near upper edge stronger than others on many specimens, and a cord or thread between periphery and lower suture. Last whorl with supramargining cord emerging on peribasal angulation, and 12-15 cords, some with interstitial threads, on base and neck. Axial sculpture of relatively prominent and numerous growth lines. Aperture small, pyriform; columella strongly twisted near middle, almost straight above, concave below; siphonal canal short, shallowly notched. Inner lip smooth, strongly impressed; outer lip thin, with a moderately deep, strongly asymmetric anal sinus, its apex low down on ramp.

Otaian-Altonian; Mount Harris Formation, Awamoa, Oamaru, Altonian (type); Pukeuri; excavation for Oamaru Borough Council septic tank, South Oamaru; Oneroa, Waiheke Island; Pakaurangi Point.

Tomopleura finlayi (Altonian, Ardgowan Shellbed) is similar to *T. transenna* in sculptural plan, but the spiral sculpture—particularly the peripheral cord—is considerably stronger. *T. excavata* (Altonian, White Rock River, Sutherlands, Target Gully and Ardgowan Shellbeds) is much more distinct, having a much broader shell than *T. transenna*, a less prominent peripheral keel (scarcely stronger than the basal cords) and more numerous and more closely spaced cords on the base and neck.

Tomopleura (sensu stricto) has a recorded range of Wangaloan to Waiauian in New Zealand, and is still extant in the Indo-Pacific realm. The subgenus *T. (Maoritomella)*—which differs in having a paucispiral rather than a conical protoconch—is first recorded from the Duntroonian and is represented in the Recent fauna by at least four species.

Figured specimen (Pl. 22r): GS9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru, Altonian (NZGS) x 5.3.

Pl. 22 n. *Vexithara nodosolirata* (Suter, 1917) [*Ptychatractus nodosoliratus* Suter 1917, p. 25] (Turridae: Mitromorphinae).

Size moderate for subfamily (height 10-12 mm), narrowly fusiform, spire about half total height. Protoconch narrowly mamillate, of about 1.5 smooth whorls. Teleoconch of about 6 whorls, broadly angled near middle on spire, sutural ramp steep, almost flat; last whorl weakly excavated. Axial sculpture of narrow, rounded, orthocline or slightly opisthocline costae with broader interspaces, reaching from suture to suture on spire (though weaker on ramp than below), dying out on upper part of base on last whorl, in some shells becoming obsolete on last half whorl; 12-14 on penultimate whorl. Spiral sculpture highly variable, of low flat-topped cords with occasional interstitial threads and threadlets, typically less well developed on ramp than below, slightly thickened or nodular where they cross axial costae; 3-6 on penultimate whorl, 14-18 more on base and neck of last whorl. Aperture narrow, columella slightly convex with 2 low plaits posteriorly. Outer lip with a very weak concavity on ramp, lirate within.

Otaian; Mount Harris Formation, Bluecliffs, Otaio River (type); foot of Mt Horrible, Pareora River, common.

Vexithara vexilliformis (Altonian, Pukeuri road cutting, Oamaru)—the type species of the genus—is smaller and less slender than *V. nodosolirata*, and has less prominent spiral sculpture (almost obsolete on spire whorls on some shells). *V. magna* (Waitakian, Hakataramea Valley) is considerably larger than either *V. nodosolirata* or *V. vexilliformis*, and has four rather than two columellar plaits. *Vexithara* is very similar to *Mitrolumna*, differing mainly in having distinctly shouldered rather than convex whorls, and in having relatively strong axial sculpture.

Figured specimen (Pl. 22n): GS11154, J39/f26, foot of Mt Horrible, Pareora River, South Canterbury, Otaian (NZGS) x 4.

Pl. 22 t. *Neoguraleus (Fusiguraleus) flexicostatus* Powell, 1942 [p. 141] (Turridae: Mangeliinae).

Size moderate for subfamily (height 9-11.5 mm), narrowly fusiform, spire half total height. Protoconch narrowly dome-shaped, of about 3 strongly convex whorls, first 1.5 whorls smooth, remainder with 4 or 5 spiral cords and axial costae, both increasing quickly in strength. Teleoconch of about 6 whorls, broadly shouldered at about 0.67 whorl height on spire, ramp almost flat, sides gently convex; last whorl strongly excavated with a moderately long, straight neck. Axial sculpture of prominent, slightly opisthocline costae, narrow on ramp, broader and more rounded below; almost straight and reaching from suture to suture on spire, distinctly flexuous on last whorl and dying out on lower part of base; 9-12 costae on penultimate whorl. Spiral sculpture weak, subobsolete to obsolete on spire, very subdued on base of last whorl, strongest on neck where it consists of closely spaced, narrow cords. Aperture narrow, columella weakly flexuous, siphonal canal short, unnotched. Outer lip thin, with shallow, U-shaped anal sinus on ramp.

Otaian; Pareora River (type—probably from Mount Harris Formation, foot of Mt Horrible); Bluecliffs, Otaio River, uncommon.

Neoguraleus flexicostatus is distinguished from most other species of *N. (Fusiguraleus)* by its relatively large size, its prominent, slightly flexuous axial costae, and its very weak spiral sculpture. *N. (Fusiguraleus) major* (Altonian, Ardgowan Shellbed, Oamaru) is most similar, but is considerably larger (height 15-16 mm) and has more weakly shouldered teleoconch whorls. The subgenus *N. (Fusiguraleus)* differs from *Neoguraleus* (sensu stricto) in having a much longer, less strongly twisted columella and,

in most species, a more slender and more fusiform shell. It is first recorded from the Duntroonian (Shell Gully, Chatton), and apparently became very speciose during the Altonian—particularly in North Otago and South Canterbury—but is rather uncommon in younger beds. It is last recorded from the Haweran Te Piki bed, Cape Runaway, and so seems likely to be recognised in the living fauna of New Zealand. Most records of *Fusiguraleus* are from moderately shallow water faunules (inner to mid-shelf equivalent) but some, including *N. (Fusiguraleus) flexicostatus*, are from outer shelf or upper bathyal assemblages.

Figured specimen (Pl. 22t): GS11154, J39/f26, foot of Mt Horrible, Pareora River, South Canterbury, Otaian (NZGS) x 4.

Pl. 22 q. *Rugobela tenuilirata* (Suter, 1917) [*Ptychatractus tenuiliratus* Suter 1917, p. 26]. Type species of *Rugobela* Finlay, 1924 (Turridae: Daphnellinae).

Size moderate for subfamily (height 7-9.5 mm), elongate-ovate, spire a little more than half total height. Protoconch conical, of about 5 whorls, last quarter whorl with opisthocyt costellae, remainder smooth. Teleoconch of 4-4.5 whorls, convex except for a narrow, shallowly concave sutural ramp; last whorl weakly excavated. Axial sculpture of low, rounded, almost orthocline costae with wider interspaces, reaching from lower suture almost to upper suture on spire, barely extending onto upper part of base on last whorl, in some shells becoming obsolete on later part of last whorl; 12-13 costae on penultimate whorl. Spiral sculpture of numerous fine, low cords, usually most prominent on neck. Aperture narrowly pyriform, columella convex with 4-6 narrow, low oblique plaits anteriorly; siphonal canal short, scarcely differentiated, shallowly notched. Inner lip with parietal callus pad, narrowly callused below; outer lip somewhat thickened internally near the shallow, asymmetric anal notch, thin below.

Altonian-Waiauian; Target Gully Shellbed, Oamaru, Altonian (type); Pukeuri; Ardgowan Shellbed; Waititi Formation, Hokianga district, Northland; Nissen Shellbeds, Clifden.

Rugobela semilaevigata (Waitakian, Otiake) is similar to *R. tenuilirata* but has a larger protoconch, and has axial costae absent from the last whorl of the teleoconch. Other species of *Rugobela* either have axial costae almost completely absent, or have strongly shouldered teleoconch whorls. *Rugobela* is one of the most characteristic turrid genera in the mid-Cenozoic of New Zealand, with a recorded range of at least Kaiatan (possibly Porangan) to Waiauian. One species, *R. humerosa*, originally described from Lorne (Kaiatan), has been recorded from the Late Eocene of Victoria, Australia (Long 1981, p. 46-47). The genus as a whole seems to have been bathymetrically tolerant, some species having been recorded from shallow-water assemblages, others from mid to outer shelf or upper bathyal faunules.

Figured specimen (Pl. 22q): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 4.

Pl. 22 f. *Maorivetia brevirostris* (Hutton, 1877) [*Turbinella brevirostris* Hutton 1877b, p. 596; *Peristernia brevirostris*; *Latirus brevirostris*; *Leucozonia brevirostris*; *Bivetia* (?) *brevirostris*]. Type species of *Maorivetia* Finlay, 1924 (Cancellariidae: Cancellariinae).

Moderately large for family (height 35-50 mm), broadly ovate, spire 0.3-0.4 total height. Protoconch prominent, mamillate, of 1.5 smooth whorls, initial whorl inrolled. Teleoconch of 4-5 whorls, first whorl or so convex, but later whorls typically turned in towards suture to form a narrow sutural shelf. Last 1-1.5 whorls with a prominent subsutural

fold with a concave zone below, thereby greatly accentuating sutural shelf; periphery of last whorl strongly convex, excavated below with a short, broad neck. Axial sculpture on first 2-3 whorls of growth lines only, prominent rounded costae appearing on 3rd or 4th whorl, reaching from suture to suture on spire and nodulose on sutural shelf, typically extending across base almost to fasciole on last whorl; 13-15 costae on last whorl. Spiral sculpture commencing as about 8 narrow, low, closely spaced cords, additional cords and threads appearing during growth, sutural shelf on last whorl smooth or only feebly sculptured, remainder of whorl covered with numerous cords (typically longitudinally grooved) and threads, coarser spirals often somewhat thickened where they cross axial costae. Aperture ovate, constricted posteriorly to form narrow channel; columella vertical, twisted to left near anterior end to form short, obliquely notched siphonal canal, bearing 2 prominent plaits posteriorly, some shells with short ridge on twist as well. Fasciole rounded, strongly protruding. Inner lip prominently callused, some shells with a few weak, irregular ridges near columellar plaits. Outer lip thin, lirate within.

Altonian; Southburn Sand, White Rock River (type); Sutherlands; Target Gully Shellbed; Ardgowan Shellbed; Mount Harris Formation, Awamoa Creek; Dyer's Run, Waihao Valley; Mount Brown Formation, Weka Pass.

Maorivetia brevirostris varies considerably in spire height and sculpture and in the prominence of the sutural shelf; in particular, subadult shells may look very different from adults because of the late development of axial costae and because the sutural shelf is far less prominent on early whorls. It is unlikely to be confused with any other New Zealand cancellariid (but see discussion under *Aphera scopalveus*, below) — the only other species of similar size is *Scalptia christiei* (Pl. 151), which differs in being taller-spined, in having a channeled sutural shelf, in its narrower, more strongly prosocline costae and in having the columella slightly but distinctly deflected to the right. *Maorivetia* is monotypic and of uncertain affinity. There is some resemblance to *Sydaphera* Iredale, 1929, but species assigned to that genus have three rather than two columellar plaits.

Figured specimen (Pl. 22f): GS9700, J38/f9681, Sutherlands, Tengawai River, South Canterbury, Altonian (NZGS) x 1.

Pl. 22 d. *Aphera scopalveus* Finlay, 1926b [p. 246] (Cancellariidae: Cancellariinae).

Rather small for family (height 18-21 mm), ovate, spire 0.4 total height. Protoconch mamillate, of 1.5 smooth whorls. Teleoconch of 4 convex whorls, last whorl unexcavated. Spiral sculpture of numerous, fine, dense grooves cutting surface up into low, flattened cords, which are finely reticulated by growth lines. Aperture ovate, anterior end weakly notched; columella bent to left near anterior end, bearing 2 plaits near posterior end, the upper one the stronger, and a 3rd much weaker one on twist. Fasciole low, rounded. Inner lip callus spreading, moderately thick, with 1 or 2 weak, irregular ridges or denticles near plaits. Outer lip thickened and strongly lirate within.

Altonian; Target Gully Shellbed (type); Ardgowan Shellbed, uncommon.

Marwick (1931, p. 121) considered *Aphera scopalveus* to be based on a juvenile *Maorivetia brevirostris*, but as Laws (1933, p. 328) correctly pointed out, there are considerable differences between the two species. *A. scopalveus* is more slender than *M. brevirostris*, and has a smaller protoconch, an unexcavated last whorl, and a shallower, less oblique anterior notch. *A. scopalveus* differs from the type species of *Aphera*, *A. tessellata* (Sowerby, 1832) (Recent, tropical western America) in having a mamillate rather than a dome-shaped protoconch, and in its much finer teleoconch sculpture,

but the two species are very similar in shape and, more importantly, in apertural characters and are considered to be congeneric. There are no other records of the genus from New Zealand.

Figured specimen (Pl. 22d): GS951A, J41/f8475, Target Gully Shellbed, Oamaru, Altonian (NZGS) x 2.

Pl. 22 c. *Inglisella pukeuriensis* (Suter, 1917) [*Ptychatractus pukeuriensis* Suter 1917, p. 26; *Broccina* [sic] *pukeuriensis*; *Narona (Inglisella) pukeuriensis*]. Type species of *Inglisella* Finlay, 1924 (Cancellariidae: Cancellariinae?).

Very small for family (height 5-7.7 mm), elongate-ovate, spire 0.6 total height. Protoconch dome-shaped, of about 3 whorls, last quarter whorl with axial costellae, remainder smooth. Teleoconch of 5-5.5 whorls, early whorls biangulate, later ones evenly convex or weakly shouldered; last whorl feebly excavated. Axial sculpture of prominent rounded costae reaching from suture to suture on spire, dying out on base of last whorl; varices at irregular intervals; 9-10 costae and varices on penultimate whorl. Spiral sculpture of narrow cords, 6-10 on penultimate whorl, an additional 8-12 on last whorl. Aperture pyriform, anterior end narrowly rounded; columella subvertical, almost straight except for slight twist to left near anterior end, defining a short siphonal spout, bearing 2 plaits of variable strength. Inner lip thinly callused; outer lip with heavy rounded varix behind leading edge and a shallow V-shaped notch above middle, bearing in most specimens 4 or 5 (as many as 7) lirae within.

Altonian; Mount Harris Formation, Pukeuri road cutting, Oamaru (type); Awamoa Creek; Old Rifle Butts; Ardgowan Shellbed; Target Gully Shellbed, moderately common.

Inglisella pukeuriensis is distinguished from other New Zealand species of *Inglisella* by its relatively small protoconch, its slender shape, its convex adult teleoconch whorls, and its prominent axial sculpture. *Inglisella* ranges from about mid-Dannevirke Series (? Mangaorapan) to Opoitian in New Zealand and seems to have been particularly speciose during the Otaian and Altonian; at several localities (including Pukeuri road cutting) from two to four species occur together and require careful examination before they can be separated. The genus seems to have been bathymetrically tolerant — some species occur in very shallow-water faunules, but most species are recorded from mid to outer shelf or upper bathyal deposits.

Figured specimen (Pl. 22c): GS9685, J41/f9499B, Pukeuri road cutting, Oamaru, Altonian (NZGS) x 6.

Pl. 22 e. *Turehua lividorupis* Beu and Maxwell, 1987 [p. 19] (Cancellariidae: Plesiotritoninae).

Small for genus (height up to 13 mm), ovate, spire about half total height. Protoconch mamillate, of 1.5 smooth whorls. Teleoconch of 3 whorls, broadly angled near middle on spire, last whorl excavated, with short, broad neck. Axial sculpture of slightly opisthocline costae that are not parallel to outer lip of aperture (i.e. they are non-collabral), becoming shorter as shell grows so last whorl of large shells bears only peripheral nodules, crossed at a low angle by numerous, fine growth lines. Spiral sculpture of low, rounded, widely spaced primary cords, 2 or 3 on sides of spire whorls, 5 or 6 on last whorl, and numerous low, narrow threads, 10-20 on sutural ramp and 4-6 between primary cords, and many more on base and neck. Aperture narrowly oval; columella subvertical, almost straight except for bend near anterior end defining a short siphonal canal, bearing 2 prominent plaits near middle; no fasciole. Inner lip callus thin, spreading laterally, outer edge raised. Outer lip narrowly reflected over low terminal varix (previous varices not retained), bearing 4-8 very low indistinct nodules on its inner edge.

Waitakian-Otaian; Mount Harris Formation, foot of Mt Horrible, Pareora River, Otaian (type); Bluecliffs, Otaian

River; Brother's Stream, Hakataramea Valley; upper Tengawai River—not common at any locality.

Turehua lividorupis is easily recognised by being much the smallest and most weakly sculptured New Zealand species of the genus. The non-collabral axial sculpture is characteristic of the genus (and of the subfamily). Other New Zealand species (reviewed by Beu and Maxwell 1987) are *T. dubia* (Bortonian, Hampden)—the type species of *Turehua* Marwick, 1943—which is larger than *T. lividorupis*, and has a concave sutural ramp, a prominent fasciole and wide inner lip, and narrower, more numerous spiral cords; *T. crassispinalis* (Kaiatan, McCulloch's Bridge), a short, strongly inflated species with few, large, rounded, closely spaced spiral cords; *T. ponscuspidis* (Runangan, Bridge Point), a small species shaped like *T. dubia* but shorter, with fewer spiral cords and a shorter siphonal canal; and *T. tenuispinalis* (Duntroonian, Wharekuri), a large shell with prominent, clearly opisthocline axial costae but weak spiral sculpture. An unnamed species from the Chatham Islands (Opoitian-Waipipian, Momoe-a-Toa and Whenuataru Tuff), close to *T. ponscuspidis* and known from only a few broken specimens, is much the youngest known species in the world.

Figured specimen (Pl. 22e): GS11154, J39/f26, holotype, foot of Mt Horrible, Pareora River, South Canterbury, Otaian (NZGS) x 4.

Pl. 22 w. *Kaitoa haroldi* Marwick, 1931 [p. 155]. Type species of *Kaitoa* Marwick, 1931 (Cylichnidae).

Size moderate for family (height c. 15 mm), subcylindrical, involute. Apex with shallow depression largely filled by thin callus. Spiral sculpture of low, flat cords, some with median groove, interspaces mostly narrower than 1 cord and bearing thin axial costellae. Aperture very capacious anteriorly, narrower above; columella strongly concave, margined by a narrow, slightly raised callus. Outer lip thin, projecting slightly above apex, gently convex from posterior end to opposite columella, then swinging backwards sharply below.

Altonian; Southburn Sand, White Rock River (type); Sutherlands, uncommon.

Kaitoa is apparently endemic to New Zealand, where it ranges from at least Otaian to Waipipian. It appears to be closely related to *Scaphander* Montfort, 1810, but differs in its more cylindrical shape and in lacking callus on the inner lip posterior to the columella.

Figured specimen (Pl. 22w): GS9700, J38/f9681, Sutherlands, Tengawai River, South Canterbury, Altonian (NZGS) x 3.

2. REPRESENTATIVE WARM-WATER EARLY AND MIDDLE MIOCENE MOLLUSCA: PLATES 23-26

Pl. 23 b. *Cryptoplax* n. sp. (Acanthochitonidae).

Shell very small (largest valve seen 3.7 x 1.7 mm), each valve very long and narrow (except anterior valve, which is semicircular), all without distinction between lateral and pleural areas. Anterior valve with straight posterior margin; long insertion plate with 3 weak, shallow slits; and an evenly granulose, relatively short and wide tegmentum lacking a jugum. Median plates very long and narrow, with a clearly differentiated, smooth jugum, a lozenge-shaped tegmentum, and narrow, strongly forward-pointing sutural laminae; sculpture of longitudinal rows of granules on lateral areas; all valves seen with a posterior, strongly overhanging mucro. Posterior valve similar to median ones but a little shorter, with a very strongly overhanging, posterior mucro, and semitubular, horseshoe-shaped, unslit insertion plate directed anteriorly all around the posterior margin.

Otaian; Waititi Formation, Pinehill Stream, Waimamaku Valley, south Hokianga; Otueka Hill road cutting, north Hokianga.

Cryptoplax is the most common chiton under coral blocks on coral reefs throughout the tropical Pacific today; large, very long and narrow, worm-like, banded light and dark brown animals that crawl rapidly and hide in deep crevices, they don't resemble chitons until their small valves are noticed protruding from the centre of the densely spinose, bristly girdle. Other less derived species occur today under intertidal boulders around southern Australia (Iredale and Hull 1925, p. 104-106), so the New Zealand records do not necessarily indicate the proximity of coral reefs (although fragments of hermatypic corals are recorded from Pinehill Stream). The Hokianga species appears to be nearest to *C. mystica* Iredale and Hull (1925, p. 104) which lives under boulders in New South Wales (*C. mystica* was regarded by Leloup (1940) as a form of the widespread, highly variable *C. striata* Lamarck, 1819). This species, and another *Cryptoplax* species with wider, more finely granulose valves, are the most common chiton plates in sediment washings from the Hokianga area, and are an interesting new record for New Zealand; they occur in shallow, soft-bottom facies with abundant other molluscs.

Figured specimen (Pl. 23b): GS12601, O6/f40, Pinehill Stream, Waimamaku Valley, south Hokianga, Otaian (NZGS) x 16.5.

Pl. 23 a,c. *Tucetona finlayi* (Laws, 1939) [*Glycymeris* (*Grandaxinea*) *finlayi* Laws 1939a, p. 470] (Glycymerididae: Melaxinaeinae).

Moderately large for genus (height 60-90 mm), relatively strongly inflated, subcircular to oval; posterior area narrow, distinctly depressed. Radial sculpture of 34-36 prominent, well spaced costae, 5 or 6 on posterior area much weaker than others, broadly triangular and sharp-crested proximally, becoming more rounded and subdued distally. Commarginal sculpture of very numerous, closely spaced growth lines, particularly noticeable on well preserved juvenile shells. Hinge rather heavy, more strongly arched on large shells than on smaller ones; ligamental area with closely spaced chevron grooves.

Altonian-Waiauian; cutting behind Clifden Racecourse, Southland, Waiauian (type); Clifden section from Long Beach Shellbed to Nissen Shellbeds, particularly common in the Lill Sand.

Tucetona finlayi is distinguished from the widespread species *T. laticostata* (Tongaporutuan?—Recent; almost certainly = *G. wairarapaensis*, Nukumaruan) by its much better-defined posterior area and by having radial costae of triangular rather than rounded section. *T. monsadusta* (Waiauian, Burnt Hill and Weka Pass, North Canterbury) is rather poorly known, but the available material suggests that it differs from *T. finlayi* in having more inflated umbones and broader, rounded costae with much narrower (linear) interspaces. As far as can be judged from the inadequate description and the poor illustration of the type, *T. aucklandica* (Otaian, Waiheke Island) seems to have similar radial costae to *T. finlayi*, and may prove to be conspecific, and therefore an earlier name for this species.

Figured specimen (Pl. 23a, c): GS11187, D45/f8824, Lill Sand, Clifden, Southland, Lillburnian (NZGS) x 1.

Pl. 23 d,e. *Septifer torquatus* (Marshall, 1918) [*Mytilus*

torquatus Marshall 1918, p. 168; *Trichomya torquata* (Mytilidae: Mytilinae).

Rather small for family (length 20-33 mm), mytiliform, of rather variable shape, many specimens of stepped profile; beaks terminal or subterminal; dorsal margin long, straight, somewhat wing-like in some shells; ventral margin almost straight except for shallow concavity towards anterior end; posterior end subquadrate. Median part of shell strongly inflated from umbones to posterior end, dorsal area distinctly concave, ventral area slightly convex except for concave zone anteriorly. Radial sculpture on median area of low, rounded, bifurcating costae, most of which do not persist to posterior margin but diverge on subdividing and cross the dorsal and ventral areas, covering them with numerous fine, closely spaced costellae. Commarginal sculpture of fine growth ridges between costae and costellae, less distinct distally than proximally. Anterior extremity with a triangular internal plate or septum to house the anterior adductor muscle. Hinge with a few weak tubercular teeth above septum. Ligament groove long, narrow, below dorsal margin. Internal margin crenulate, other internal features not known.

Otaian-Waianian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour, Otaian or Altonian (type); Paratoetoe, Parengarenga Harbour; Stillwater Mudstone, Lake Ryan, near Greymouth; Long Beach Shellbed, Clifden; greensand at base of Late Miocene sequence, Cape Foulwind.

Septifer torquatus is easily distinguished from other New Zealand mytilids by its somewhat irregular shape, its squarish posterior end, its well defined dorsal area, its divaricate sculpture, and its internal septum, the last being a diagnostic character of the genus. *Hormomya* (?) *willeitsi* (Pl. 3e) is superficially similar in shape and sculpture but is smaller and apparently lacks an internal septum. *Septifer* is widespread in subtropical and tropical seas at the present day, and is also recorded from northern New Zealand (Powell 1979, p. 372) and New South Wales. Other New Zealand records are from the upper Waihao River, South Canterbury (? Mangaorapan) and from the "Fan coral bed" (Duntroonian), Porter River, Castle Hill Basin.

Figured specimen (Pl. 23d, e): holotype, Pakaurangi Point, Kaipara Harbour, Northland, Otaian or Altonian (TM2122, NZGS) x 1.5, x 3.

Pl. 23 k,l. "*Isognomon*" cf. *zealandicus* (Hutton in Suter, 1917) [*Perna* sp. Hutton 1873b, p. 26; *Perna zealandica* Hutton 1873b, pp. xiii, 47 (nomen nudum); ? *Perna quadrata* Park 1887, p. 53 (nomen nudum); *Melina zealandica* Hutton in Suter 1917, p. 68; *Pedalion zealandicum*] (? Bakevelliidae).

Moderately large to very large (height 90-100 mm in Middle Miocene specimens, 160 mm and more in middle Pliocene ones), almost as long as high, subquadrate, with small anterior ear and long, almost square posterior wing set off from disc only by shallow concavity in both valves; hinge and umbonal area extremely thick and massive (more than 20 mm thick on large Pliocene shells) but ventral area of disc very thin and exceedingly fragile (few complete Pliocene shells are known). Moderately thick (2-3 mm) prismatic calcite outer layer, missing from most specimens; inner layer and hinge-umbonal area brightly nacreous aragonite. Ligamental plate wide (15 mm wide on Middle Miocene shells, 42 mm and more wide on large Pliocene ones), with 4 or 5 deep, wide, somewhat irregular resilial pits (a few pits spread laterally or split into 2 in some shells), deeply sinuating the otherwise smooth hinge line; the 2 ligamental areas of each articulated specimen diverge dorsally at 85°. Below anterior ear, valve edge with wide, moderately deep embayment forming large byssal gape, oval in anterior view in articulated shells. Exterior smooth apart from weak growth ridges. Adductor scar large, oval, with roughened surface of anastomosing wrinkles; an elongate, oblique (?byssal retractor) scar in front of anterior edge of adductor. Pallial line a row of widely separated small muscle impressions, ascending into deep umbonal hollow; small impressions are deep enough to form prominent nodules on some large Pliocene internal moulds.

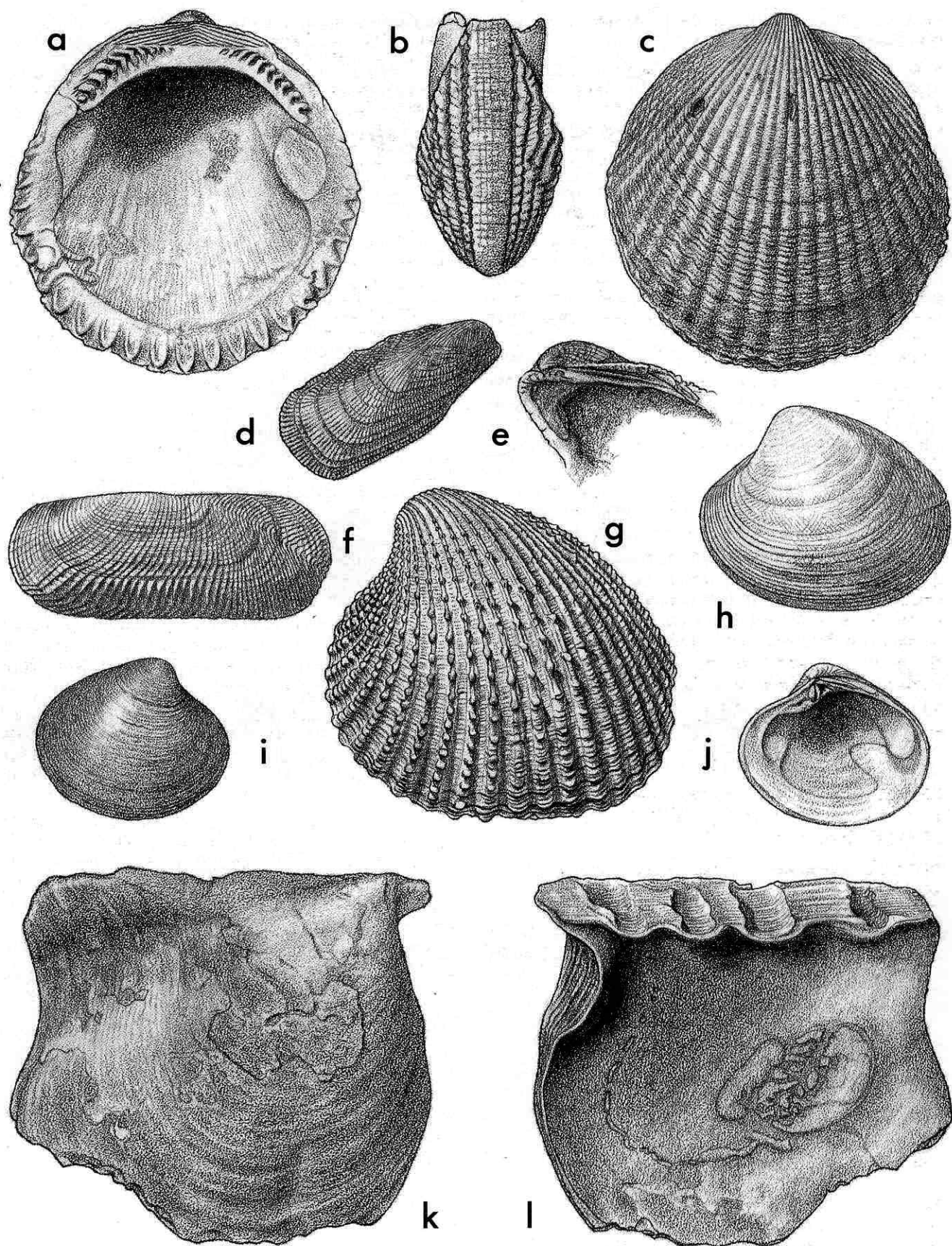
(Waitakian?-) Lillburnian-Nukumaruan; "Shrimpton's", i.e., Kikowhero Stream, Matapiro Station, north side of Ngaruroro River, central Hawke's Bay, Nukumaruan, smaller syntype of Suter (1917, pl. 8, fig. 4); Scinde Island Limestone, Napier, Nukumaruan, larger syntype (internal mould) of Suter (1917, pl. 13, fig. 2); "Castle Point" and "Taipo marls", Wairarapa, "chirotype" of Hutton (1873b, p. xiii, 26) [but bears a shelly, dark grey, coarse sandstone matrix, clearly that of the Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian], all in NZGS. Common at some Middle-Late Miocene localities in near-shore sandstone (shellbeds high in the Lillburnian at Clifden, Southland; Te Araroa, East Cape, Kapitean).

An unusually complete Clifden Miocene specimen of "*Isognomon*" cf. *zealandicus* is illustrated here, but the species is much more abundant in many Pliocene to early Pleistocene localities in shellbeds and near-shore sandstone or mudstone (Waipipi shellbeds, South Taranaki; Hawke's Bay Nukumaruan). It is not clear whether the smaller Miocene shells and larger Pliocene shells are conspecific, and their relationship to the Early Miocene "*Pteria*" *oneroaensis* also needs investigation. Similar specimens from Brydone, Mataura River, Southland (Waitakian) have thinner shells and narrower hinges and probably belong in a different species.

Although there has previously been no apparent doubt that this species group belongs in *Isognomon* Lightfoot,

Plate 23 Warm-water Early-Middle Miocene (Otaian-Lillburnian) Mollusca (1).

- a,c. *Tucetona finlayi* (Laws), x 1.
- b. *Cryptoplax* n.sp., x 16.5.
- d,e. *Septifer torquatus* (Marshall), x 1.5(d) and x 3(e).
- f. *Solecurtus bensoni* Finlay, x 2.
- g. *Glyptoactis* (*Fasciculicardia*) *subintermedia* (Suter), x 1.
- h. *Pitar* (*Hyphantosoma*) *sculpturata* (Marshall), x 1.5.
- i,j. *Rohea trigonalis* (Marwick), x 1.5.
- k,l. "*Isognomon*" cf. *zealandicus* (Hutton in Suter), x 1.



1786 (= *Melina* Retzius, 1788, = *Pedalion* Dillwyn, 1817, = *Perna* of many authors), comparison of specimens with the newly prepared holotype of "*Pedalion*" *fortissimum* (Tongaporutuan) and with New Zealand and European Mesozoic species of *Isognomon* showed that *I. fortissimus* is the only named Cenozoic species correctly referred to *Isognomon* (although others are named by Crampton 1988). *Isognomon* species have nearly vertical ligamental areas (almost parallel in articulated shells) with a large number of regular, narrow, parallel resilial pits, no hollow beneath the hinge plate and umbo, and no anterior ear. The widely diverging ligamental plates, few wide resilial pits, prominent anterior ear, and deep umbonal hollow of "*I. zealandicus*" are nearest to characters of *Panis* Stephenson (1952, p. 67) (type species: *P. cuneiformis* Stephenson, 1952, Cenomanian (Late Cretaceous), Texas) and differ little from *Aguileria* White, 1887 (Stephenson 1952, p. 66), also from the Cenomanian of Texas; both *Panis* and *Aguileria* were included in the family Bakevelliidae by Cox (in Moore 1969, p. N308-310). If this relationship is correct (it needs further study), the New Zealand species would be the youngest known bakevelliid (the only other Cenozoic members of the family are several species of *Aviculoperna* and one of *Gervillia* reported from the Lower Eocene of Europe).

Suter (1917, p. 68) clearly attributed the species name to Hutton, in the designation "*Melina zealandica* (Hutton) nov. sp.", and the specific epithet was first proposed (as a nomen nudum) by Hutton (1873b, p. xiii); in our opinion the name should be attributed to "Hutton in Suter, 1917".

Figured specimen (Pl. 23k, l): GS2938, D45/f8471, shellbed, Cucullaea Point, Third Bay, Clifden, Southland, Lillburnian (NZGS) x 1.

Pl. 23 g. *Glyptoactis (Fasciculicardia) subintermedia* (Suter, 1917) [*Venericardia subintermedia* Suter 1917, p. 74; *V. (Fasciculicardia) subintermedia*; *Cardita (Glans) kaiparaensis* Marshall 1918, p. 272 (as *Cardium* (sic); see Laws 1944, p. 312)]. Type species of *Fasciculicardia* Maxwell, 1969 (Carditidae: Venericardiinae).

Rather large for family (length 50-70 mm), ovate-subquadrate to subrectangular, large shells more elongate than subadult shells, posterior margin slightly truncate, umbones very close to anterior end; posterior area weakly differentiated, slightly flattened or weakly concave. Lunule small, strongly pouting. Radial sculpture of 28-31 prominent, elevated costae with much broader interspaces, narrowly triangular in section proximally but becoming lower, broader and more rounded distally; most shells with 2 costae in middle of posterior area substantially less prominent than those on either side. Many costae flanked on posterior side, and in some shells on anterior side as well, by a much weaker ridge, producing characteristic fasciculate sculpture of genus. Crests of costae with prominent triangular tubercles or spines, or rounded nodules, which in most shells are not arranged in regular commarginal fashion; tubercles strongest anteriorly, over anterior part of flanks, and on posteriormost 2 or 3 costae, but weaker, even absent, elsewhere, and becoming obsolete distally on largest shells. Lower flanks of costae and intercostal spaces on well preserved shells with radial rows of minute papillae. Commarginal sculpture of growth wrinkles and ridges, most prominent distally, particularly near posterior margin. Hinge similar to that of *G. (Fasciculicardia) acanthodes* (Pl. 5g) but with left anterior cardinal tooth much closer to, and almost fused to, the lunular margin.

Otaian-Lillburnian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour; Otaian or Altonian (type locality of both *V. subintermedia* and *C. (Glans) kaiparaensis*); Coral Point, Kaipara Harbour; Stillwater Mudstone near Lake Ryan, near Greymouth; Clifden

section from Calamity Point Sandstone to Lill Sand, locally common.

Glyptoactis subintermedia is distinguished from other New Zealand species of *Glyptoactis* by its very large size, the number of radial costae (similar to that in *G. benhami* (Pl. 9c, d) but considerably greater than in *G. acanthodes* (21-24) (Pl. 5g, h)), and the wide spacing of the costae. Judging by the distribution of this distinctive carditid (Northland, Westland and Southland) and its association at many localities with species of *Septifer*, *Spondylus*, *Oniscidia*, Conidae, etc., this was a warm-water species, possibly occupying the niche taken in the cooler east coast region by "*Cyclocardia*" *awamoensis*. The only record of *Glyptoactis* from the temperate province is from the Gee Greensand (Altonian) at Target Gully, stratigraphically below the famous shellbed. The specimen concerned differs from typical *G. subintermedia* in having more closely spaced and more densely nodulose radial costae, and probably represents a new species.

Figured specimen (Pl. 23g): GS5095, D45/f8599, Slip Point, Clifden, Southland, Clifdenian (NZGS) x 1.

Pl. 23 f. *Solecortus bensoni* Finlay, 1924b [p. 471-472] (Solecortidae).

Size moderate for genus (length 20-36 mm), elongate-elliptical, gaping widely at both ends, beaks situated well forward of centre. Commarginal sculpture of very fine striae and somewhat stronger growth ridges; some shells with broad commarginal colour bands. Other sculpture neither commarginal nor radial, highly variable, consisting of very low, step-like ridges or terraces with steep edge always on posterior margin, absent from small area near anterodorsal margin, but typically present over rest of shell. Ridges slightly wavy, bent back on posterior area, degree of bending typically increasing with distance from umbo. Left valve with a small, subvertical anterior cardinal tooth and a thin posterior cardinal tooth coalescent with nymph plate. Right valve with a narrow, triangular anterior cardinal and a thin, oblique posterior cardinal. Ligament external, extending about a quarter distance to posterior end, nymphs distinctly raised. Pallial sinus linguliform, extending in front of beaks.

Altonian-Lillburnian; Calamity Point Sandstone, Clifden, Altonian (type), also Otahu Formation, Fouraye Siltstone and Lill Sand, Clifden; New Chum Creek, Karamea district; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour. Moderately common at type locality, less so at other localities.

Solecortus evolutus (Altonian, Oamaru) is less elongate than *S. bensoni*, and has its beaks nearer the middle of the shell. *S. chattonensis* (Duntroonian, Southland) is larger than *S. bensoni* and has more widely spaced ridges that are less strongly bent on the posterior area. An undescribed species of *Solecortus*, differing in its larger size and coarser sculpture, replaces *S. bensoni* in the lowest Nissen Shellbed ("no. 1") in the Clifden section. *Solecortus* has a recorded range of Duntroonian to Kapitean in New Zealand, mostly in shallow-water (inner to mid shelf) assemblages. Although extinct in New Zealand, *Solecortus* is widespread in shallow, warm waters elsewhere, including northern New South Wales and Queensland. Modern species are moderately rapid burrowers living in long mucus-lined burrows that bifurcate posteriorly to form separate openings for the inhalent and exhalent siphons (Dworschak 1987).

Figured specimen (Pl. 23f): GS10344, D45/f8483, Calamity Point, Clifden, Altonian (NZGS) x 2.

Pl. 23 h. *Pitar (Hyphantosoma) sculpturata* (Marshall, 1918) [*Macrocallista sculpturata* Marshall 1918, p. 272] (Veneridae: Pitarinae).

Size moderate for subfamily (length 25-40 mm), ovate, strongly inflated; posterior area poorly defined, slightly concave. Lunule moderately large, bounded by a shallow groove but not impressed; no escutcheon. Sculpture, apart from fine growth lines, of narrow zig-zag grooves, strongest at both ends. Left hinge with a prominent anterior lateral tooth well separated from lunule and from cardinals; a lamellar, almost vertical anterior cardinal; and a thin median cardinal which is subparallel to the lamellar posterior cardinal which in turn is separated by a narrow groove from the thin nymph. Right valve with a deep anterior lateral socket; a thin anterior cardinal tooth with a narrowly triangular median cardinal close behind, and a narrowly triangular, strongly bifid posterior cardinal. Pallial sinus moderately deep, slightly ascending, apex rounded. Margins smooth.

Otaian-Altonian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type); east of the Puketoi Range, southern Hawke's Bay. A poorly preserved right valve from the Tongaporutuan of Gisborne district was doubtfully referred here by Marwick (1931, p. 79).

Pitar sculpturata is readily distinguished from other New Zealand venerids by the unusual zig-zag sculpture. Altonian specimens of *Pitar (Hyphantosoma)* from Clifden, Southland (Calamity Point Sandstone, Long Beach Shellbed) have been assigned to this species, but they differ from topotypes in having narrower but higher umbones and may not be conspecific. The occurrence of this distinctive subgenus in the New Zealand Miocene is biogeographically interesting, as the only other records are from the Oligocene to Pliocene of the West Indies.

Figured specimen (Pl. 23h): GS9730, Q8/f9828, Holland's Point, Pakaurangi Point, Kaipara Harbour, Otaian (NZGS) x 1.5.

Pl. 23 i,j. *Rohea trigonalis* (Marwick, 1927) [*Paradione (Notocallista) trigonalis* Marwick 1927, p. 593-594]. Type species of *Rohea* Marwick, 1938 (Veneridae: Pitarinae).

Rather small for subfamily (length 20-30 mm), subtrigonal, relatively robust, moderately inflated. Lunule well-defined; escutcheon barely differentiated. Sculpture of fine, closely spaced commarginal ridges and grooves anteriorly and posteriorly, remainder smooth, somewhat polished. Hinge plate broad, flat; left valve with a tubercular anterior lateral tooth, bounded above and below by a socket; a narrow anterior cardinal tooth; a triangular median cardinal; and a short, narrow posterior cardinal. Right valve with 2 tubercular anterior laterals; 2 narrow, sharp anterior cardinal teeth; and a short, weakly bifid posterior cardinal. Ligament deeply impressed. Adductor muscle scars somewhat raised above interior. Pallial sinus moderately deep, rounded, ascending. Margins smooth.

Altonian-Lillburnian; Long Beach Shellbed, Clifden, Southland, Altonian (type) (uncommon); Lill Sand, Clifden (rare).

Rohea trigonalis, the only known species of the genus, superficially resembles species of *Notocallista*, but has a flat rather than an excavated hinge plate, has relatively long right anterior lateral teeth, and has lateral teeth more widely separated from the cardinals than in *Notocallista*.

Figured specimen (Pl. 23i, j): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Southland, Altonian (NZGS) x 1.5.

Pl. 24 a,b. *Parapholas aucklandica* Powell, 1938a [p. 368] (Pholadidae: Martesiinae).

Size moderate for family (length 25-33 mm), subcylindrical, complete individuals (with callum) rounded anteriorly, narrower posteriorly.

Callum weakly radially sculptured; remainder of shell divided into 3 parts. Anterior slope with low, narrow radial costae, crenulated by numerous, fine growth lines. Flank smooth except for growth lines, separated from anterior slope by shallow umbonal-ventral sulcus. Posterior slope with distant commarginal ridges, separated from flank by radial row of small triangular pits. Protoplax broad. Mesoplax and metaplax confluent, double, extending from protoplax almost to posterior end, broad medially, tapering behind.

Otaian, Squadron Bay, Waiheke Island, Auckland (type), boring into greywacke boulders.

Parapholas aucklandica is easily recognised by its relatively short form and strong inflation, its rounded posterior end, its shell divided into three areas by two weak radial grooves, and its large, complex, dorsal accessory plates. This is the only New Zealand record of this widespread rock-boring pholad. *Pholadidea* differs from *Parapholas* in not having the posterior slope clearly defined, in not having the metaplax (if present at all) as a separate plate, and in having a siphonoplax.

The figured specimen (AMTM586) is labelled "Holotype" in A.W.B. Powell's handwriting, but differs from Powell's (1938a, pl.38, fig. 5) figure of the holotype in subtle details, and is much smaller (length 24 mm, rather than 33 mm cited by Powell). We assume it is a paratype.

Figured specimen (Pl. 24a, b): paratype?, Squadron Bay, Waiheke Island, Auckland, Otaian (AMTM586, Auckland Institute and Museum) x 2.

Pl. 24 c. *Guildfordia (Opella)* n. sp. (Turbinidae: Turbininae).

Large for subgenus (height about 40 mm, greatest diameter 41 mm), trochiform; spire tall, conic, almost flat-sided, apex flattened. Protoconch of little more than 1 smooth whorl. Teleoconch of 6-7 whorls, first whorl planorboid, later whorls descending; periphery of last whorl sharply angled with short, thick solid spines protruding outward and downward; base very weakly convex with smooth, flat umbilical area occupying central half. Suture undulating strongly around bases of former spines. Sculpture of several rows of very small, rounded granules, largest just below suture, very fine in mid-whorl and just above periphery; outer third of base with fine, regular, undulating spiral threads and similar radial threads. Aperture oval, with strongly curved columella, and excavated lower lip; outer lip swinging strongly forward from periphery then curving up to pass almost straight to suture. Operculum relatively small (compared with *G. (Guildfordia)* of similar diameter), thin and flat, with rounded margin and exceedingly faint "finger-print" sculpture.

Altonian, Paratoetoe and Te Pokere, north shore of Parengarenga Harbour, moderately common in siltstone of probable outer shelf or upper bathyal facies.

This unnamed species is larger and has a much taller and narrower spire and larger peripheral spines than *G. (Opella) subfimbriata* (Otaian-Altonian, Pakaurangi Point), the type species of *Opella* Finlay, 1926, and is one of the most elegant of all Turbinidae. These two typical, tall-spined species of *Opella* resemble typical *Guildfordia* in almost all characters, especially the details of arrangement of sculptural granules, and of peripheral spines in relation to the peripheral keel; the only important distinguishing points are the much taller, flatter-sided spire and the shorter spines compared with *Guildfordia* (sensu stricto), and the absence of a hollow in the basal callus. We therefore follow Beu and Ponder (1979, p. 4) and treat *Opella* as a subgenus of *Guildfordia*; it appears to be an endemic New Zealand taxon. Marwick (1934, p. 11) named as *Opella hendersoni* a much lower-spined but still conic, very beautifully gemmate species

from Tarakohe cement quarry, Takaka, northwest Nelson (Altonian), and similar specimens are known from Clifden (Lillburnian); they closely resemble some of the living Western Pacific short-spined species of *Guildfordia* (sensu stricto) such as *G. monilifera* (Hedley and Willey 1896, p. 107). It is difficult to decide whether *O. hendersoni* should be referred to *G. (Guildfordia)* or *G. (Opella)*; we retain it in *G. (Opella)* because it has a flat base, lacking a central hollow. A further small, unnamed species of *G. (Opella)* is represented by a few specimens in Auckland Museum from the Waitakere Ranges, Auckland (Otaian ?) that are similar to, but shorter than *G. (Opella) subfimbriata*.

Magne and Vergneau-Saubade (1971) provided the new name *Astraea suteri* for *G. subfimbriata* because of supposed secondary homonymy with "*Astraea*" *subfimbriata* (Cossmann and Peyrot, 1916) but the replacement name was unnecessary, as *Bolma subfimbriata* Tournouer in Cossmann and Peyrot, 1916 had not previously been referred to *Astraea*, and clearly belongs in *Bolma (Bolma)*.

Figured specimen (Pl. 24c): GS9723, N2/f7594, Paratoetoe, north shore, Parengarenga Harbour, Altonian (NZGS) x 1.

Pl. 24 h. *Maoricolpus* (sensu lato) *ongleyi* Marwick, 1931 [p. 93] (Turritellidae).

Very large for family (height 100-170 mm), narrowly conical, with a relatively wide spire angle, spire 0.85 total height. Protoconch very small, conical, of about 3 strongly convex whorls. Teleoconch of 10-15 whorls of variable shape, weakly campanulate, frustate or subcylindrical. Spiral cords B and C appearing at beginning of teleoconch, B dominant for a few whorls, A appearing later, rivalling C in strength for a while (thereby giving whorls a biangulate profile) but then like B fading into "background" spirals; C remaining distinct for several whorls then to becoming indistinguishable from supernumary spirals, although its position is marked by a narrow anterior cingulum on many shells. Subadult and adult whorls covered with numerous, closely spaced, subuniform spiral cords. Well preserved shells with very numerous fine, lamellar axial ridges that give adult whorls a finely rasp-like texture; those on crests of spiral cords more or less collabral, but some in interspaces of adapical cords distinctly opisthocline and hence, non-collabral. Sinus moderately deep, abapical limb steeper than adapical limb.

Otaian-Kapitean; Island Creek, Waipaoa River, Gisborne district, Lillburnian (type); and from numerous localities in North and South Islands. The youngest record is from the Kapitean of Maruhou Point, east of Te Araroa, East Cape (National Museum of N.Z.). Not recorded from the Altonian of North Otago and South Canterbury, where other "giant" turritellids (e.g. *Tropicolpus abscisus* and *T. (Amplicolpus) cavershamensis*) are common.

Maoricolpus ongleyi is readily distinguished from other large turritellids by its relatively large spire angle, by the subadult and adult spiral sculpture of numerous subuniform cords, and by the non-collabral interstitial ridges. *M. waitemataensis* (Otaian, Waiheke Island) is related, but is considerably smaller (height 70-80 mm), has a narrower spire, and has finer, weaker spirals on the whorl sides but considerably stronger cords on the base.

Figured specimen (Pl. 24h): Long Beach Shellbed, Clifden, Altonian (M27900, National Museum of NZ) x 1.

Pl. 24 g. *Willungia maoria* Powell, 1938a [p. 371-372] (Triviidae: Eratoinae).

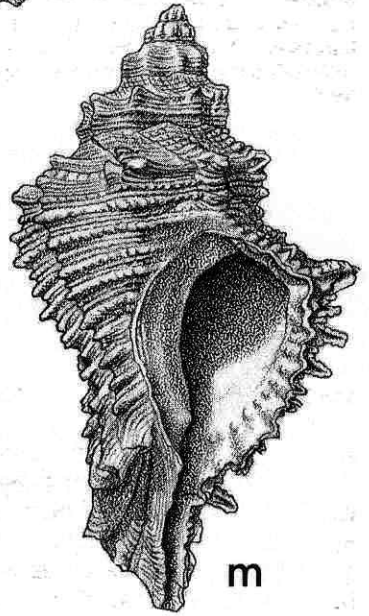
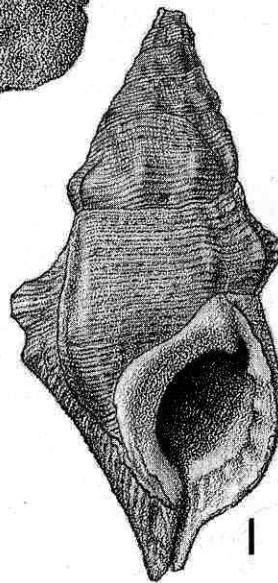
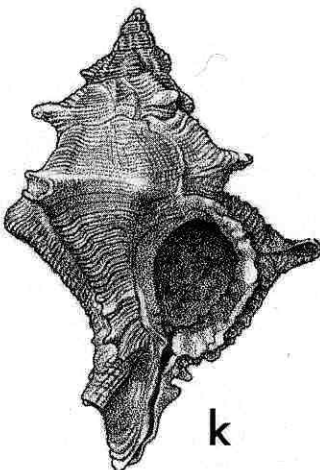
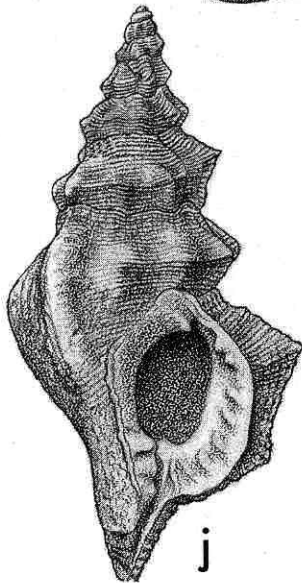
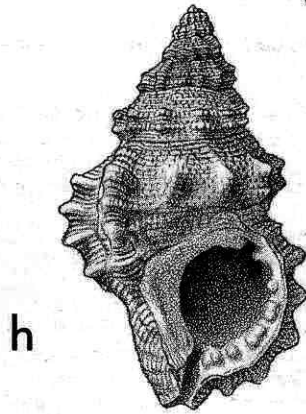
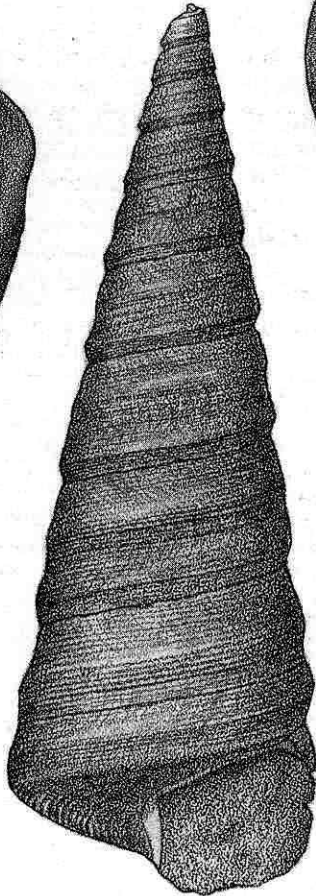
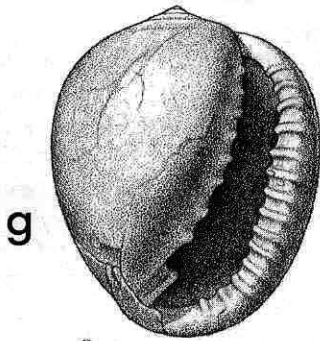
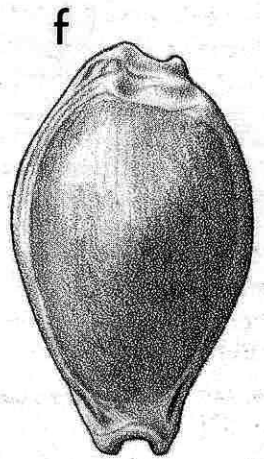
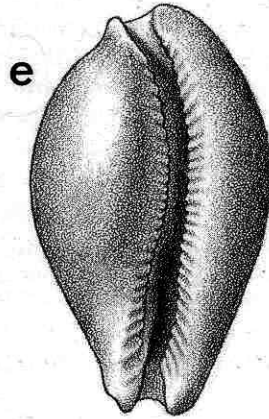
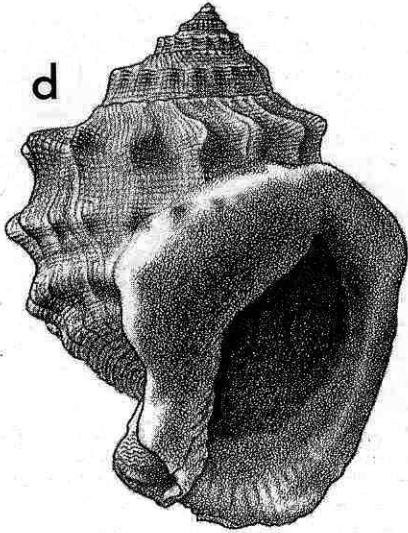
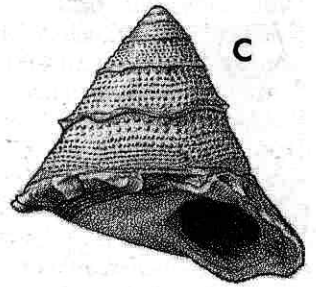
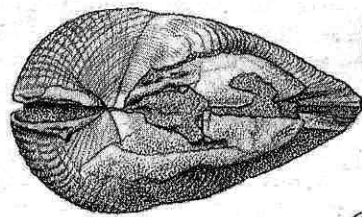
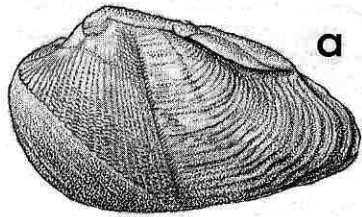
Large for subfamily (height c. 20 mm), thin-shelled, ovate. Protoconch obscured by callus; spire very low, last whorl capacious. No sculpture. Aperture large, anterior end rounded; inner lip with a strongly projecting ridge at anterior end and 8-10 prominent denticles or ridges above, the anterior 3 or 4 persisting across fossula. Outer lip with prominent varix, front face with 12 or 13 strong denticles or ridges.

?Otaian, Altonian-Clifdenian; Fouraye Siltstone, Clifden, Altonian (type); Otahu Formation, Long Beach Shellbed and Slip Point Siltstone, Clifden; Mount Harris Formation, Awamoa Creek. Not common at any locality. The specimen from Squadron Bay, Waiheke Island (Otaian) figured by Powell (1938a, pl. 39, fig. 7) as *W. fracta* probably belongs here.

The genus *Willungia* Powell, 1938, which is based on the Tasmanian Longfordian (Early Miocene) species *W. tasmanica* Powell, 1938, has a sporadic record in New Zealand from at least Kaiatan to Waiau. *W. fracta* (= *Marginella ventricosa* Hutton, 1873 (preoccupied), Duntroonian, Castle Hill Basin), has a less inflated last

Plate 24 Warm-water Early-Middle Miocene (Otaian-Lillburnian) Mollusca (2).

- a,b. *Parapholas aucklandica* Powell, x 2.
- c. *Guildfordia (Opella)* n.sp., x 1.
- d. *Echinophoria pollens* (Finlay), x 1.
- e,f. *Cypraea (Notadusta) clifdenensis* (Cernohorsky), x 1.5.
- g. *Willungia maoria* Powell, x 2.
- h. *Maoricolpus* (sensu lato) *ongleyi* Marwick, x 1.
- i. *Sassia (Sassia) tortirostris* (Tate), x 1.
- j. *Sassia (Sassia) zealta* (Laws), x 1.5.
- k. *Chicoreus (Siratus) komiticus* (Suter), x 1.5.
- l. *Sassia (Sassia) neozelanica* (Marshall and Murdoch), x 1.
- m. *Murexsul scobinus* Finlay, x 1.5.



whorl than *W. maoria* and has inner and outer lips diverging more strongly towards the anterior end. *W. erro* (Otaian, Pakaurangi Point) is much smaller (height c. 6 mm) than either *W. maoria* or *W. fracta* and also differs in having distinct sculpture of irregular ridges and granules.

Figured specimen (Pl. 24g): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 2.

Pl. 24 e,f. *Cypraea (Notadusta) clifdenensis* (Cernohorsky, 1971) [*Notoluponia (Notadusta) clifdenensis* Cernohorsky 1971a, p. 123] (Cypraeidae).

Size moderate for family (height 30-55 mm), elongate-ovate. Spire covered by callus, barely distinguishable on most shells except by a shallow groove around its base. No sculpture. Aperture narrow, not strongly curved, inner and outer lips almost parallel, denticulate over virtually entire length; inner lip flattened anteriorly, outer edge sharply margined, with a prominent oblique ridge at base and 18-20 denticles above. Outer lip margined anteriorly and posteriorly, bearing 24-29 denticles within.

Otaian-Kapitean; Long Beach Shellbed, Clifden, Altonian (type); Fouraye Siltstone, Calamity Point Sandstone and Slip Point Siltstone, Clifden; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour; Paratoetoe, Parengarenga Harbour; Ngakonui Stream, Pahaoa River, Wairarapa, Waiauian; Maruhou Point, Te Araroa, East Cape, Kapitean.

Cypraea clifdenensis is by far the most widespread and therefore best-known New Zealand fossil cypraeid, and is not uncommon in the Long Beach Shellbed at Clifden. *C. (Notadusta) trellissickensis* (Duntroonian, Castle Hill Basin) is much smaller (height about 18 mm), has a more strongly curved aperture, and has a non-projecting spire. (The shell from Pakaurangi Point so identified by Cernohorsky (1971a, fig. 16) is probably not conspecific). Only three other species of cypraeids have been described from New Zealand; two of these, *Cypraea ficoides* (?Whaingaroan, "Oamaru"—possibly Hutchinson's Quarry) and *Bernaya zoiloides* (Bortonian, Pahi, Northland) were based on very poorly preserved internal moulds and should never have been named. In particular, the type of *C. ficoides* is an incomplete steinkern partly imbedded in very hard limestone and is quite indeterminate, although this has not deterred some workers from applying the name to a variety of fossil cypraeids (e.g. the large steinkern from Parengarenga Harbour (Altonian) figured by Cernohorsky 1971a, fig. 15).

Cypraeids have a sporadic record from Late Paleocene (see *Cypraea (Zoila)* n.sp., Pl. 4j,k) to Recent in New Zealand. Their general rarity and low diversity suggest that New Zealand was never fully tropical.

Figured specimen (Pl. 24e, f): GS10344, D45/f8483, Calamity Point, Clifden, Altonian (NZGS) x 1.5.

Pl. 24 d. *Echinophoria pollens* (Finlay, 1926) [*Cassis muricata* Hector 1886, p.51 (not of Menke, 1828); *Euspinacassis pollens* Finlay 1926b, p.230; *Phalium (Echinophoria) hectori* Abbott 1968, p.112-114 (new name for *Cassis muricata* Hector, 1886, preoccupied); *Euspinacassis muricata*; *Galeodea muricata*; *Phalium (Echinophoria) muricata*; *Phalium (Echinophoria) pollens*]. Type species of *Euspinacassis* Finlay, 1926, synonymised with *Echinophoria* Sacco, 1896 by Rutsch (1931) (Cassidae: Phaliinae).

Size moderate for subfamily (height 45-70 mm), robust, spire low, about a third total height. Protoconch dome-shaped, of about 3.5 smooth, convex whorls. Teleoconch of 5-6 whorls, sharply angled at or above middle on spire; last whorl with 3 additional angulations, the lowest much weaker than the others; neck short, thick, twisted. Suture typically undulating around tubercles on uppermost basal angulation. Axial sculpture, apart from numerous fine growth lines, appearing on shoulder angle of third whorl as small nodules, quickly increasing in strength to become vertically compressed, subtriangular spines, radial in some shells, directed upwards to some degree in others; typically 7-9 on last whorl but up to 14 on some shells. Last whorl with tubercles or nodules on basal angulations, not as prominent as those on shoulder angle and typically not corresponding in number or position with the latter, those on each row becoming obsolete earlier than on the row above. Suture submargined by narrow band of short growth ridges. Spiral sculpture of very numerous fine threads and threadlets over whole surface, those on anterior part of base noticeably stronger than those above, all finely reticulated by growth lines. Aperture large, heavily armoured; columella almost straight, bearing rather irregular ridges extending within aperture and, in most shells, a much thicker raised fold near middle as well. Siphonal canal short, deeply notched, directed to left and away from aperture, broken on most specimens; fasciole very prominent, of squarish section, margined above by a sharp ridge. Inner lip with very heavy callus spreading laterally over fasciole and forming prominent hollows on either side. Outer lip with heavy varix, inner edge with weak lirae, in many shells obsolete on the posterior half. Most adult shells retaining 1 or 2 previous varices.

Otaian-Clifdenian; Calamity Point Sandstone, Calamity Point, Clifden, Altonian (type locality of *E. pollens*); Fouraye Siltstone, Long Beach Shellbed and Slip Point Siltstone, Clifden; Pakaurangi Point, Kaipara Harbour, Otaian or Altonian (type locality of *C. muricata*); Paratoetoe and Te Pokere, Parengarenga Harbour; Puketotara Peninsula, Kaipara Harbour; Awakino Gorge, southwest Auckland. Not particularly common at any locality, but conspicuous because of its size and sculpture.

Echinophoria pollens is the most strongly "armoured" and one of the most spectacular of New Zealand cassids. Powell (1928b, p. 634) distinguished *E. pollens* from *E. muricata* (= *E. hectori*) on supposed differences in the number and disposition of shoulder tubercles, but examination of much larger suites of specimens than were available to Finlay and Powell has shown that these differences are not constant, and that only one species can be recognised. The relationship of *E. pollens* to other nominal Early Miocene *Echinophoria* is less clear, however. *E. emilyae* (Altonian, Ardgowan Shellbed, Oamaru) is somewhat taller-spired than typical *E. pollens* and has less prominent shoulder tubercles and a thinner parietal callus, but in other respects they are very similar. *E. emilyae* may merely be a cool-water variant of *E. pollens* and is probably not worth recognising. Rather more distinctive is the cassid usually called *Echinophoria multinodosa*, which was described from Motutara, west Auckland (Altonian); this differs from *E. pollens* in its smaller size (height 35-50 mm), in having more numerous and smaller nodules (13-16 on shoulder of last whorl) and in having more numerous rows of nodules (5 or 6 on last whorl). In the Clifden section, shells of this type are present in the Lillburnian and Waiauian (i.e. succeeding *E. pollens*). Powell's name unfortunately cannot be used for the New Zealand shells; *Cassis multinodosa* Speyer, 1863 is an *Echinophoria* and although it is synonymised with *E. rondeleti* (Basterot, 1825) by Abbott (1968, p. 97) it must be regarded a secondary senior homonym of *E. multinodosa* (Powell). We do not propose a replacement name for Powell's species, however, as we consider it

conspecific with *E. toreuma*, also described from Motutara. Another synonym may be *E. oneroaensis* (Otaian, Waiheke Island).

Echinophoria (regarded as a subgenus of *Phalium* by some workers) is recorded fossil from Europe, North and South America, Indonesia and Japan, and in the modern fauna (from very shallow waters down to over 1000 m) of Japan, Australia, the Caribbean and East Africa (Abbott 1968). It ranges from at least Duntroonian (possibly Runangan) to Tongaporutuan in New Zealand. Figured specimen (Pl. 24d): GS10344, D45/f8483, Calamity Point, Clifden, Altonian (NZGS) x 1.

Pl. 24 i. *Sassia (Sassia) tortirostris* (Tate, 1888) [*Triton minimum* Tenison-Woods 1877, p. 107 (not *Triton minimus* Hutton, 1873); *T. tortirostris* Tate 1888, p. 123; *T. crassicostratus* Tate 1888, p. 125; *T. oligostirus* Tate 1888, p. 126; *Cymatium octoserratum* Finlay 1924b, p. 459; *Austrotriton morgani* Marwick 1931, p. 103 (not *Triton morgani* Ortmann, 1900); *Austrosassia tortirostris*; *Cymatiella oligostira*; *C. octoserrata*; *Austrosassia morgani*] (Ranellidae: Cymatiinae).

Moderately large for subgenus (height 35–60 mm), spire moderately tall, about half total height, weakly stepped. Protoconch like that of *S. maoria* (Pl.20o) and *S. parkinsonia* (Pl.48f) but slightly smaller. Teleoconch whorls well inflated, angled at about middle on spire. Low varices at each 0.67 whorl down whole teleoconch. Sculpture of 5 major but very low, wide spiral cords forming 5 nodules on each varix, the upper 3 (or, on a few specimens, 4) cords bearing low, vertically compressed nodules where they cross the low, widely spaced axial costae; remainder of surface closely crowded with fine, low, finely gemmate spiral threads and very fine growth lines. Aperture large, subcircular; siphonal canal short to moderately long, weakly deflected, no fasciole. Inner lip with a parietal tubercle and a few ridges on base of columella; outer lip weakly flared, with 6–9 low, rounded nodules inside.

Otaian ?; Altonian-Waiauian. Although not previously recorded as such from New Zealand, *S. tortirostris* is common in the Long Beach Shellbed, Clifden (Altonian), juvenile specimens from Target Gully, Oamaru (Altonian) were described by Finlay (1924b) under the name *Cymatium octoserratum*, and a severely abraded specimen from the “Tutamoe conglomerate” facies (Lillburnian) from the Gisborne district was named *Austrotriton morgani* by Marwick (1931) (but this is a secondary homonym of *Sassia morgani* (Ortmann, 1900), a Patagonian Oligocene member of the *S. zealta* group). Other specimens have been collected uncommonly from a wide range of Early to late Middle Miocene localities, in shallow-water, soft-bottom facies or shellbeds (Fouraye Siltstone (Altonian) to Nissen shellbeds (Waiauian), Clifden; Fallon’s shellbed, Oamaru (Altonian); several North Auckland localities (Otaian, Altonian)). The type of *T. tortirostris* is from Mornington, Victoria (Balcombian, Middle Miocene), *T. minimum* and *T. crassicostratus* were described from Table Cape, Tasmania (Longfordian, Early Miocene) and *T. oligostirus* from Adelaide Bore, South Australia (Aldingan, Late Eocene). All Australian specimens of *S. tortirostris* from Late Eocene localities are small (not more than 35 mm high) so *S. oligostira* might be recognisable as an ancestral Eocene form—we are not aware of specimens of *S. tortirostris* from the New Zealand Eocene, and a possible Duntroonian specimen is not well-enough preserved to be sure of the identification. Most New Zealand records are from Early to Middle Miocene rocks of North

Auckland or Clifden, Southland, and it is rare in Oamaru district; *S. tortirostris* was evidently a relatively warm-water species.

Sassia tortirostris is easily distinguished from members of the *S. maoria*–*S. parkinsonia* species group by its larger size, its more inflated whorls, its more prominent sculpture of three peripheral rows of low nodules, and its more prominent varices. Its overall appearance is therefore as much like *Cabestana* as *Sassia*, but the fine surface sculpture is more like that of the *S. maoria* group than the prominent, wide spiral cords of *Cabestana*. It differs from species of the *S. zealta* group by its shorter spire and lower nodules.

Figured specimen (Pl. 24i): GS10365, D45/f8598, Long Beach, Clifden, Altonian (NZGS) x 1.

Pl. 24 j. *Sassia (Sassia) zealta* (Laws, 1939) [*Austrosassia zealta* Laws 1939a, p. 490] (Ranellidae: Cymatiinae).

Very large for subgenus (height 53–106 mm), tall and moderately narrow, spire about half total height. Protoconch as in *S. maoria* (Pl.20o) but a little taller. Teleoconch whorls taller and narrower than in *S. tortirostris* or the *S. maoria*–*parkinsonia* group, strongly angled (near middle on spire) by a peripheral row of large, pointed, vertically compressed nodules, present also on varices. Varices high, narrow, at each 0.67 whorl down whole teleoconch. Sculpture of 3 major spiral cords on last whorl (extending onto varix and angulating whorl surface), very low, narrow and widely spaced; uppermost bearing peripheral spines, middle one bearing low nodules, and lowest one finely gemmate. Remainder of surface bearing many closely spaced, fine, finely gemmate spiral cords and growth ridges. Aperture oval, siphonal canal long (at least as long as aperture), narrow, almost straight. Inner lip callus thin but with raised rim, smooth except for a few basal ridges; outer lip with 7 low nodules within on small shells, but these become low and obscure on adults.

Otaian–Clifdenian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour, Otaian and Altonian (type); Coral Point, Kaipara (Otaian); Paratoetoe Formation, Paratoetoe and Te Pokere, Parengarenga Harbour; Mount Harris Formation, Bluecliffs, Otaio River; Clifden (Calamity Point Sandstone to basal Slip Point Siltstone).

Laws’ holotype of “*Austrosassia*” *zealta* proves to be a small shell (height 53 mm) of a large, sharply nodulose species, and although shells from the different localities listed above are all subtly different they seem best regarded as one species. Even larger, *Charonia*-like shells (up to 120–150 mm high) are not uncommon at some Oligocene localities (particularly Wharekuri Greensand, head of Lake Waitaki, Duntroonian); they have lower and more rounded nodules than Miocene shells. As noted in the appendix to the checklist, *S. minima* appears to apply to this Oligocene species. Small, elongate shells from McCulloch’s Bridge, South Canterbury (Kaiatan) and Waihao Downs (Bortonian) appear to represent an Eocene member of the group. The species group is also represented outside New Zealand by *S. abbotti* (T. Woods, 1876) (Early Miocene, northern Tasmania) and an unnamed Oligocene species in Victoria, Australia, by the Chilean Miocene *S. armata* (Hupé, 1854), and by the Patagonian Oligocene *S. morgani* (Ortmann, 1900) and *S. bicegoi* (Ihering, 1899).

Figured specimen (Pl. 24j): holotype, Pakaurangi Point, Kaipara Harbour, Altonian (TM1261, NZGS) x 1.5.

Pl. 24 l. *Sassia (Sassia) neozelanica* (Marshall and Murdoch, 1923) [*Austrotriton neozelanica* Marshall and Murdoch 1923a, p. 123; *Charonia neozelanica*;

Proxicharonia neozelanica; *Charonia clifdenensis* Finlay, 1924b, p. 460; *Proxicharonia clifdenensis*] (Ranellidae: Cymatiinae).

Moderately large for subgenus (height 45–78 mm), elongate-fusiform, spire conic, almost straight-sided, about half total height. Protoconch dome-shaped to low turbiniform, of about 2.5 smooth whorls. Teleoconch with very low, wide varices at each 0.67 whorl, merging into whorl surface behind but moderately elevated above surface in front, each intervariceal interval expanded and coarsely nodulose immediately after each varix but low and weakly sculptured before succeeding varix, producing a flattened area behind aperture at each growth stage and an irregularly coiled, alternately expanded and contracted shell resembling the much larger *Charonia*. Sculpture of a peripheral row of prominent, rounded nodules, from 3 very large ones to 7 relatively small ones in each intervariceal interval; whole surface crossed by low, narrow, widely spaced, weakly gemmate spiral lirae and faint growth ridges. Aperture oval to subcircular; inner lip callus thick, smooth except for a large parietal ridge and 3–8 low, indistinct ridges at base of columella. Outer lip lightly flared over terminal varix, with 7–8 low nodules within.

Altonian-Lillburnian; Target Gully Shellbed, Oamaru, Altonian (type locality of *A. neozelanica*); Awamoa Creek; Calamity Point Sandstone, Clifden, Altonian (type locality of *C. clifdenensis*) and other Altonian-Lillburnian horizons at Clifden.

The accumulation by New Zealand Geological Survey of reasonably large suites of specimens of the *Sassia neozelanica*-*S. palmeri* group (particularly from Long Beach Shellbed, Clifden, also other horizons at Clifden; four from Target Gully Shellbed and Awamoa Creek; three small specimens from Clifdenian-Tongaporutuan of eastern North Island; the National Museum Opoitian specimen from Oweka Creek reported by Beu (1976a, p. 305, fig. 10)); and the acquisition of a large number of Recent specimens by the National Museum of N.Z. from Northland, the Kermadec Ridge and the Norfolk Ridge (Beu 1978b, p. 32) has demonstrated that apart from *S. arthritica* and the undescribed species mentioned below, two members of this species group seem to be recognisable in New Zealand: *S. neozelanica* (Altonian-Lillburnian ?) and *S. palmeri* (Tongaporutuan-Recent). The Long Beach sample (14 specimens, probably also the figured specimen) is very variable in coiling, in number and size of peripheral nodules, and in coarseness of spiral lirae, and some modern shells and Awamoa Creek shells are closely comparable in these respects. However, most Tongaporutuan to Recent specimens have more prominent varices than older specimens, and *S. palmeri* is probably a separate species. A few specimens from Awamoa Creek and Clifden and some modern juvenile specimens retain the protoconch, which is almost exactly like that of *S. maoria*, but slightly shorter. There are no significant teleoconch characters distinguishing *S. neozelanica* from other species of *S. (Sassia)*, and as the radula is also very similar to that of *S. parkinsonia* (Cernohorsky 1970b), *S. neozelanica* is regarded as a member of a local species group of *S. (Sassia)* with unusually elongate shells. An unnamed small, coarsely gemmate species of this group is known from a few poor specimens from McCulloch's Bridge, South Canterbury (Kaiatan). The only other known members of the group are an unnamed species from Parengarenga Harbour (Altonian), and *S. arthritica* (type species of *Proxicharonia* Powell, 1938) which is known by two specimens from Waiheke Island, Auckland (Otaian) and one from Trig

Z, Otiake (Waitakian)—these differ from *S. neozelanica* mainly by their much finer spiral threads.

Figured specimen (Pl. 24l): Clifden, J.A. Thomson Collection (almost certainly from Long Beach Shellbed), Altonian (M21617, National Museum of NZ) x 1.

Pl. 24 k. *Chicoreus (Siratus) komiticus* (Suter, 1917) [*Murex zelandicus* var. *komiticus* Suter 1917, p.37; *Chicoreus* (?) *komiticus*] (Muricidae: Muricinae).

Size moderate for subgenus (height 35–50 mm), broadly biconic, spire 0.4 total height. Protoconch conical, of about 4 whorls, last whorl or so with a narrow keel just above suture, otherwise smooth. Teleoconch of 5–6 whorls, convex at first, then becoming bluntly shouldered at third to half whorl height; sutural ramp broad, almost flat; last whorl contracted to moderately long neck. Varices prominent, rounded, at slightly less than a third of a whorl apart, reaching to top of siphonal canal, bearing a strong, hollow peripheral spine open in front (typically almost horizontal, but directed upwards in holotype). Other axial sculpture on early whorls of rounded costae reaching from suture to suture, not clearly distinguishable from varices at first, then with 1–3 costae between each pair of varices, last 2 whorls usually with a single prominent rounded peripheral tubercle about halfway between varices, some shells with a much weaker additional costa. Spiral sculpture commencing as 4 or 5 moderately strong cords, adult whorls covered with numerous fine cords and threads, rendered finely scabrous by lamellar growth ridges; stronger spirals forming small, open spines where they cross varices on holotype, but scarcely altered on most topotypes. Neck of last whorl with 2 or 3 somewhat stronger cords that form distinct small, open spines at edge of siphonal canal. Aperture ovate; siphonal canal moderately long, almost closed, deflected to left, slightly curved. Inner lip moderately callused with 1 or 2 weak ridges near posterior end and 2 very weak denticles just above siphonal canal. Outer lip projecting slightly in front of terminal varix, slightly concave from suture to periphery, convex below, edge crenulated by internal lirae.

Otaian-Altonian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type); Paratoetoe Formation, Paratoetoe and Te Pokere, Parengarenga Harbour. (Uncommon at all localities).

The only other New Zealand species of *Chicoreus* named to date are *C. (Siratus) syngenes* and *C. (Siratus) lawsi*. The former species was described from Slip Point, Clifden (Clifdenian) where it seems to be very rare, but specimens of *Chicoreus* from Calamity Point (Altonian) are probably conspecific. These closely resemble *C. komiticus* in overall appearance, but have shorter peripheral spines and have a single spiral cord on the neck that is much stronger than the two or three present in *C. komiticus*. Calamity Point shells are up to at least 65 mm in height, much larger than any recorded *C. komiticus*. *C. lawsi* (Otaian ?, Pakaurangi Point), which was originally described as a *Murex*, differs from *C. komiticus* and *C. syngenes* in having varices aligned across succeeding whorls, in having two prominent costae between each pair of varices, and in having coarser spiral sculpture. *C. komiticus* and *C. syngenes* superficially resemble some species of *Murexsul* but differ in having a clear distinction between varices and intervariceal axial sculpture, and in having the outer lip projecting in front of the terminal varix, particularly below the periphery. Living species of *C. (Siratus)* occur in subtropical or tropical regions.

Figured specimen (Pl. 24k): GS1161, Q8/f9687, Pakaurangi Point, Kaipara Harbour (probably from Pakaurangi Member, Pakaurangi Formation), Altonian (NZGS) x 1.5.

Pl. 24 m. *Murexsul scobinus* Finlay, 1930b [p. 74] (Muricidae: Muricinae).

Size moderate for genus (height 30-60 mm), broadly fusiform, spire 0.35-0.4 total height. Protoconch imperfectly known, conical, of about 3 whorls. Teleoconch whorls 5-7, prominently shouldered at 0.5-0.6 whorl height on spire; last whorl elongate, broadly excavated with moderately long neck. Axial sculpture of prominent broadly triangular costae with broad interspaces, reaching from suture to suture on early whorls, almost obsolete on sutural ramp on later whorls, extending across base and onto neck of last whorl; penultimate whorl with 8-10 costae. Spiral sculpture of prominent narrow cords with interstitial threads, less prominent on ramp than below, neck with 2 cords noticeably stronger than those above. Hollow triangular spines formed at intersections of stronger spirals with costae, the most prominent on shoulder angle; and fine scales produced where spirals are crossed by growth lamellae, giving the shell a distinctly file-like appearance. Aperture ovate; siphonal canal long, slightly curved, fasciole prominent with a deep pseudumbilicus between it and inner lip. Inner lip moderately callused, smooth except for low ridge at base of columella; outer lip finely crenulated along margin, finely denticulate within.

Altonian; Calamity Point Sandstone, Calamity Point, Clifden (type); Fouraye Siltstone, Clifden, moderately common. Also recorded by Finlay (1930b, p. 74) from Long Beach Shellbed, Clifden.

Murexsul scobinus is distinguished from other New Zealand species of *Murexsul* by its relatively slender shape and its densely scaly sculpture. *M. proavitus* (Altonian, Target Gully and Ardgowan Shellbeds, Oamaru) has similar sculpture, but is less elongate and has evenly convex or only weakly shouldered teleoconch whorls.

Figured specimen (Pl. 24m): GS11182, D45/f8819, Fouraye Siltstone, Clifden, Altonian (NZGS) x 1.5.

Pl. 25 o. *Rugotyphis vellai* (Maxwell, 1971) [*Typhis* (*Rugotyphis*) *vellai* Maxwell 1971, p. 779] (Muricidae: Typhinae).

Small for genus (height 20-24 mm), broadly fusiform, spire 0.4 total height. Protoconch subcylindrical, of 1.25 smooth whorls. Teleoconch of 7 whorls, angled near middle on spire; each whorl with 4 prosocline varices continuous across whorls. Varices low and thin on sutural ramp, triangular and sharp-crested below, each with up to 9 trough-like crenulations on front (adapertural) face, forming weak spines on crest. Intervariceal tubes fairly prominent, situated midway between varices on early whorls, closer to succeeding than to preceding varix on later whorls, directed backwards at about 40° and upwards at about 30°. Weak spiral threads between periphery and base of aperture on last whorl. Aperture small, ovate, peristome continuous; siphonal canal triangular, closed.

Altonian, Paratoetoe Formation, Paratoetoe, north shore Parengarenga Harbour, Northland (type) and other localities nearby, moderately common.

Rugotyphis francescae (Altonian, Clifden) (type species of *Rugotyphis* Vella, 1961) and *R. secundus* (Altonian-Lillburnian, Clifden) are larger than *R. vellai*, are more broadly biconic in shape, lack spiral sculpture, have almost obsolete variceal spines, and have almost radial intervariceal tubes. *Rugotyphis* differs from *Typhis* in having transverse ridges or crenulations on the adapertural face of the varices, and in having the variceal spines only feebly developed. It seems to have been a warm-water genus and is recorded in New Zealand only from Early and Middle Miocene faunules from Northland and Southland. It is also recorded from the Miocene and Pliocene of Florida (Gertman 1969, p. 152-153) and Panama (Vokes 1983, p. 126, 128).

Figured specimen (Pl. 25o): holotype, GS9723, N2/f7594, Paratoetoe, north shore, Parengarenga Harbour, Altonian (TM4934, NZGS) x 2.

Pl. 25 r. *Coralliophila turneri* Laws, 1941b [p.150] (Muricidae: Coralliophilinae).

Rather small for subfamily (height 10-16 mm), biconic to broadly fusiform, spire 0.4 total height. Protoconch conical, of about 3 convex, rather irregular whorls, apparently smooth but probably worn in available specimens. Teleoconch of 4-5 whorls, weakly shouldered at variable position, from just above suture to near mid-whorl on spire; last whorl weakly excavated. Axial sculpture of rounded, prosocline costae with broad, concave interspaces reaching from suture to suture on spire, and well down base on last whorl; 9-10 costae on penultimate whorl. Spiral sculpture of narrow cords of variable prominence and spacing, which are scaly or nodulose where they are crossed by growth ridges; 18-21 on last whorl. Aperture elongate-ovate; siphonal canal short, weakly differentiated, notched; fasciole narrow, raised, with a prominent pseudumbilicus between it and inner lip. Inner lip callus moderately thick, flush in some shells, raised in others; outer lip thin, edge finely crenulate.

Otaian?, Altonian; Pakaurangi Formation, Pakaurangi Point (type) (rare); Paratoetoe Formation, Paramateha, north shore Parengarenga Harbour.

Coralliophila turneri is possibly the same as *C. kaiparaensis*, also from Pakaurangi Point; the alleged differences between these species cited by Laws (1941b, p. 150) could easily result from intraspecific variation. However, the rather poorly preserved type of *C. kaiparaensis* has coarser spiral cords on the anterior part of the last whorl than on any of the specimens examined in writing the above description. *C. lividorupis* (Otaian, Bluecliffs, Otaio River) and *C. sertata* (Pl. 48n) are much larger than *C. turneri* and have denser spiral sculpture. The assignment to *Coralliophila* is discussed under *C. sertata*.

Figured specimen (Pl. 25r): GS9869, N2/f7608, Paramatetaha, north shore, Parengarenga Harbour, Northland, Altonian (NZGS) x 3.

Pl. 25 m. *Coluzea kiosk* Finlay, 1930e [p. 270] (Turbinellidae: Columbariinae).

Moderately large for genus (height 47-115 mm), very long and slender, fusiform, spire pagodiform, 0.35 total height. Protoconch reportedly like that of *C. dentata* (Pl. 21h) but more elongate. Teleoconch of 8 to about 10 whorls, sharply and prominently keeled slightly below middle on spire, keel becoming progressively more and more projecting and compressed during growth so that on adult whorls it forms a prominent, thin carina. Last whorl with a weak peribasal angulation, contracted quickly below to a very long, slender, almost straight neck. Axial sculpture of weak, short costae on early whorls, becoming confined to peripheral serrations or undulations on later whorls; 15-17 on adult whorls. Spiral sculpture on sutural ramp of a weak thread margining upper suture and 3 narrow, distant cords below; sides with a narrow cord margining lower suture and a stronger one about halfway between it and periphery. Supramargining cord emerging on last whorl to mark peribasal angulation, accompanied by 2 somewhat narrower ones on base, and about 12 thin, finely spinose or scaly cords on neck, becoming indistinct anteriorly. Other spiral sculpture of fine striae over most of surface except neck. Aperture triangular, constricted anteriorly; siphonal canal very long, almost straight, almost completely closed. Inner lip callus rather thin, restricted; outer lip thin, apparently smooth within.

Altonian-Clifdenian; Calamity Point Sandstone, Calamity Point, Clifden, Southland, Altonian (type); Fouraye Siltstone, Long Beach Shellbed and Slip Point Siltstone, Clifden. Rare at all localities.

As Finlay (1930b, p. 270) stated, "this cannot be confounded with any other species, being the most bizarre of the group". In particular, it differs from all other species of *Coluzea* in its very slender shape, its strongly projecting peripheral carina, and in having spinose spirals on the neck. A specimen from Postal Creek, Oparara

district, southwest Nelson (Clifdenian) in the NZGS collection may represent a distinct, related species; it differs in having the early teleoconch whorls descending more rapidly (i.e. having greater translation along the coiling axis), and in having five spiral cords (in addition to a submarginating thread) on the sutural ramp.

Figured specimen (Pl. 25m): GS11212, D45/f183, middle Slip Point Siltstone, Clifden, Clifdenian (NZGS) x 1.

Pl. 25 a. *Austrofusus (Austrofusus) magnificus* Finlay, 1926 [A. (*Nassicola*) *magnificus* Finlay 1926b, p.236-237] (Buccinidae).

Moderately large to large for genus (height 45-60 mm), broadly bucciniform, spire 0.4-0.6 total height. Protoconch as in *A. spiniferus* (Pl. 21 k). Teleoconch of 7-8 whorls, first 2 or 3 convex, later whorls sharply shouldered near middle on spire; sutural ramp broad, slightly concave, whorl sides sloping inwards; last whorl with peribasal keel almost as prominent as shoulder angle, both keels becoming less prominent on later half of last whorl. Axial sculpture on early whorls of narrow, rounded costae reaching from lower suture to about 0.67 whorl height; later whorls with sharp, vertically compressed tubercles on keels—those on shoulder keel more prominent than others—joined by low, rounded costae. Spines (particularly on lower keel) becoming less prominent on later part of last whorl of some shells, and connecting costae becoming obsolete; 8-10 spines or costae per whorl. Spiral sculpture variable, of low, narrow, rounded cords and fine threads, considerably coarser on base than elsewhere. Aperture ovate, columella slightly concave above, strongly twisted to left below, forming a short, deeply notched siphonal canal; fasciole very prominent, margined above by a sharp ridge. Inner lip moderately to thickly callused; outer lip thin, finely lirate within.

Altonian-Lillburnian; Slip Point Siltstone, Slip Point, Clifden, Southland, Clifdenian (type) and from most units from Fouraye Siltstone to Lill Sand in the Clifden section, moderately common; ? Bell Bird Stream, Karamaea district. *Austrofusus magnificus* is probably most closely related to *A. spiniferus* (Pl. 21k) but has fewer axial costae, and has more sharply compressed spines on the spiral keels.

Figured specimen (Pl. 25a): GS11185, D45/f8822, Slip Point, Clifden, Clifdenian (NZGS) x 1.

The "Neocola bioseries"

Pl. 25 b. *Austrofusus (Neocola) alpha* Finlay, 1926b [p. 233-234] (Buccinidae).

Small for genus (height 24-34 mm), elongate-ovate, spire 0.45-0.5 total height. Protoconch conical, of about 3.5 whorls, last half-whorl or so with narrow opisthocyrt costellae, remainder smooth. Teleoconch of 5.5-6 whorls, first whorl convex, later whorls prominently shouldered at, or somewhat below, middle on spire; sutural ramp steep, concave, riding up high onto previous whorl. Last whorl with weak basal subangulation, contracted below to short, twisted neck. Axial sculpture commencing as low, rounded costae reaching from suture to suture but soon becoming obsolete on sutural ramp, and on last whorl of many shells restricted to nodules on shoulder angulation and much weaker, irregular nodules or folds on basal subangulation, typically without obvious connecting costae; 10-13 nodules or costae on last whorl. Spiral sculpture of numerous narrow, rounded cords with interstitial threads, those on shoulder angle and on basal subangulation typically slightly but noticeably stronger than others and slightly thickened where they cross axial nodules or costae. All spirals crossed by numerous, fine growth lines. Aperture ovate, constricted posteriorly, columella almost straight above, strongly twisted to left below; siphonal canal short, deeply notched; fasciole very prominent, bounded above by a sharp, continuous ridge. Inner lip rather thickly callused; outer lip thin, with a shallow notch near anterior end, margin finely crenulate, lirate within, 2-4 lirae at posterior end typically stronger than others.

Early Altonian; Fouraye Siltstone, Clifden (type); Otahu Formation, Clifden; Mount Brown Formation, Tommy's

Creek, Upper Waipara River; Karamaea district; upper Takaka valley.

Figured specimen (Pl. 25b): GS11182, D45/f8819, Fouraye Siltstone, Clifden, Altonian (NZGS) x 1.5.

Pl. 25 c. *Austrofusus (Neocola) beta* Finlay, 1926b [p. 234]. Type species of *Neocola* Finlay, 1926 (Buccinidae).

Very similar to *A. (Neocola) alpha*, but tending to differ in the following ways—(1) in having a more prominent peripheral angulation, particularly on the last whorl, thereby giving the shell an angulate rather than a rounded outline, (2) in having more prominent nodules on the basal subangulation, and (3) in having 3 basal spiral cords noticeably stronger than other spiral sculpture.

Altonian; Calamity Point Sandstone, Clifden (type); Long Beach Shellbed, Clifden; Weka Pass; New Chum Creek, Oparara, Karamaea district.

Figured specimen (Pl. 25c): GS10344, D45/f8483, Calamity Point, Clifden, Altonian (NZGS) x 1.5.

Pl. 25 d. *Austrofusus (Neocola) gamma* Finlay, 1926b [p. 235] (Buccinidae).

Similar to *A. (Neocola) beta*—particularly to the more "advanced" forms (e.g. from Long Beach Shellbed, Clifden)—but differing—(1) in having a narrower and much sharper peripheral keel and a more pronounced basal angulation; (2) in having vertically compressed, sharp tubercles, rather than rounded nodules, on the peripheral keel. The nodules on the basal angulation are no stronger than on *A. beta*, but are accentuated by the basal spiral cords, which are thickened and slightly tubercular where they cross them; and (3) in having the 3 basal spiral cords considerably more prominent, partly because the spiral threads between the peripheral keel and basal angulation are more subdued than in *A. beta* in most specimens.

Clifdenian-Lillburnian, Slip Point, Clifden, Clifdenian (type); Slip Point Siltstone and Lill Sand, Clifden; Oparara River, Karamaea district.

Figured specimen (Pl. 25d): GS11185, D45/f8822, Slip Point, Clifden, Clifdenian (NZGS) x 1.5.

Finlay (1926b, p. 234) regarded these three species of *Austrofusus* as members of a simple evolutionary lineage leading from *A. alpha* through *A. beta* to *A. gamma*, a view that seems to be well supported by subsequent study of large suites of specimens collected from throughout most of the Clifden section. However, these collections show that, rather than a simple succession of well defined species with equally well defined stratigraphic ranges, each population passes gradually into the succeeding one, so that the boundaries between the species are blurred, i.e. the *A. alpha-beta-gamma* lineage appears to be a good example of "phyletic gradualism" (Eldredge and Gould 1972) or gradual anagenetic speciation. The main morphological changes are—(1) an increase in the prominence of the peripheral angulation (more strongly projecting in *A. beta* than in *A. alpha*, much sharper in *A. gamma* than in *A. beta*) and a similar change in the prominence of the basal angulation (rounded in *A. alpha*, slightly more marked in *A. beta*, sharply angled in *A. gamma*); (2) an increase in the strength of the basal nodules from *A. alpha* to *A. beta*. (The basal nodules on *A. gamma* are on the whole no stronger than on *A. beta*, but are more prominent because of the development of prickly sculpture where they are crossed by the basal cords); (3) a change from the rounded peripheral nodules of *A. alpha* and *A. beta* to the sharp, prickly tubercles of *A. gamma*, related no doubt to the increase in the sharpness of the peripheral keel; and (4) an increase in

the relative strength of the basal cords from *A. alpha* to *A. gamma*. These changes are statistical in nature and involve an increase in the proportion of individuals with "advanced" (or derived) characters between successive populations, so that in adequate samples it is possible to find specimens that closely match those in younger and in older populations. This means that it is usually difficult confidently to assign individual shells to one or other of the species recognised in this lineage.

Specimens of *A. (Neocola)* are uncommon in the units above the Slip Point Siltstone at Clifden, but those from the Lill Sand (Lillburnian) closely resemble typical *A. gamma* in shape and sculpture, although some are much larger than any Slip Point shell. However, the very few specimens collected from the basal Nissen Shellbed (Waiauan) differ from typical Slip Point shells in having a much more rounded peripheral keel and less strongly differentiated basal spirals, and therefore more closely resemble *A. beta*. The significance of this is unclear, but it may indicate that *A. beta* persisted outside the Clifden area during the Clifdenian and Lillburnian, only to return during the Waiauan, possibly in response to warming or cooling conditions. It is unfortunate that no other sections have been discovered where all three of the Clifden species occur in sequence, so at present there are no direct, independent checks on their inferred stratigraphic and evolutionary relationships. Nonetheless, these relationships are not contradicted by the scattered records of the nominal Clifden species from other parts of New Zealand. Thus, *A. alpha* is present in the Altonian of Tommy's Creek, Upper Waipara River, North Canterbury; upper Takaka River, northwest Nelson, and lower Tengawai River, South Canterbury (although otherwise similar specimens from Target Gully and Ardgowan Shellbeds, Oamaru (Altonian) differ in having distinct axial costae on the last whorl). Altonian specimens from Weka Creek, North Canterbury, however, are more like typical *A. beta* in sculptural development, suggesting that they are from a younger horizon than those from Tommy's Creek, a conclusion consistent with local stratigraphy but requiring confirmation from microfossil evidence. Good collections of *Austrofusus* have been made from several horizons of Altonian and Clifdenian age in the Oparara River and its tributaries, and from Little Wanganui River, West Nelson. Specimens from late Altonian horizons resemble those from the Long Beach Shellbed and the lower part of the Slip Point Siltstone (i.e. late Altonian-early Clifdenian), whereas Clifdenian specimens are very similar to *Neocola* from the middle part of the Slip Point Siltstone. Although we have seen no large or well preserved lots of *A. (Neocola)* from Tongaporutuan rocks, the available specimens from Hurupi Stream and nearby localities in Palliser Bay (type locality of *A. (Neocola) marwicki*) show no marked differences from Clifden specimens of *A. gamma*.

The *Austrofusus (Neocola)* form occurring in great profusion in Altonian siltstone at Parengarenga Harbour, however, does not fit comfortably into the above scheme. It resembles *A. beta* and *A. gamma* in having strongly differentiated basal spiral cords, but differs from both of these species in lacking definite nodules on the basal subangulation. The absence of basal nodules also

differentiates this form from *A. alpha*, some specimens of which do have such nodules. In addition, the Parengarenga species differs from all three Clifden species in its larger size (height often greater than 35 mm), its more elongate shape, and its longer siphonal canal, and in having a fasciole that is more like the one on *A. flexuosus* (see below). It evidently belongs in a different group from the Clifden species.

Finlay (1926b, p. 233) proposed *Neocola* for species of *Austrofusus* that differ from typical members of the genus in being smaller and more solid, and in having a smaller aperture, a less concave columella, and a more prominent fasciole. The earliest known species appears to be *A. zitteli* (Whaingaroan, The Cliffs, Nelson)—material from this locality is poorly preserved but seems to have the diagnostic characters of the subgenus. The youngest record of the subgenus is the Opoitian *A. ngatuturaensis* (Pl. 37l); we are not aware of Kapitean records. Where present, Miocene species of *A. (Neocola)* often occur in large numbers and at most localities greatly outnumber specimens of other species of *Austrofusus*.

Pl. 25 g. *Austrofusus (Neocola) flexuosus* (Marshall, 1918) [*Siphonalia flexuosa* Marshall 1918, p. 264-265] (Buccinidae).

Similar to *A. (Neocola) alpha* but somewhat taller (height 25-37 mm) and more slender. Protoconch like that of *A. alpha*; teleoconch of 5-6 whorls, first whorl convex, then developing a shoulder at about mid-height, shoulder sharply angled from about 3rd to 5th whorls then becoming rounded and sutural ramp becoming steeper and concave; last whorl with only a weak basal subangulation. Axial sculpture commencing as narrow costae reaching from suture to suture but soon becoming obsolete on ramp, later becoming broader and lower as shoulder becomes more rounded, then becoming obsolete for 0.2-0.5 of a whorl only to reappear as low, rather weak nodules on shoulder. No trace of basal nodules. Spiral sculpture of numerous narrow, low cords with interstitial threads and, on last whorl, threadlets as well. Basal cords clearly differentiated on some shells, barely distinguishable from other cords on other shells. Aperture similar to that of *A. alpha* except that the internal lirations on the outer lip are more prominent, there is a much more distinct sinus ("stromboid notch") near the anterior end of the outer lip, and the siphonal canal is longer. Fasciole margined by a thin, continuous ridge in shells less than about 30 mm in height, ridge discontinuous in larger shells as anterior ends of previous canals become more prominent.

Otaian-(early) Altonian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type), common in Pakaurangi Member; mouth of Waioha Stream, north shore Parengarenga Harbour (uncommon).

Austrofusus (Neocola) flexuosus is easily distinguished from other species of the subgenus by the peculiar behaviour of its axial sculpture, i.e. it becomes obsolete, only to reappear after a short distance. It is probably most closely related to the unnamed Altonian Parengarenga species (see above), sharing with it its elongate shape, its relatively large size, its long siphonal canal, and its prominent "stromboid notch", but differing in its more subdued axial sculpture and less strongly differentiated basal spiral cords. The poorly known *A. (Neocola) oneroaensis* (Otaian, Waiheke Island) seems to have stronger axial sculpture and a more sharply twisted columella than *A. flexuosus*.

Figured specimen (Pl.25g): GS3245, Q8/f9687, Pakaurangi Point, Kaipara Harbour, Otaian (NZGS) x 1.5.

Pl. 25 e. *Paracomina lignaria* (Powell and Bartrum,

1929) [*Cominella* (*Paracomina*) *lignaria* Powell and Bartrum 1929, p. 433-434]. Type species of *Paracomina* Powell and Bartrum, 1929 (Buccinidae).

Moderate-sized for family (height 40-52 mm), elongate-ovate, spire about half total height. Protoconch reportedly conical, of about 3 smooth whorls. Teleoconch of about 6 whorls, first 3 convex, later whorls with a very prominent, rounded subsutural fold, bordered below by a narrow sulcus of variable depth; last whorl contracted gradually, profile only slightly interrupted by fasciole. Axial sculpture on early whorls of distant costae reaching from suture to suture, but becoming very weak on subsutural collar and strongest just below sulcus, typically reduced to rounded nodules with little or no axial extension on last whorl; 10 or 11 on penultimate whorl. Spiral sculpture absent from most shells, but present as very weak, low ridges below sulcus on others. Surface covered with numerous, narrow, sinuous, anastomosing lines imbedded in the outer shell layer and differentiated from it by their darker colour, weathering to form a system of fine ridges resembling wood-grain (possibly calcitic rods in the aragonitic shell structure). Aperture pyriform, constricted posteriorly to form a short channel; columella slightly concave above, twisted below to form a short, deeply and obliquely notched siphonal canal; fasciole prominent, bordered above by a narrow ridge but scarcely projecting. Inner lip moderately callused at posterior end, thinly below; outer lip thin.

Otaian, Oneroa, Waiheke Island (type).

Paracomina lignaria is readily distinguished from other species of *Paracomina* by its unusual wood-like colour pattern, apparently formed by calcitic shell material in the outer shell layer. *Paracomina* was proposed for buccinids closely resembling species of *Cominella* in most shell characters, but differing in having a conical protoconch, and in the presence of a very prominent subsutural fold or collar. The genus has a recorded range of Waitakian to Altonian; most occurrences are in very shallow-water assemblages, and it apparently occupied the same ecological niche as *Cominella* does now.

Figured specimen (Pl. 25e): Oneroa, Waiheke Island, Auckland, Otaian (NZGS, ex Fleming Collection) x 1.

Pl. 25 h. *Penion bartrumi* (Laws, 1941) [*Verconella bartrumi* Laws 1941b, p. 147] (Buccinidae).

Small for genus (height c. 60 mm), broadly fusiform, spire 0.4 total height. Protoconch relatively small, mamillate, of 2 smooth, strongly convex whorls. Teleoconch of 8 whorls, convex at first, then becoming sharply shouldered, angulation near middle of whorl at first, then moving much lower. Last whorl with basal subangulation, broadly excavated below, with long, slightly recurved neck. Axial sculpture of prominent, rounded costae reaching from suture to suture on early whorls, later becoming obsolete on all except lower part of sutural ramp and slightly tubercular on periphery, dying out on base of last whorl; 7 costae per whorl. Spiral sculpture of fine threads over whorl surface, with a stronger thread on periphery and several of similar strength on base and neck. Aperture ovate; columella strongly concave above, twisted to left below; siphonal canal moderately long, slightly curved, shallowly notched.

Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (rare).

Penion bartrumi is distinguished from most New Zealand fossil *Penion* species by its small size and small protoconch. *P. parans* (Altonian, Clifden) is similar but has a considerably larger protoconch, more prominently angled teleoconch whorls, the shoulder at a higher position on adult whorls, and somewhat stronger spiral sculpture. These species probably represent a warmer-water group of *Penion* than the large, contemporaneous species from North Otago and Canterbury (e.g. *P. marwicki*, Pl. 20m), and the small protoconch is shared with Australian fossil and living *Penion* species (Ponder 1973).

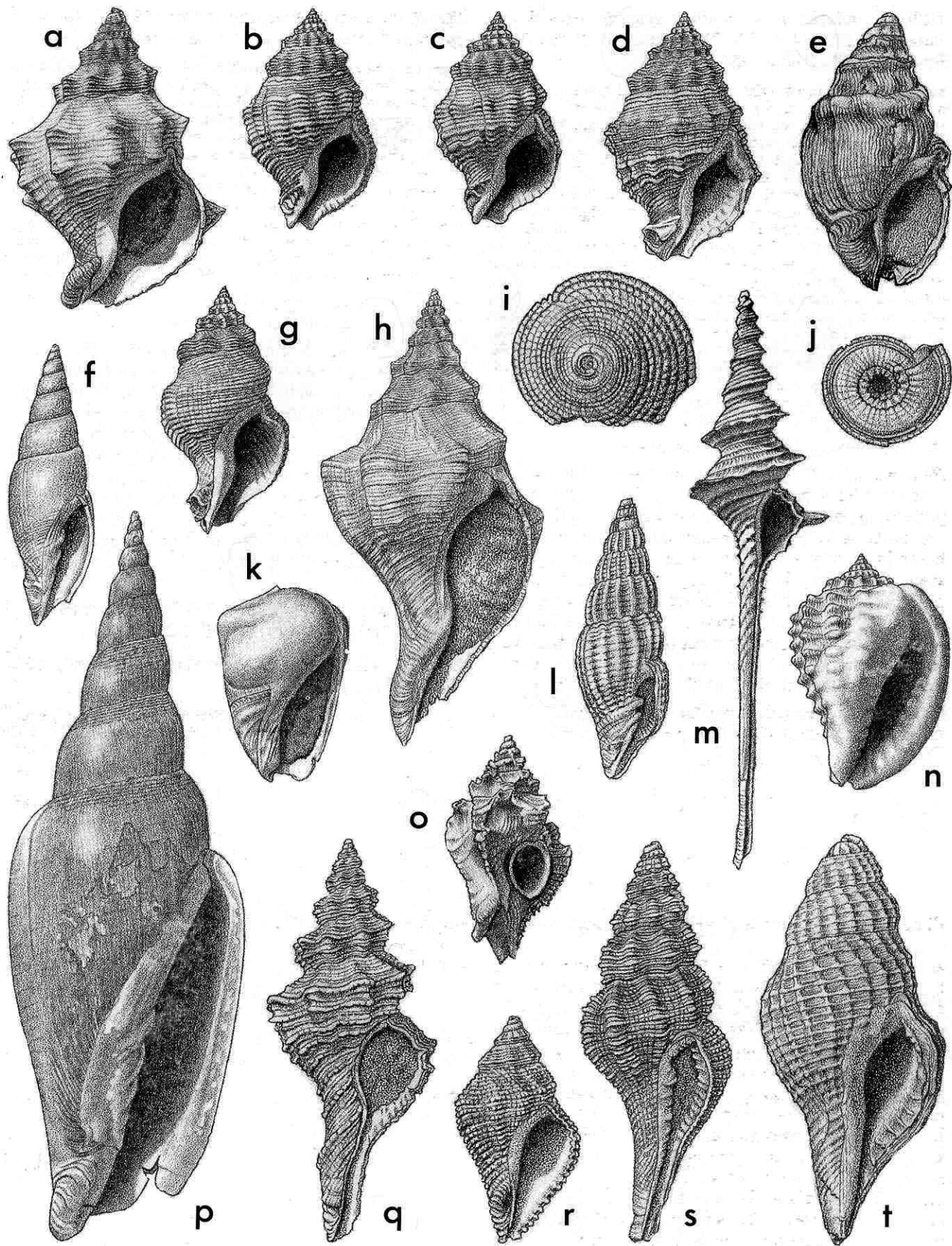
Figured specimen (Pl. 25h): holotype, Pakaurangi Point, Kaipara Harbour, Altonian (TM1288, NZGS) x 1.5.

Pl. 25 t. *Falsiculus* (sensu lato) *gemmata* Powell, 1935b [p. 336] (Fascioliariidae).

Size moderate for genus (height 45-60 mm), fusiform, spire 0.4 total height. Protoconch not known, but probably conical, of about 3 whorls

Plate 25 Warm-water Early-Middle Miocene (Otaian-Lillburnian) Mollusca (3).

- a. *Austrofuscus* (*Austrofuscus*) *magnificus* Finlay, x 1.
- b. *Austrofuscus* (*Neocola*) *alpha* Finlay, x 1.5.
- c. *Austrofuscus* (*Neocola*) *beta* Finlay, x 1.5.
- d. *Austrofuscus* (*Neocola*) *gamma* Finlay, x 1.5.
- e. *Paracomina lignaria* (Powell and Bartrum), x 1.
- f. *Eumitra nitens* (Marshall), x 2.
- g. *Austrofuscus* (*Neocola*) *flexuosus* (Marshall), x 1.5.
- h. *Penion bartrumi* (Laws), x 1.5.
- i,j. *Discotectonica hokianga* (Vella), x 3.
- k. *Amalda* (*Spinaspira*) *stortha* (Olson), x 1.
- l. *Uromitra neozelanica* Laws, x 3.
- m. *Coluzea kiosk* Finlay, x 1.
- n. *Morum* (*Oniscidia*) *finlayi* (Laws), x 1.
- o. *Rugotypis vellai* (Maxwell), x 2.
- p. *Clifdenia turneri turneri* Laws, x 1.
- q. *Falsiculus* (sensu lato) *inurbana* Laws, x 1.5.
- r. *Coralliophila turneri* Laws, x 3.
- s. *Latirogona ornata* (Marshall), x 3.
- t. *Falsiculus* (sensu lato) *gemmata* Powell, x 1.5.



as in other species. Teleoconch of 6 or 7 whorls, early whorls almost straight-sided, later whorls slightly concave on posterior half, gently convex below; last whorl with broadly convex periphery, shallowly excavated below with long, straight neck. Axial sculpture of low, narrow, rounded, prosocline costae reaching from suture to suture on spire, broadly curved on last whorl and extending across base, becoming obsolete near outer lip; 19-23 on penultimate whorl. Spiral sculpture of narrow, low cords, 4 or 5 on penultimate whorl and about 17 additional ones on last whorl, most with very fine interstitial threads. Spiral cords gemmate at intersections with axial costae. Aperture ovate, columella slightly concave above, twisted to left to form moderately long, straight siphonal canal. Inner lip moderately callused; outer lip slightly flexuous, lirate within.

Altonian; Motutara, West Auckland (type); Oyster Point, Kaipara Harbour.

Falsiculus gemmata is easily distinguished from most other members of the genus by the gemmate sculpture. A specimen from Sawyer's Creek, Boddytown, near Greymouth, Westland (Clifdenian) differs from the North Island shells mainly in having somewhat coarser nodules, and may be conspecific. *F. ectypa* (Lillburnian, Gisborne district)—which was originally assigned to *Buccinum* (Ponder 1971b, p. 278)—has more closely spaced costae and cords, and considerably coarser gemmules than *F. gemmata*.

Figured specimen (Pl. 25t): GS9839B, Q10/f9531, near Oyster Point, Kaipara Harbour, Northland, Altonian (NZGS) x 1.5.

Pl. 25 q. *Falsiculus* (sensu lato) *inurbana* Laws, 1932 [p. 195] (Fasciariidae).

Rather small for genus (height 40-55 mm), fusiform, spire pagodiform, about half total height. Protoconch narrowly conical, of about 4 convex whorls, last whorl with axial costellae. Teleoconch of 7-8 whorls, sharply keeled near middle on spire; last whorl strongly excavated, with a long, slightly curved neck. Axial sculpture of prominent rounded costae reaching virtually from suture to suture on spire, but not extending onto neck on last whorl; 7-10 per whorl. Spiral sculpture prominent, consisting of a strong cord on peripheral keel, a slightly weaker one about halfway between it and lower suture, and 5-6 additional cords, some with interstitial threads, on base. Neck with numerous cords and threads, 3 considerably stronger than others. Peripheral cord forming vertically compressed tubercles where it crosses axial costae; other cords slightly thickened at intersections. All spirals rendered scaly by numerous lamellar growth ridges. Aperture ovate, with long siphonal canal; inner lip with prominent callus, its outer edge standing clear of the last whorl; outer lip thin, lirate within.

Altonian-Clifdenian; Long Beach Shellbed, Clifden, Altonian (type); Slip Point Siltstone, Clifden, uncommon.

Falsiculus inurbana is only doubtfully distinct from *F. corrugata* (Altonian?, Pakaurangi Point) as the alleged differences cited by Laws (1932, p. 195) do not seem to be constant; however, the only available topotypes of *F. corrugata* are subadult and therefore difficult to compare satisfactorily with the Clifden specimens. *F. corrugata* and *F. inurbana* differ markedly from typical *Falsiculus* in having a prominent, raised columellar callus plate (or collar) and in having scaly spiral sculpture. They are very similar in teleoconch characters to "*Fusinus*" *dictyotis* (Tate, 1888) (Balcombian, Middle Miocene, Victoria) but differ in having a conical rather a mamillate protoconch. These species are worth segregating at the subgeneric, or even generic level from *Falsiculus* (sensu stricto).

Figured specimen (Pl. 25q): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 1.5.

Pl. 25 s. *Latirogona ornata* (Marshall, 1918)

[*Dolicholaturus ornatus* Marshall 1918, p. 264]. Type species of *Latirogona* Laws, 1944 (Fasciariidae).

Rather small for family (height 25 mm), fusiform, spire half total height. Protoconch conical, of 3.5 whorls, lower suture margined by a narrow cord, last fifth of a whorl with axial costae, otherwise smooth. Teleoconch of about 6 whorls, spire whorls strongly convex, last whorl excavated with a long, slender neck. Axial sculpture of very prominent, rounded, prosocline costae with broad interspaces, reaching from suture to suture on spire, and over base on last whorl; 7 costae on penultimate whorl. Spiral sculpture of numerous closely spaced fine cords and threads, the coarser ones slightly thickened where they surmount axial costae, all finely granulated by growth lines. Aperture ovate, very constricted, with a long, almost straight siphonal canal. Inner lip thinly callused, columella with 2 or 3 definite plaits and 3-6 additional short ridges and tubercles; parietal region with 2-4 short ridges. Outer lip with 9-11 narrow lirae within.

Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (uncommon).

Latirogona is a monotypic genus closely similar to *Dolicholaturus* Bellardi, 1884, but apparently differing in having a conical rather than a mamillate protoconch, in being less slender, and in having a more strongly armoured aperture.

Figured specimen (Pl. 25s): holotype, Pakaurangi Point, Kaipara Harbour, Altonian (TM 6855, NZGS) x 3.

Pl. 25 p. *Clifdenia turneri turneri* Laws, 1932 [p. 196-197]. Type species of *Clifdenia* Laws, 1932 (Mitridae: Mitrinae).

Very large for family (height up to about 150 mm), fusiform, spire 0.45 total height. Protoconch unknown, but probably narrowly conical like many other mitrids. Teleoconch of about 10 whorls, early whorls gently convex, later whorls more strongly convex and turned in towards upper suture; last whorl contracted gradually, not excavated. Spiral sculpture of moderately strong, narrow cords on base of small shells, and much weaker ones below suture, the former becoming obsolete on large shells (greater than 60 mm), which are smooth and polished except for growth striae and feeble spirals. Aperture rather narrow, small shells without anterior notch, large shells strongly notched with a prominent, rounded fasciole. Columella almost straight with 4 or 5 plaits decreasing in strength anteriorly. Inner lip without definite callus on small shells but typically with prominent, spreading, shiny callus on large shells. Outer lip thin, smooth within.

Altonian-Lillburnian; Long Beach Shellbed, Clifden, Altonian (type); Otahu Formation, Fouraye Siltstone, Calamity Point Sandstone and Lill Sand, Clifden, uncommon at all localities.

Clifdenia turneri is one of the most elegant and spectacular of all New Zealand Cenozoic gastropods. A closely similar form—separated as the subspecies *C. turneri inflata* by Grant-Mackie (1965)—is recorded from Pakaurangi Point (Otaian and Altonian); it differs in minor characters (e.g. in being relatively wider) from the coeval Clifden shells, and may have been a true geographic subspecies. Laws (1932) referred *Clifdenia* to the Mitridae, but Cernohorsky (1970a, p. 61) placed it in the Volutidae. Unpublished studies by Maxwell (in prep.) on the ontogeny of *C. turneri* and other species indicate that *Clifdenia* is a mitrid, probably descended from a species of *Fusimitra* Conrad, 1855, and the shell morphology (particularly the anteriorly decreasing columellar plaits) is much more like that of Mitridae than of Volutidae. *Clifdenia* is first definitely recorded from the Duntroonian (Chatton, Wendon Valley and Wharekuri) and is last known from the Kapitean of Te Araroa, East Cape. *Mitra hectori* (Bortonian-Kaaitan, North Otago and South Canterbury) and *M. mystica*

(Bortonian, Kakahu) may be earlier members of the genus, but both are much smaller and more slender than typical species.

Figured specimen (Pl. 25p): GS11211, D45/f182, Otahu Formation, left bank Waiau River, Clifden, Altonian (NZGS) x 1.

Pl. 25 f. *Eumitra nitens* (Marshall, 1918) [*Cymbiola nitens* Marshall 1918, p. 266; *C. masefieldi* Marshall 1918, p. 266; *Diplomitra nitens*; *D. masefieldi*; *Mitra (Eumitra) nitens*; *M. (Eumitra) masefieldi*]. Type species of *Diplomitra* Finlay, 1926, which was synonymised with *Eumitra* Tate, 1889 by Cernohorsky (1970a) (Mitridae: Mitrinae).

Rather small for family (height 15-30 mm), narrowly fusiform, spire half total height. Protoconch narrowly conical, of about 4 smooth whorls. Teleoconch of 6-7 whorls, spire whorls lightly convex; last whorl broadly excavated, contracted gradually. Spiral sculpture highly variable, some shells with weak cords on base and neck and a few feeble grooves or striae on spire whorls, others with prominent cords on base and neck and well marked cords or grooves above. No axial sculpture apart from growth lines. Aperture narrow, siphonal canal only weakly differentiated, weakly notched; columella almost straight, bearing 2 well developed plaits—the posterior one the stronger—and a much weaker one (obsolete on some shells) below. Inner lip moderately callused; outer lip thin, almost straight, smooth within.

Waitakian-Altonian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour, Otaian-Altonian (type locality of *C. nitens* and *C. masefieldi*) (uncommon); Te Pokere, north shore, Parengarenga Harbour (moderately common); upper Tengawai River, South Canterbury (uncommon).

Eumitra nitens is distinguished from other New Zealand mitriform gastropods by its slender shape, the restriction of spiral sculpture to the base and neck of most specimens (but present on the rest of the shell on some specimens), and in having only two prominent columellar plaits (and a third much weaker one on some shells). Cernohorsky (1976b, p. 392) suggested that *Cymbiola calcar* (Otaian or Altonian, Pakaurangi) and *Diplomitra waitemataensis* (Otaian, Waiheke Island) may be additional synonyms of *E. nitens*. The holotype of *Cymbiola calcar* is a juvenile shell that is much broader than comparable-sized specimens of *E. nitens*, and has much fewer but coarser basal spiral cords, and has axial costellae similar in strength to the spiral cords on the first few teleoconch whorls; its affinities are uncertain. The holotype of *D. waitemataensis* is considerably broader than typical *E. nitens* and has only one weak columellar plait, but these differences may be related to its greater size (height 41 mm).

Figured specimen (Pl. 25f): GS9872, N2/f7611, Te Pokere, north shore Parengarenga Harbour, Northland, Altonian (NZGS) x 2.

Pl. 25 i. *Uromitra neozelanica* Laws, 1939a [p. 495] [*Vexillum (Costellaria) neozelanica*; *Costellaria neozelanica*] (Costellariidae).

Size moderate for family (height 19-25 mm), fusiform, spire 0.6 total height. Protoconch imperfectly known, narrowly conical, of about 4 smooth whorls. Teleoconch of 7-8 whorls, spire whorls gently convex with strongly impressed sutures, last whorl broadly excavated with short neck. Axial sculpture of low, rounded or flattened, narrow costae of variable strength and spacing—even on an individual shell—reaching from suture to suture on spire whorls and across base of last whorl, typically becoming more obscure near outer lip; 14-32 costae on

penultimate whorl. Spiral sculpture of low, flattened strap-like cords with much narrower interspaces, for the most part confined to the intercostal spaces—particularly on the spire whorls—barely surmounting axial costae on base and towards end of last whorl; 6-8 on penultimate whorl, an additional 5 or 6 on base; and 6-9 on neck, one of which near upper end is considerably broader than the others. Intersection of axial and spiral elements producing a strongly cancellate effect. Aperture rather small, pyriform; siphonal canal moderately long, weakly notched. Columella with 4 plaits decreasing in strength anteriorly. Inner lip thinly callused; outer lip finely lirate within.

Otaian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (rare). A shell from Te Pokere, Parengarenga Harbour (Altonian) differs in its finer spiral sculpture but may be conspecific.

Uromitra etremoides (Altonian, Target Gully Shellbed, Oamaru) has much coarser and less numerous axial costae (seven to nine per whorl), much broader spaces between the spiral cords than *U. neozelanica*, and only three columellar plaits. Cernohorsky (1970a, p. 54) synonymised *Uromitra* Bellardi, 1887 with *Costellaria* Swainson, 1840, but whereas species of *Uromitra* have a narrowly fusiform shell and a narrow, weakly notched siphonal canal, the type species of *Costellaria* (*C. semifasciata* (Lamarck, 1811); Recent, Indo-Pacific) and its relatives have an elongate-ovate shell with a short, broad and deeply notched siphonal canal. *Uromitra* is here retained as a distinct genus in the Costellariidae; *U. neozelanica* seems to be very similar to the type species, *U. antegressa* Bellardi, 1887 (Miocene, Europe).

Figured specimen (Pl. 25l): holotype, Pakaurangi Point, Kaipara Harbour, Otaian (TM1297, NZGS) x 3.

Pl. 25 n. *Morum (Oniscidia) finlayi* (Laws, 1932) [*Oniscidia finlayi* Laws 1932, p.188] (Harpidae).

Size moderate for genus (height 40-46 mm), oval, spire very low, about 0.1 total height. Protoconch conical, of about 3.5 smooth, convex whorls. Teleoconch of 5-5.5 whorls, strongly shouldered at or above middle on spire with strongly concave sutural ramp; last whorl large, enveloping, inflated posteriorly, neck short and broad. Axial sculpture of very prominent, raised, rounded costae with much broader interspaces, reaching from suture to suture on early whorls but subobsolete to obsolete on sutural ramp on later whorls; 8-11 costae (and terminal varix) on last whorl. Spiral sculpture of wide, raised, rounded, widely spaced cords, 2 on penultimate whorl, 10-12 on last whorl, crossed by many, closely spaced, high axial lamellae. Aperture long and narrow, parallel-sided; siphonal canal short, straight, moderately notched; fasciole very low. Inner lip thickly callused, spread smoothly over much of apertural face of last whorl, with a few weak nodules and ridges over inner columellar area, very variable in development. Outer lip very strongly thickened and flared to form heavy, rounded terminal varix, bearing 8-10 low nodules on inner edge.

Otaian-Lillburnian; North bank, Waiau River, Clifden, "bed C" (= Third Bay Sandstone), Lillburnian (type); Calamity Point Sandstone and Long Beach Shellbed, Clifden; Mount Brown Formation, Weka Creek, North Canterbury; Upper Waipara River, North Canterbury; Stillwater Mudstone, Lake Ryan, Greymouth. Uncommon at all localities.

Specimens of *Morum (Oniscidia)* from Pakaurangi Point, Kaipara Harbour, Northland (Otaian-Altonian) have a shorter spire and have the axial costae more compressed posteriorly than South Island shells, but are otherwise very similar. A similar but smaller, narrower species with a more obvious, twisted fasciole is *M. harpaforme* (Otaian, Oneroa, Waiheke Island; Kawau Island). A larger, unnamed species occurs in the Wharekuri Greensand, Waitaki Valley (Duntroonian); its spiral cords

are much lower and less distinct than in *M. finlayi*. The genus was therefore well represented in New Zealand during warm-water periods of the Oligocene and Miocene. Beu (1976b) pointed out that *M. finlayi* may have been ancestral to the living southwest Pacific *M. bruuni* (Powell, 1958) (Kermadec Islands, New South Wales and, very rarely, northern New Zealand) which differs only in its much weaker spiral cords.

Morum finlayi is an interesting and attractive member of a tropical and subtropical genus, widely distributed on soft substrates of the inner to middle shelf zone, in Indo-Pacific and Caribbean seas. *Morum* was for a long time thought to be a cassid (i.e. in the Mesogastropoda), but recent studies on the anatomy of *M. tuberosum* (Reeve, 1842) have shown that it should be transferred to the neogastropod family Harpidae (Hughes 1986). As the name chosen by Powell and Bartrum (1929, p. 428) for their species suggests, some species of *Morum*—particularly in the subgenus *Oniscidia*—are not unlike more typical harpids in shell characters.

Figured specimen (Pl. 25n): topotype, left bank Waiau River, Clifden, Lillburnian (Canterbury Museum) x 1.

Pl. 25 k. *Amalda (Spinaspira) stortha* (Olson, 1956) [*Baryspira (Spinaspira) stortha* Olson 1956, p. 18; *B. (Spinaspira) stortha* var. *irrisa* Olson 1956, p. 18]. Type species of *Spinaspira* Olson, 1956 (Olividae: Ancillinae).

Size moderate for genus (height 30–40 mm), elongate-ovate; spire conical, 0.15–0.3 total height, covered with callus; apex small and pointed, probably indicating a conical protoconch. Last whorl with prominent, rounded, projecting, rim-like keel on periphery, sides flat or weakly convex between shoulder and edge of fasciole, contracted thence to broad anterior end. No sculpture other than growth lines. Aperture capacious, but posterior end constricted, a shallow, curved channel (posterior siphonal groove) extending up spire callus. Anterior notch deep; fasciole bounded by a rounded ridge (poorly developed in some shells), covered by smooth callus that spreads up to edge of moderately wide depressed band. Columella short, almost straight, with 6 or 7 very weak plaits separated by narrow grooves, ascending within aperture. Basal groove of variable development, bordered by a sharp ridge running from base of columellar pillar to base of parietal callus, bounded in turn by a broad sulcus running obliquely across columellar pillar. Parietal callus very prominent, thick and smooth except for obscure rugosities near posterior siphonal groove, spreading laterally as a tongue-shaped pad for up to 180°, and spreading posteriorly up to level of apex in some shells, but in most specimens not obscuring apex. Spire callus spreading well down last whorl. Outer lip moderately prosocline, almost straight, complete examples with small denticle at end of depressed band.

Altonian-Waiauian; Long Beach Shellbed, Clifden, Altonian (type locality of both *B. stortha* and *B. stortha* var. *irrisa*); Calamity Point Sandstone, Slip Point Siltstone and Lill Sand, Clifden; Burnt Hill, North Canterbury; Gisborne district. Common at Clifden localities.

The “variety” *irrisa* was synonymised with *Amalda stortha* by Beu (1970a); the holotype differs from typical specimens only in being higher-spined. *Amalda cingulata* (also described from Long Beach Shellbed) was referred to *Spinaspira* by Olson (1956, p. 18–19); it differs from *A. stortha* in having a higher spire, a thinner parietal callus, and a distinctly convex last whorl, and in lacking a rim-like shoulder keel on the last whorl. *A. spinigera* (Otaian-Altonian, Pakaurangi Point) is much smaller than either of the Clifden species (height c. 22 mm) and has a rounded shoulder. *A. pakaurangiensis* (Otaian or Altonian, Pakaurangi Point, also Coral Point, Kaipara

Harbour) is similar to *A. stortha* in most respects, but has a much wider depressed band and a much stronger fasciolar ridge. *A. cincta* (Otaian or Altonian, Pakaurangi Point) has a broad depressed band like that of *A. pakaurangiensis* but differs from it and other species of the subgenus in having a much thinner parietal callus (indistinguishable from the spire callus posteriorly), and a strongly convex last whorl; its relationships are uncertain and it is only doubtfully referred to *Spinaspira*.

Olson (1956, p. 17) proposed *Spinaspira* (as a subgenus of *Baryspira*) for species with a heavy, laterally spreading, tongue-like parietal callus similar to that in species of the *Amalda robusta* group (Pl. 22h) but having a spine-like apex. The apical whorls are normally obscured by callus, but partly abraded individuals show that the protoconch is probably conical, suggesting that the larvae had planktonic dispersal capabilities. Other New Zealand *Amalda*, by contrast, seem to have a paucispiral protoconch and hence, limited powers of dispersal. The stratigraphic and geographic distribution of *Amalda (Spinaspira)* in New Zealand indicate that it was a warm-water group that arrived here during the Early Miocene. Very similar olivids are recorded from the Miocene of Europe (e.g. the specimen from the Helvetian of Bossé, France illustrated by Cossmann (1899, pl. 3, fig. 4) under the name *Baryspira glandiformis* (Lamarck). Powell (1967c, p. 198) described a Recent species, *A. (Spinaspira) raoulensis* from the Kermadec Islands but this is not consubgeneric with the New Zealand species; it appears to belong in *Amalda (Amalda)*.

Figured specimen (Pl. 25k): holotype of *A. stortha*, GS2937, D45/f8479, Long Beach Shellbed, Clifden, Altonian (TM5754, NZGS) x 1.

Pl. 26 c. *Lyria zelandica* Finlay, 1924b [p. 470–471] (Volutidae: Lyriinae).

Small for family (height 40–60 mm), broadly fusiform, spire 0.4–0.45 total height. Protoconch small, conical, of about 3 whorls. Teleoconch of 6–7 whorls, spire whorls convex; last whorl excavated, with short neck; sutures impressed. Axial sculpture of prominent, narrowly rounded costae reaching from suture to suture on spire, and across base almost to fasciole on last whorl; 13–16 costae per whorl. No other sculpture apart from obscure spiral cords on anterior end of last whorl, and weak growth lines. Aperture rather small, pyriform; columella almost straight, with 3 moderately strong plaits anteriorly, and 4–8 weak ridges above. Siphonal canal short, shallowly notched; fasciole convex, prominent. Inner lip callus moderately thick posteriorly, thinner below; outer lip with a low rounded varix, front face somewhat flattened, smooth within.

Altonian-Clifdenian; Waiauian ?; Slip Point Siltstone, Clifden, Clifdenian (type) (rare); Long Beach Shellbed, Clifden (uncommon).

Lyria zelandica is the only species of this typically warm-water genus to have been described from New Zealand, and because of its broadly but evenly fusiform shape, its long axial costae, and its numerous weak ridges on the upper part of the columella, it is unlikely to be confused with any other local volute. An apical fragment from Fox River, Westland (Waiauian) may belong here.

Figured specimen (Pl. 26c): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 1.

Pl. 26 b. *Alcithoe (Leporemax) bathgatei* Finlay, 1926 [*Alcithoe bathgatei* Finlay 1926b, p. 248; *Waihaioia (Waihaioia) bathgatei*] (Volutidae: Zidoninae).

Size moderate for subgenus (height 45-60 mm), slender, fusiform, spire about half total height. Protoconch depressed-cylindrical, of about 2 whorls, first whorl highly compressed with narrowly rounded periphery, in most specimens overhanging second whorl. Teleoconch of 5-6 whorls, early whorls gently convex, later whorls becoming progressively more strongly angled at about half whorl height, sutural ramp steep, slightly concave; last whorl weakly subangled about halfway between shoulder angle and anterior end, straight or feebly concave below. Axial sculpture of prominent, narrow-crested costae with much wider interspaces, reaching from suture to suture on spire whorls and about halfway across base of last whorl; 12-16 on penultimate whorl. Costae becoming tubercular on shoulder angle on last whorl (or somewhat earlier on some shells), strength of tubercles variable, but not strongly projecting in any specimens seen. Spiral sculpture of weak grooves on early whorls, later whorls of well-preserved shells with very numerous, microscopic striae. Aperture elongate-ovate, columella with 4 narrow plaits, the anterior one weaker and more oblique than the others, some shells with a fifth, weak plait at posterior end. Siphonal notch rather shallow; fasciole low, rounded.

Altonian, Fouraye Siltstone, Clifden (type) (moderately common). *Alcithoe bathgatei* is distinguished from other species of *Alcithoe* (*Leporemax*) by its slender shape, its tall spire and its axial sculpture of narrow-crested costae with small tubercles developed on the shoulder angle.

Figured specimen (Pl. 26b): GS11182, D45/f8819, Fouraye Siltstone, Clifden, Altonian (NZGS) x 1.

Pl. 26 a. *Alcithoe* (*Leporemax*) *phymatias* Finlay, 1926. [*Alcithoe phymatias* Finlay 1926b, p. 248; *Waihaoia* (*Waihaoia*) *phymatias*] (Volutidae: Zidoninae).

Similar to *A. bathgatei* but less slender and growing to a larger size (height up to at least 85 mm). Protoconch like that of *A. bathgatei*. Early teleoconch whorls resembling those of *A. bathgatei* but shoulder angulation typically becoming obvious at an earlier stage of growth and becoming much more prominent on later whorls. Axial sculpture developing in much the same way as in *A. bathgatei*, but tubercles quickly becoming much larger and strongly projecting, those on last whorl (and on some shells on later part of penultimate whorl as well) with little or no axial extension; 8-12 on penultimate whorl. Spiral sculpture apparently much as in *A. bathgatei*. Subadult shells with 4 columellar plaits, most adults with 5, in some shells on a padded portion of the columella.

Altonian; Long Beach Shellbed, Clifden (type); Calamity Point Sandstone, Clifden; moderately common at both localities.

Alcithoe phymatias succeeds *A. bathgatei* in the Clifden section, and is almost certainly its direct descendant. Most specimens from the Calamity Point Sandstone (stratigraphically intermediate between the Fouraye Siltstone and the Long Beach Shellbed) are unambiguously assignable to *A. phymatias*, but some subadult shells (height 45-50 mm) cannot be satisfactorily distinguished from topotypes of *A. bathgatei*. A few volutes from the Slip Point Siltstone (Clifdenian) in the Clifden section compare quite closely with some individuals from the Long Beach Shellbed, but most are squatter and have more strongly angled whorls. Some are biconic with very strongly projecting peripheral tubercles, and closely resemble the holotype of *Alcithoe dyscrita*, which was described from Slip Point. It seems that these three nominal species are members of a gradually evolving lineage akin to that described for *Austrofusus alpha*, *beta* and *gamma* (see above), but considerably more material is needed before it can be adequately documented.

Although these species have long been included in *Waihaoia*, they lack the apical spike present on the protoconch of the type species (*W. allani*, Pl. 8p), and are here referred to the subgenus *Alcithoe* (*Leporemax*).

Figured specimen (Pl. 26a): GS10344, D45/f8483, Calamity Point Sandstone, Clifden, Altonian (NZGS) x 1.

Pl. 26 d. *Metamelon clifdenensis* (Finlay, 1926) [*Miomelon clifdenensis* Finlay 1926b, p. 246]. Type species of *Metamelon* Marwick, 1926 (Volutidae: Zidoninae).

Rather small for subfamily (height 42-55 mm), elongate-ovate, spire 0.35 total height. Protoconch mamillate, of about 3 smooth whorls, with a prominent apical spike. Teleoconch of 4-5 whorls, early whorls gently convex, later whorls bluntly shouldered somewhat above mid-whorl on spire; last whorl with weak basal subangulation, slightly concave below. Axial sculpture, apart from growth lines, absent from first 2 whorls or so, later whorls with well spaced, sharp-crested costae that are noticeably thickened on shoulder angle, particularly on last whorl—in some shells only peripheral nodules remain on last half-whorl; 9-13 on last whorl. Whole surface covered with numerous very fine spiral striae. Aperture elongate-ovate; siphonal notch deep, fasciole prominent, margined above by a low, sharp ridge. Columella with 5 plaits. Inner lip with a thin callus glaze; outer lip slightly thickened within.

Altonian-Lillburnian; Calamity Point Sandstone, Clifden, Altonian (type); Fouraye Siltstone, Long Beach Shellbed, Slip Point Siltstone and Third Bay Sandstone, Clifden, moderately common.

Specimens of *Metamelon clifdenensis* from higher in the Clifden section (late Lillburnian and Waiuan) have more rounded whorls than typical Altonian shells, with little or no suggestion of a shoulder—some shells have a very inflated last whorl and so have a superficial resemblance to *Lyria zelandica*. *Metamelon* resembles *Spinomelon* in having an apical spike, but differs in its smaller size, and in having a deep siphonal notch and a prominent, ridge-margined fasciole. *M. clifdenensis* differs from other described species in having distinctly shouldered whorls and prominent axial costae.

Figured specimen (Pl. 26d): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 1.

Pl. 26 o. *Conus* (sensu lato) *armoricus* Suter, 1917 [*Conus* (*Leptoconus*) *armoricus* Suter 1917, p. 61] (Conidae).

Small for family (height c. 25 mm), biconic, spire low, 0.2 total height. Protoconch conical, of about 4 smooth whorls. Teleoconch of 7-8 whorls, sharply angled a very short distance above suture; last whorl gently convex posteriorly, weakly excavated below. Axial sculpture of weak nodules on periphery of first whorl, and fine arcuate growth ridges on sutural ramp. Spiral sculpture of feeble threads on ramp on some shells, and 10-12 grooves of variable width on anterior part of last whorl. Aperture narrow, inner and outer lips almost straight and parallel; outer lip with U-shaped sinus on ramp.

Otaian-Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (uncommon).

This rather nondescript species is similar to *Conolithes wollastoni* (Pl. 22v) in some respects, but is consistently lower-spined, and has peripheral nodules confined to the first teleoconch whorl. *C. lyratus* (= *C. marshalli* Finlay, 1926, unnecessary name change; Otaian-Altonian, Pakaurangi Point) is similar in shape and axial sculpture to *C. armoricus*, but has spiral grooves over the whole of the last whorl; its status is uncertain, but it probably is a distinct species.

Figured specimen (Pl. 26o): Paratype, Pakaurangi Point, Kaipara Harbour, Otaian or Altonian (TM6856, NZGS) x 2.

Pl. 26 h. *Austrotoma excavata* (Suter, 1917) [*Bathytoma*

sulcata excavata Suter 1917, p. 55]. Type species of *Austrotoma* Finlay, 1924 (Turridae: Pseudotominae).

Size moderate for genus (height 30-40 mm), narrowly biconic, spire half total height. Protoconch conical, of about 4 convex whorls, last half whorl with spiral cords crossed by weak axial costellae. Teleoconch of 6 whorls, sharply shouldered at or slightly below middle on spire, sutural ramp concave with weak subsutural fold; last whorl shallowly excavated. Axial sculpture, apart from growth lines, confined to first 3 whorls or so, of narrow costae reaching from shoulder angle to lower suture. Spiral sculpture on ramp of very fine threads reticulated by growth lines, rest of shell with very low, flat-topped cords with interstitial threads; last 2 or 3 whorls with smooth band on peripheral angle. Overall appearance polished. Aperture subrectangular; siphonal notch moderately deep, fasciole not prominent, margining ridge obsolete in some shells. Anal sinus shallowly arcuate, apex below middle of ramp.

Otaian-Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type), moderately common in Pakaurangi Member.

Records of *Austrotoma excavata* from other localities require confirmation. Specimens so identified from White Rock River, South Canterbury (Altonian) are almost entirely smooth except for weak spirals on the lower part of the last whorl, and are probably referable to *A. suteri* (Altonian, "Broken River"), which was incorrectly synonymised with *A. neozelanica* by Powell (1942, p. 75). *A. excavata* is readily distinguished from other species by the early obsolescence of axial costae, by the smooth peripheral band, by the subdued spiral sculpture, and by the weakly defined fasciole. The protoconch is smaller and narrower than in most other species. *A. kaiparaensis* (Otaian-Altonian, Pakaurangi Point) is superficially similar but has a larger protoconch and more prominent spiral sculpture.

Figured specimen (Pl. 26h): GS3245, Q8/f9687, Pakaurangi Point, Kaipara Harbour, probably from Pakaurangi Member, Altonian (NZGS) x 2.

Pl. 26 e. *Austrotoma clifdenica* Powell, 1942 [p. 42] (Turridae: Pseudotominae).

Size moderate for genus (height 30-45 mm), fusiform, spire half total height. Protoconch similar to that of *A. excavata*, but much larger. Teleoconch of 5-6 whorls, strongly shouldered near middle on spire, periphery rather broad, somewhat projecting in some shells; sutural ramp strongly concave, with pronounced subsutural fold. Axial sculpture on early whorls of narrow costae reaching from periphery to lower suture, but on later whorls consisting of rounded peripheral nodules, subobsolete or obsolete below; 10-13 per whorl. Spiral sculpture of fine threads on sutural ramp, and prominent, crisp cords below, some with interstitial threads, crossed and slightly granulated by growth lines. Aperture with deep siphonal notch; fasciole prominent, sunken, bordered above by a low, sharp ridge.

Altonian-Clifdenian; Long Beach Shellbed, Clifden, Altonian (type); Calamity Point Sandstone and Slip Point Siltstone, Clifden; Postal Creek, Karamaea district; ? Alexander Street, Greymouth. Not uncommon at Clifden localities.

Austrotoma clifdenica is readily distinguished from similar species by the rather coarse peripheral nodules on adult whorls, and by the prominent spiral sculpture. Specimens from lower in the Clifden Section (e.g. from the Fouraye Siltstone, Altonian) have very similar spiral sculpture to typical *A. clifdenica*, but have axial costae confined to the first three or four whorls. They appear to be conspecific with shells from Altonian siltstone on the north shore of Parengarenga Harbour, Northland.

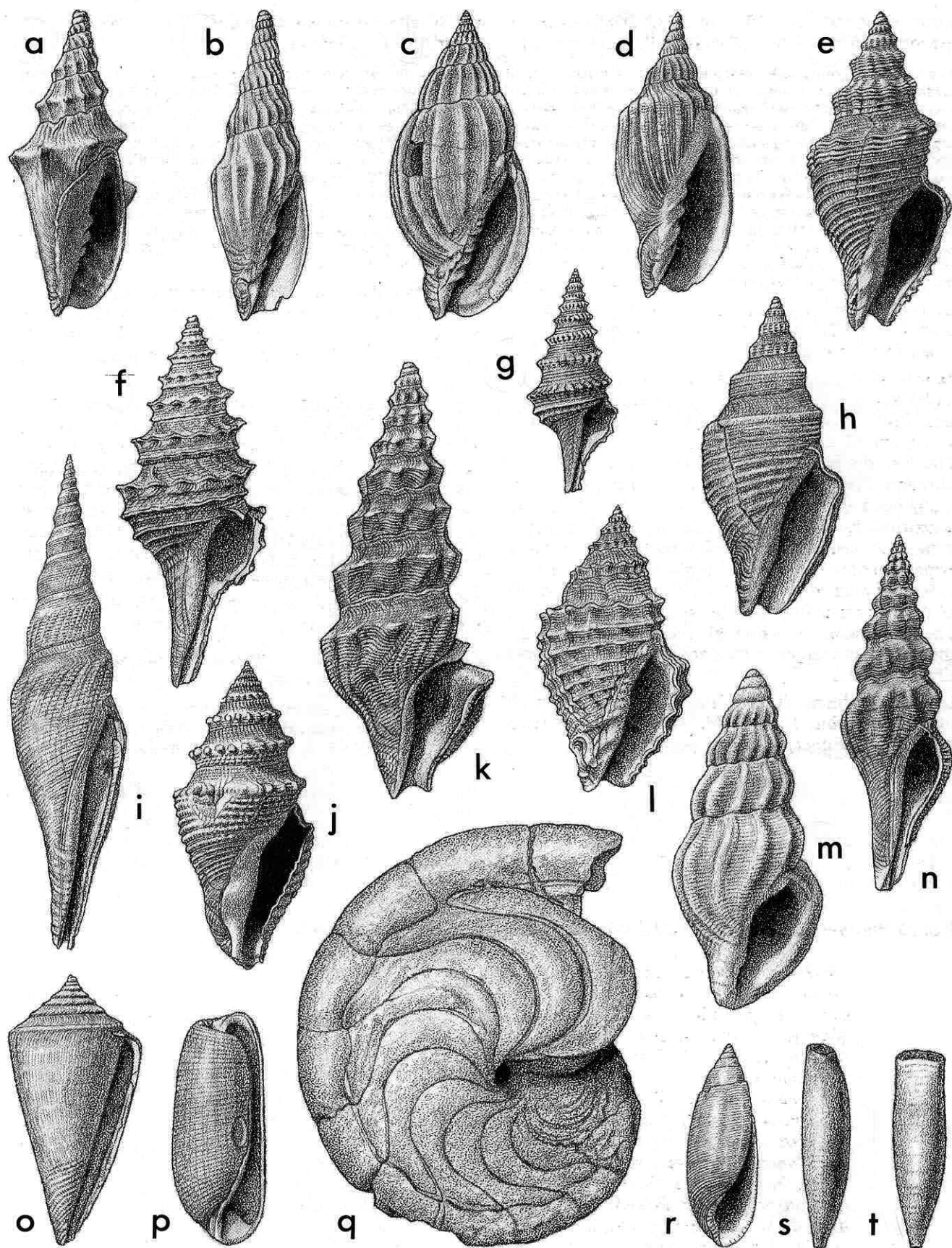
Figured specimen (Pl. 26e): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 2.

Pl. 26 l. *Austrotoma echinata* Powell, 1942 [p. 74] (Turridae: Pseudotominae).

Small for genus (height 23-30 mm), biconic, spire half total height. Protoconch like that of *A. clifdenica*. Teleoconch of 5 whorls, sharply keeled at or near middle on spire, sutural ramp relatively broad, strongly

Plate 26 Warm-water Early-Middle Miocene (Otaian-Lillburnian) Mollusca (4).

- a. *Alcithoe* (*Leporemax*) *phymatias* Finlay, x 1.
- b. *Alcithoe* (*Leporemax*) *bathgatei* Finlay, x 1.
- c. *Lyria* *zelandica* Finlay, x 1.
- d. *Metamelon* *clifdenensis* (Finlay), x 1.
- e. *Austrotoma* *clifdenica* Powell, x 2.
- f. *Gemmula* n.sp., x 2.
- g. *Gemmula* *clifdenensis* Powell, x 2.
- h. *Austrotoma* *excavata* (Suter), x 2.
- i. *Zemacies* *elator* Finlay, x 1.
- j. *Bathytoma* (*Bathytoma*) *bartrumi* Laws, x 1.
- k. *Austroclavus* *tenuispiralis* (Marshall), x 6.
- l. *Austrotoma* *echinata* Powell, x 2.
- m. *Anacithara* *axialis* (Marshall), x 10.
- n. *Comitas* *latiaxialis* (Marshall), x 1.5.
- o. *Conus* (sensu lato) *armoricus* Suter, x 2.
- p. *Cylichnania* *bartrumi* Marwick, x 4.
- q. *Aturia* *cubaensis* (Lea), x 1.
- r. *Crenilabium* *zelandicum* Marshall, x 3.
- s,t. *Vaginella* *torpedo* Marshall, x 3.



concave with a subsutural fold of variable strength; last whorl weakly excavated. Axial sculpture of low, well spaced, rounded costae, reaching from shoulder keel to lower suture on spire, and across base of last whorl; 13-15 per whorl. Spiral sculpture of very fine threads on sutural ramp, and well spaced, narrow but prominent cords with fine interstitial threads below; 9 on last whorl, the lowest 3 considerably weaker than those above. Sharp tubercles formed at intersections of axial costae and spiral cords. Spiral threads finely reticulated by growth lines. Siphonal notch deep; fasciole prominent, sunken, margining ridge raised, sharp.

Clifdenian-Lillburnian; Slip Point Siltstone, Slip Point, Clifden, Clifdenian (type), moderately common; Third Bay Sandstone, Clifden.

Austrotoma echinata is one of the most distinctive species of the genus, distinguished by its small size, its squat shape and its prickly sculpture. Specimens from the Altonian-Clifdenian of Karamea district are very similar, but are more slender, have more closely spaced axial costae, and have smaller tubercles than Clifden shells — they may represent a species ancestral to *A. echinata*.

Figured specimen (Pl. 26l): GS11185, D45/f8822, Slip Point, Clifden, Clifdenian (NZGS) x 2.

Pl. 26 n. *Comitas latiaxialis* (Marshall, 1918) [*Surcula latiaxialis* Marshall 1918, p. 267] (Turridae: Turrinae).

Size moderate for genus (height 35-45 mm), fusiform, spire a little over half total height. Protoconch small, conical, of about 2.5 smooth whorls. Teleoconch of 9 whorls, bluntly shouldered near middle on spire, sutural ramp concave with low subsutural fold; last whorl broadly excavated, with a moderately long neck. Axial sculpture of prominent, rounded costae with broad, concave interspaces, reaching from near middle of sutural ramp to lower suture on spire, dying out on base of last whorl; 6-8 per whorl. Spiral sculpture on ramp of a narrow cord on subsutural fold, and fine threads below; rest of shell with numerous fine cords, some with interstitial threads. Aperture pyriform, rather narrow, with a moderately long, unnotched siphonal canal; columella almost straight. Inner lip weakly impressed; outer lip thin with a moderately deep U-shaped sinus on ramp.

Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (rare).

Comitas latiaxialis differs from other New Zealand *Comitas* species by its slender shape, its small, conical protoconch and its very fine spiral sculpture. A similar, unnamed species from the north shore of Parengarenga Harbour (Altonian) has a mamillate protoconch and somewhat coarser spiral sculpture.

Figured specimen (Pl. 26n): GS7068, Q8/f9687, Pakaurangi Point, Kaipara Harbour, probably from Pakaurangi Member, Altonian (NZGS, ex C.R. Laws Colln.) x 1.5.

Pl. 26 g. *Gemmula clifdenensis* Powell, 1942 [p. 49-50] (Turridae: Turrinae).

Rather small for subfamily (height 15-35 mm), narrowly fusiform, spire 0.6 total height. Protoconch narrowly conical, of 5 whorls, last 2.5 whorls with narrow, distant axial costellae, remainder smooth. Teleoconch of 7-8 whorls, sharply keeled at or slightly below middle on spire; sutural ramp steep, with slight subsutural fold; last whorl strongly excavated with moderately long neck. Axial sculpture of narrow, rather sharp peripheral tubercles, 20-24 per whorl. Spiral sculpture of a narrow cord on subsutural fold, 2 or 3 of similar strength on peripheral keel, and 3-6 finer ones between. A narrow cord appearing between periphery and lower suture during growth, in some shells becoming as strong as subsutural cord. An additional 2 prominent cords, typically stronger than other spirals, appearing on base of last whorl, with numerous much weaker ones below. Aperture ovate, with a moderately long, narrow siphonal canal. Outer lip thin with a deep, V-shaped anal sinus, its apex on peripheral keel, lirate within.

Altonian-Clifdenian; Slip Point Siltstone, Slip Point,

Clifden, Clifdenian (type) (not uncommon); Fouraye Siltstone, Clifden (uncommon); north shore, Parengarenga Harbour (very common).

Gemmula clifdenensis is very similar to *G. kaiparaensis* (Otaian-Altonian, Pakaurangi Point, Kaipara Harbour) and possibly not really distinct, but apparently has a narrower, more sharply projecting peripheral keel, sharper and more numerous peripheral tubercles (17-20 per whorl in *G. kaiparaensis*), and crisper spiral sculpture. Many species of *Gemmula* have basically similar sculptural plans and require careful examination of protoconch as well as teleoconch characters for discrimination.

Figured specimen (Pl. 26g): GS13811, D45/f311, middle Slip Point Siltstone, Clifden, Clifdenian (NZGS) x 2.

Pl. 26 f. *Gemmula* n. sp. (Turridae: Turrinae).

Rather small for subfamily but large for New Zealand members of the genus (height 25-40 mm), fusiform, spire about half total height. Protoconch conical, of about 4 whorls, last 2.5 whorls with narrow, distant axial costellae and a narrow cord margining upper suture. Teleoconch of 8-9 whorls, sharply keeled at or somewhat below middle on spire, sutural ramp concave; last whorl with 2 additional angulations, excavated below, with a moderately long neck. Axial sculpture of tubercles on peripheral keel, somewhat rounded on early whorls, but becoming vertically compressed and subtriangular on later whorls, producing a serrate periphery; 13-15 tubercles on each adult whorl. Spiral sculpture on spire whorls of a low, flat-topped cord on periphery, a narrow suprasutural cord that rises above suture on penultimate whorl to form one of the prominent keels on the last whorl, and fine threads between these cords and on ramp. Last whorl with a prominent cord emerging near top of base, similar in strength to the one above, and several much weaker cords, with interstitial threads, on lower part of base and on neck. Stronger basal spirals weakly crenulate. Outer lip with a deep, narrowly V-shaped anal sinus, its apex on peripheral keel, lirate within.

Altonian-Clifdenian; Paratoetoe Formation, Paratoetoe and Te Pokere, north shore, Parengarenga Harbour (very common); mouth of Little Wanganui River, west Nelson (uncommon); Calamity Point Sandstone, Clifden (uncommon).

This highly distinctive species differs from other New Zealand *Gemmula* species in its relatively large size, in having a sharply serrate peripheral keel, and in its relatively simple spiral sculpture. It occurs with *G. clifdenensis* in siltstone of the Paratoetoe Formation at Parengarenga Harbour.

Figured specimen (Pl. 26f): GS9872, N2/f7611, Te Pokere, north shore of Parengarenga Harbour, Northland, Altonian (NZGS) x 2.

Pl. 26 i. *Zemacies elatior* Finlay, 1926b [p. 252]. Type species of *Zemacies* Finlay, 1926 (Turridae: Turrinae).

Rather large for subfamily (height 55-100 mm), narrowly fusiform, spire about half total height. Protoconch narrowly conical, of about 4 strongly convex, smooth whorls. Teleoconch of 8-10 whorls, bluntly shouldered somewhat above middle on spire; last whorl with weak basal subangulation, below which it is drawn out into a long, slender neck; sutural ramp concave, typically with a low subsutural swelling. Axial sculpture of small nodules on shoulder angle of early whorls, some shells with short, strongly opisthocline, ill-defined costae on periphery of later spire whorls. Spiral sculpture of a few weak threads on ramp, most shells with a considerably more prominent one on subsutural swelling; and narrow, low, rounded cords below, becoming obsolete on lower part of neck. Aperture narrow, elongate, with a long, slender, unnotched siphonal canal. Columella long, almost straight; inner lip thinly callused; outer lip thin with a deep, rounded anal sinus, its apex near middle of ramp, smooth within.

Altonian-Clifdenian; Fouraye Siltstone, Clifden, Altonian (type); Long Beach Shellbed and Slip Point Siltstone, Clifden; Paratoetoe Formation, Paratoetoe and Te Pokere, Parengarenga Harbour; ? Ardgowan Shellbed, Oamaru.

This very elegant turrid is distinguished from other species of the genus by its slender shape and bluntly shouldered teleoconch whorls, and in having axial sculpture normally absent from all but the earliest teleoconch whorls. *Z. lividorupis* (Otaian, Bluecliffs and Pareora River, South Canterbury) is very similar, but has distinct axial sculpture persisting to a much later stage of growth. Specimens recorded from Ardgowan Shellbed (Altonian) as *Zemacies elatior* (Laws 1935c, p.34) are badly worn and could be *Z. lividorupis* rather than *Z. elatior*. Although *Z. elatior* is quite common in the early Altonian siltstone at Parengarenga Harbour, it is not recorded from beds of similar age at Pakaurangi Point, where another species, *Z. ordinaria* occurs; this differs from *Z. elatior* in having more strongly shouldered teleoconch whorls and more prominent peripheral nodules.

Figured specimen (Pl. 26i): GS10365, D45/f8598, Long Beach Shellbed, Clifden, Altonian (NZGS) x 1.

Pl. 26 k. *Austroclavus tenuispiralis* (Marshall, 1918) [*Drillia tenuispiralis* Marshall 1918, p. 269]. Type species of *Austroclavus* Powell, 1942 (Turridae: Drilliinae).

Rather small for subfamily (height 10-12.5 mm), elongate-ovate, spire 0.6 total height. Protoconch conical, of 4 smooth whorls. Teleoconch of 7 whorls, sharply shouldered near middle on spire, sutural ramp steep, slightly concave; last whorl excavated, with short, rather broad neck. Axial sculpture of prominent, opisthocline, rounded costae with broad interspaces on spire, extending from lower suture to shoulder angle where they are sharply and abruptly truncated forming a serrate periphery; extending across base but not onto neck on last whorl; 9-11 costae on penultimate whorl. Spiral sculpture of a few very feeble threads on ramp, and considerably stronger but nonetheless fine threads below, extending onto neck. Aperture rather narrow, with a short, strongly notched siphonal canal. Inner lip with a heavy parietal callus pad, narrowly but quite thickly callused below; columella slightly convex. Outer lip with deep, constricted anal notch on ramp, directed somewhat away from aperture, a heavy rounded varix below; well preserved shells with a shallow "stromboid notch" near anterior end.

Altonian; Pakaurangi Formation, Pakaurangi Point (type); Fouraye Siltstone and Calamity Point Sandstone, Clifden.

A related, undescribed species from Parengarenga Harbour (Altonian) differs from *Austroclavus tenuispiralis* in having fewer, noticeably coarser spirals on the base and neck. *A. marshalli* (Pl. 22o) is more slender, does not have the axial costae sharply truncated at the shoulder angle, and has spiral sculpture restricted to the neck. *Austroclavus* ranges from Waitakian to Clifdenian in New Zealand, and is also recorded from the Middle Miocene of Victoria, Australia. New Zealand representatives occur in mid-shelf to upper bathyal assemblages.

Figured specimen (Pl. 26k): holotype, Pakaurangi Point, Kaipara Harbour, probably Altonian (TM4946, NZGS) x 6.

Pl. 26 j. *Bathytoma (Bathytoma) bartrumi* Laws, 1939a [p. 496-497] (Turridae: Borsoniinae).

Rather large for genus (height 35-60 mm), biconic, spire about half total height. Protoconch conical, of 3 whorls, last fifth of a whorl with opisthocyrt costellae, remainder smooth. Teleoconch of 8-9 whorls, sharply angled well below middle on spire, sutural ramp steep, almost

flat; last whorl weakly excavated. Axial sculpture of prominent blunt tubercles on periphery, tending to become obsolete on last whorl (14-18 per whorl); numerous short and fine costellae just below suture; and fine growth lines. Spiral sculpture of fine threads on ramp and moderately strong, narrow, granulose cords with finely nodulose interstitial threads below, about 8 cords on last whorl and numerous fine, irregular threads on fasciole. Aperture narrow, elongate, siphonal canal short, scarcely differentiated, shallowly notched; fasciole rounded. Columella almost straight except for blunt twist. Inner lip callus moderately thick over columella, thin above; outer lip thin, weakly crenulate, with a deep slot-like anal sinus on peripheral keel.

Otaian-Altonian, Pakaurangi Formation, Pakaurangi Point (type), uncommon.

Bathytoma bartrumi is readily distinguished from *B. haasti* (Pl. 22m) by having relatively sparse and much stronger peripheral tubercles. *B. finlayi* (Altonian-Lillburnian, Clifden) has more numerous peripheral nodules (21-25 per whorl), and more widely spaced and more strongly nodulose spiral cords than *B. bartrumi*.

Figured specimen (Pl. 26j): GS3245, Q8/f9687, Pakaurangi Member, Pakaurangi Point, Kaipara Harbour, Altonian (NZGS) x 1.

Pl. 26 m. *Anacithara axialis* (Marshall, 1918 [*Mangilia axialis* Marshall 1918, p. 269; "*Guraleus*" *axialis*] (Turridae: Mangiliinae).

Rather small for subfamily (height c. 6.5 mm), elongate-ovate, spire 0.5 total height. Protoconch narrowly conical, of about 2.5 whorls, last fifth of a whorl with narrow, opisthocyrt costellae, remainder smooth. Teleoconch of 4-5 whorls, weakly subangled near middle on spire, sutural ramp gently concave, whorl sides convex; last whorl weakly excavated. Axial sculpture of prominent, narrowly rounded costae with much broader interspaces, reaching from suture to suture on spire but considerably weaker on ramp than below, dying out on lower part of base of last whorl; 10-11 per whorl. Spiral sculpture of numerous very fine threads which are considerably weaker on ramp than below. Aperture ovate with scarcely differentiated siphonal canal. Inner lip with moderately well developed parietal callus pad; outer lip with narrow, rounded varix, anal sinus very shallow, arcuate, on ramp.

Altonian, Pakaurangi Point (type).

Anacithara axialis is distinguished from other New Zealand species of the genus by its relatively narrow protoconch and by having spiral threads over the whorl surface. *Anacithara* is a warm-water genus at the present day (Powell 1966, p.111). In New Zealand it ranges from Duntroonian to Lillburnian.

Figured specimen (Pl. 26m): paralectotype (incorrectly assumed by Powell (1942, p.156) to be the "holotype", but see Laws 1939a, p.498), Pakaurangi Point, Kaipara Harbour, probably Altonian (TM6850, NZGS) x 10.

Pl. 25 i,j. *Discotectonica hokianga* (Vella, 1954) [*Architectonica (Discotectonica) marwicki* Laws 1948, p.149 (not of Allan, 1926); *A. hokianga* Vella 1954, p.544 (new name for *A. marwicki* Laws, preoccupied)] (Architectonicidae).

Moderate-sized for genus (diameter 7-15 mm), lenticular, spire a depressed cone. Protoconch smooth, heterostrophic, with strongly immersed initial whorl. Teleoconch of 4-4.5 whorls, spire whorls gently convex; last whorl with prominent, narrowly rounded peripheral keel, base sharply contracted, gently convex with a deep, moderately wide umbilicus. Spiral sculpture of very low, flat-topped or gently convex cords with narrow interspaces, 5 on penultimate whorl, the lowest emerging on last whorl as peripheral keel, all cut up into low gemmules or flat-topped lozenges by strongly prosocline, incised growth lines. Base with a narrow rounded cord bordering the peripheral keel and a much weaker one between; a deeply incised groove bounding a broad, coarsely and irregularly crenulate circumumbilical band; space between with

prominent radial ridges and weak spiral threads. Aperture ovate, inner lip vertical, with a short, horizontal channel at end of circumumbilical band.

Otaian-Altonian; Hokianga South Head, Northland, Otaian (type); north shore, Parengarenga Harbour; ? Gisborne district.

Discotectonica hokianga is distinguished from other New Zealand architectonicids by its depressed-lenticular shape, its relatively narrow umbilicus, and its coarsely crenulate circumumbilical band, in having low, flattened spiral cords cut into lozenges by growth lines, and in having a deeply incised groove bordering the circumumbilical band. *Discotectonica seniscula* (Altonian-Lillburnian, Gisborne district) is most similar, but differs in having a broad, almost smooth band between a narrow, very low subsutural band and the peripheral cord.

Discotectonica Marwick, 1931 (type species *D. balcombensis* (Finlay, 1927); Middle Miocene, Victoria, Australia) differs from *Architectonica* Röding, 1798 (type species *A. perspectiva* Linné, 1758; Recent, Indo-Pacific) in having a relatively low spire, in having the outer lip attached to the peripheral cord (rather than some distance above), and in lacking a prominent abapical cord margining the lower suture (on spire whorls) or the peripheral cord (on last whorl). Although usually classed as a subgenus of *Architectonica*, *Discotectonica* was given generic rank by Bieler (1985, p. 241) who we follow here. *Architectonica* (sensu stricto) does not seem to have been recorded from New Zealand—the modern *A. reevei* (Hanley, 1862), which occurs rarely in the northern part of the North Island, has recently been made the type of a new subgenus *Adelphotectonica* on the basis of shell and radular characters (Bieler 1987, p. 208).

Figured specimens: (Pl. 25i) holotype, Hokianga South Head, Otaian (TM1273, NZGS); (Pl. 25j) GS9869, N2/f7608, Paramateha, north shore, Parengarenga Harbour, Altonian (NZGS), both x 3.

Pl. 26 r. *Crenilabium zelandicum* Marshall, 1918 [p. 270] (Acteonidae).

Rather small for family (height 10–12 mm), narrowly ovate, spire 0.35 total height. Protoconch heterostrophic, small, strongly tilted. Teleoconch of 5 whorls, spire whorls gently convex, last whorl elongate, enveloping much of rest of shell, anterior end rounded; sutures impressed. Axial sculpture of very fine costellae in spiral interspaces, clearly visible only near anterior end. Spiral sculpture of fine, low, flattened cords, interspaces very narrow except near anterior end of last whorl where they become as wide as the cords. Aperture lachrymiform, constricted posteriorly; columella strongly concave, narrowly callused, bearing about 17 fine, short, transverse ridges. Outer lip thin, gently convex, opisthocline, edge finely crenulate.

Altonian, Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type) (uncommon).

The only other species of *Crenilabium* recorded from New Zealand is *C. starboroughense* (= *C. obsoletum* Marwick, 1965) (Opoitian-Mangapanian ?) (see appendix to checklist). The genus is otherwise known only from the Late Cretaceous to Recent of Europe.

Figured specimen (Pl. 26r): GS1161, Q8/f9687, Pakaurangi Point, Kaipara Harbour, probably Altonian (hypotype of Marwick 1965, pl. 11, fig. 25) (NZGS) x 3.

Pl. 26 p. *Cylichnania bartrumi* Marwick, 1931 [p. 153]. Type species of *Cylichnania* Marwick, 1931 (Cylichnidae).

Size moderate for family (height 6.5–11.5 mm), cylindrical, involute, apex with deep depression. Axial sculpture of fine growth lines, typically best-developed between spirals near posterior end. Spiral sculpture of numerous, very low, flat-topped cords of variable width; interspaces linear over most of length, considerably wider near posterior end and more so near anterior end. Aperture narrow over most of its length, wider anteriorly, columella very short, subvertical, with a weak but definite oblique fold near middle. Inner lip moderately callused over columella, forming a narrow pseudumbilical chink; thinly callused above. Outer lip thin, subparallel to inner lip over much of its length, edge finely crenulate; prosocline anteriorly, almost straight and orthocline above, extending well above posterior end of inner lip.

Otaian-Altonian; Pakaurangi Formation, Pakaurangi Point, Kaipara Harbour (type, probably from the Altonian Pakaurangi Member where it is common); Paratoetoe Formation, north shore, Parengarenga Harbour. Also recorded by Marwick (1931, p. 154) from the Clifdenian and Lillburnian of Gisborne district, but specimens are not well enough preserved to confirm the identification.

Cylichnania is recognisable by its subcylindrical shape, its sculpture of even, low, flat-topped spiral cords, and its deep apical depression, with the outer lip extending well posteriorly to the inner lip. Distinct species occur in the Altonian of Oamaru district and at Clifden. *Cylichnania* appears to be endemic to New Zealand, where it ranges from Wangaloan to at least Tongaporutuan, and possibly to Opoitian. Records indicate a mid-shelf to upper bathyal habitat.

Figured specimen (Pl. 26p): Pakaurangi Member, Pakaurangi Point, Kaipara Harbour, Altonian (NZGS, ex Marshall and Murdoch Colln.) x 4.

Pl. 26 s,t. *Vaginella torpedo* Marshall, 1918 [p. 263] (Cavoliniidae: Cuvierinae).

Moderately large for genus (height 11.5–13.5 mm), sheath-shaped, apex broken off most specimens, tube sealed by convex septum. Early part of shell conical, later part subcylindrical, with ventral side somewhat more convex than dorsal side except near aperture where ventral side is slightly concave. Shell slightly wider near middle and at aperture than in between. Sculpture of weak transverse growth lines and exceedingly fine longitudinal striae, otherwise polished. Aperture reniform, lip thin, rounded, not expanded, slightly higher dorsally than ventrally.

Late Otaian-early Altonian, Pakaurangi Point, Kaipara Harbour (type).

Only three other species of this widespread pteropod genus have been described from New Zealand. *V. aucklandica* (Otaian, Auckland) is more slender than *V. torpedo* and has a less marked subapertural constriction. *V. inflata* (mid-Altonian, Auckland) is considerably smaller than either *V. aucklandica* or *V. torpedo*, is much shorter in relation to width, and is much more strongly inflated. *V. urenuensis* (allegedly from Whitecliffs, Taranaki (Tongaporutuan) but almost certainly from the Waitemata Group near Auckland (Otaian or Altonian) (F.R. Brook, pers. comm.)) is narrower than the other species and is scarcely constricted below the aperture. Many species of *Vaginella* have been described from Europe and elsewhere, mainly from the Miocene, and some appear to have short stratigraphic ranges. In view of the widespread occurrence of many thecosome pteropods it is likely that the New Zealand species of *Vaginella* occur elsewhere and are therefore potentially useful for correlation (and may have received earlier names elsewhere).

Figured specimen (Pl. 26s, t): lectotype, Pakaurangi Point, Kaipara Harbour, Otaian? (TM5419, NZGS) x 3 (probably from the "pteropod bed" in Waiteroa Member, Holland's Bay, Otaian).

Pl. 26 q. *Aturia cubaensis* (Lea, 1841) [*Nautilus cubaensis* Lea 1841, p. 259; *Aturia ziczac* var. *australis* McCoy 1876, p. 21; *A. curvilineata* Miller and Thompson 1937, p. 69; *A. grangei* Fleming 1945, p. 411; *A. minoensis* Kobayashi 1954b, p. 36] (Aturiidae).

Moderately large for genus (diameter 50-200 mm), shaped as in *Nautilus* (i.e. planispiral and completely involute) but narrower; last whorl completely enveloping preceding whorls, so previous whorl protrudes into base of last whorl to about lowest quarter of whorl height; centre of last whorl forming a small, pocket-like umbilicus on each side. Suture swinging strongly forward from umbilicus in a deep, regular arch occupying lower 0.67 of whorl, then backward to form a deep, narrow, pointed lateral lobe, visible on septal face as a very deep, narrow pocket on each side; suture then swinging strongly forward again to position of apex of curvature of previous suture on wide saddle below, where it turns abruptly at right angles to its previous course to pass straight across venter (without a ventral lobe). Septal face with a deep, narrow, conical hollow in mid-dorsal position, at exit of siphuncle; deeply concave above. Most specimens occurring as phragmocones only, i.e. lacking the body chamber. Exterior of complete shells smooth, polished, except for weak growth lines; sides almost flat, venter narrowly rounded.

Otaian ?; Altonian-Kapitean; widespread but nowhere common in New Zealand (type of *A. grangei* from near Okahukura, Te Kuiti district, ?Waiauan-Tongaporutuan).

Jung (1966) pointed out that there are two widely distributed (cosmopolitan ?) Miocene species of *Aturia*—*A. aturi* (Basterot, 1825) (type species of *Aturia*) with the septa weakly concave above the siphonal aperture, and *A. cubaensis* with the septa strongly concave above the siphonal aperture; he regarded *A. australis* as a synonym of *A. cubaensis*. Beu (1973a) noted that the common New Zealand Miocene *Aturia* is *A. cubaensis*, but that it is accompanied by a species with a deep V-shaped lobe at the summit of the ventral saddle: *A. coxi* Miller, 1947 (Clifdenian-Tongaporutuan). Both species occur widely, but in most places uncommonly, in shelf-facies sandstone and mudstone throughout New Zealand. To judge from modern *Nautilus* they were carnivores that swam near, but above, the substrate in tropical and subtropical regions (although dead shells float well, and some New Zealand specimens could have drifted from further north). The much larger (diameter up to 300 mm) *A. mackayi* (Dannevirke Series?; Bortonian-Kaiatan) appears to be related to the Northern Hemisphere *A. ziczac* (J. Sowerby, 1812). Another giant, unnamed species, at least 0.5 m in diameter, occurs in North Otago Oligocene rocks (Hamilton 1903; Hamilton's specimen from Wharekuri is in Otago Museum).

Figured specimen (Pl. 26q): Tarakohe cement-works quarry, Takaka, northwest Nelson, Altonian (NZGS, from a private collection; specimen with shell missing, showing sutures) x 1.

CHAPTER 12. NEOGENE BATHYAL MOLLUSCAN FAUNAS: PLATE 27

INTRODUCTION

An interesting and as yet little-studied aspect of the New Zealand Cenozoic molluscan fauna is the reasonably consistent presence of bathyal faunules throughout rocks of Paleocene to latest Pliocene age. Bathyal faunules are particularly widespread in Miocene and Pliocene rocks, and we illustrate some characteristic Miocene bathyal taxa in Pl. 27. Some of the main Neogene bathyal molluscan localities are shown in Fig. 19.

Characters by which faunules that lived at bathyal depths (depths greater than about 200 m and less than about 3500 m) can be recognised are: (1) at most localities, fossils occur scattered sparsely in a matrix of massive or poorly bedded blue-grey siltstone. Much less commonly,

they occur sparsely in a volcanic matrix, such as at Motutara, West Auckland; or in thin conglomerate beds slumped into bathyal siltstone sequences, quite commonly seen in the "Tutamoe conglomerate" facies of Clifdenian to Waiauan age (Middle Miocene) in the Gisborne-east coast district, in which case shallow-water taxa may also be present. (2) most Mollusca are of small size, ranging from about three to 15 mm in largest dimension; only a few bathyal taxa such as *Bartrumia*, *Pholadomya*, and the Waiauan and Tongaporutuan species *Falsiculus tangituensis* (all on Pl. 27) reach more than about 40 mm in maximum dimension, although a few specimens of such large eurybathyal taxa as *Galeodea*, *Penion* and *Alcithoe* occur in some bathyal faunules. (3) particular

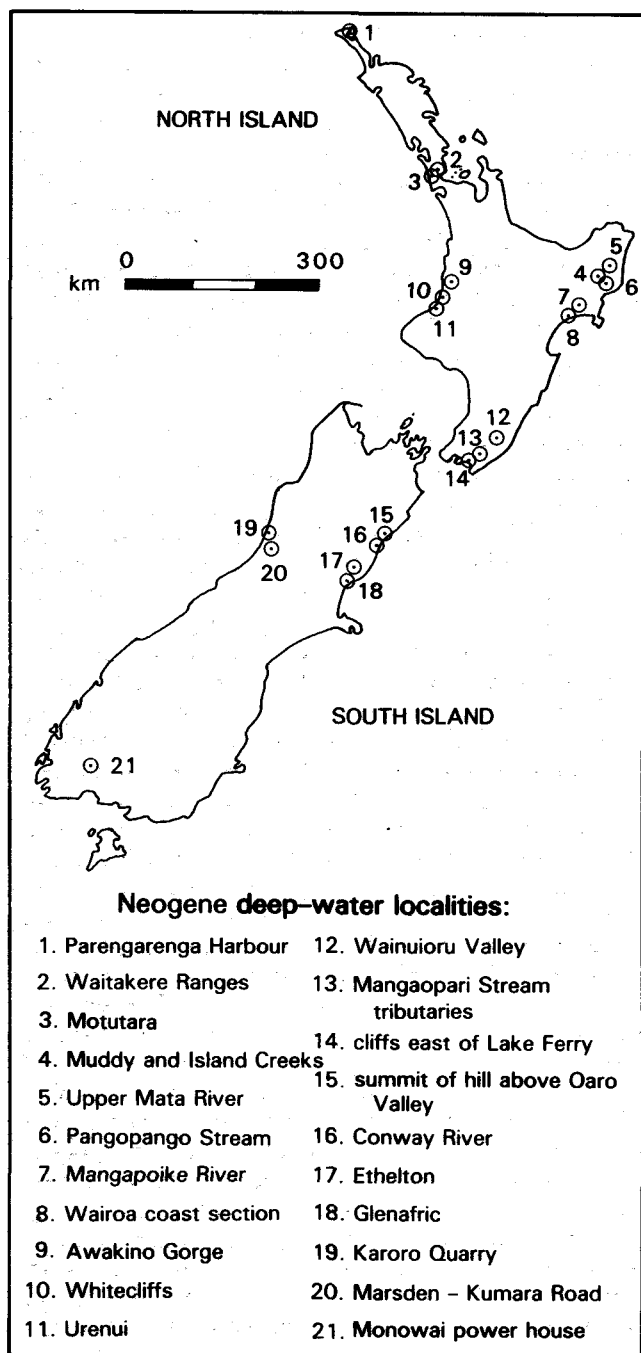


Figure 19 Location of some Neogene bathyal molluscan faunules.

taxonomic groups consistently dominate the molluscan assemblages. The assemblages consistently contain relatively diverse (compared with shallower-water faunules, and particularly in terms of their proportion of the total bivalve faunule) taxa of protobranch bivalves (Nuculacea and Nuculanacea and more rarely Solemyoida); small, thin-shelled "mud pectens" of the Propeamussiidae; anomalodesmatan bivalves such as *Pholadomya*, Verticordiidae and Cuspidariidae; a few gastropod groups such as small Cancellariidae, bullomorph ("bubble shells"), pyramidellid and pteropod opisthobranchs and, above all, a high diversity of Turridae (which commonly constitute more than 50% of species in bathyal assemblages); and scaphopods, particularly the more weakly sculptured taxa such as

Laevidentalium and Gadilidae, although large *Fissidentalium* species are common in some faunules.

Characteristic protobranch bivalves in New Zealand Neogene bathyal faunules are the nuculids *Linucula* and giant "Ennucula" species close to "*E.*" *otamaringensis*, the nuculanids *Jupiteria*, *Ledella* (specially *L. pakaurangensis*), *Yoldiella* and *Zealeda*, the superficially similar neilonellids *Austrotindaria* and *Pseudotindaria* (Pl. 27a, c), the small malletiid *Minormalletia* and, in Late Miocene to Pliocene faunules, the large, almost smooth, thick-shelled malletiid *Neilo sublaevis* (Pl. 28b). The Propeamussiidae are thin-shelled, very fragile, externally almost smooth pectens with internal strengthening ribs; *Propeamussium zitteli* (Pl. 27e), *Parvamussium* species and other, poorly understood propeamussioid species are common at many bathyal localities of Oligocene to Late Miocene age, and are replaced in some Pliocene and younger faunules by *Parvamussium maorium*. Giant Limidae of the genus *Acesta* (Pl. 3i) occur in some bathyal faunules, and are almost unknown in shelf facies, but are rare and difficult to collect because they are large (to 250 mm high) and extremely thin and fragile. Particularly characteristic of Miocene bathyal mudstone is the thin-shelled tellinid *Bartrumia tenuiplicata* (Pl. 27d, f); at many localities it is the sole mollusc present, implying it was one of very few molluscs able to tolerate conditions of rapid deposition of fine sediment. However, it occurs also in shelf facies. Another bivalve group diagnostic of bathyal depths is the thin-shelled, nacreous anomalodesmatan bivalves, particularly in the Pholadomyidae, Parilimyidae and Verticordiidae. The large (to 100 mm long), weakly dimpled, highly nacreous shells of *Pholadomya neozelanica* (Pl. 27b) are more characteristic of bathyal than of shelf assemblages, although they are nowhere common, and the smaller and more elongate species *Parilimya warreni* and *P. waitotarana* occur only in shelf faunas. Characteristic bathyal gastropod groups are (1) the deep-water limpets of the genus *Pectinodonta* and the families Cocculinidae and Pseudococculinidae (Marshall 1985, 1986), which attach to logs and other rare hard substrates in the deep sea; (2) some of the small trochaceans of the family Skeneidae; (3) all Seguenziidae (Marshall 1983a); (4) a few rissoaceans, particularly *Ihungia*; (5) some groups of Naticidae, particularly *Uberella cicatrix* (Pl. 27g, h) in Miocene faunules, but also species of *Friginatica* and *Falsilunatia*, and the small, heavily callused species placed at present in *Taniella* (*T. mima*, *T. motutaraensis*, and *T. polinificiformis*); (6) some taxa of Cerithiellidae, Cerithiopsidae and Triphoridae; (7) some Buccinidae, although (unlike northern hemisphere and particularly boreal bathyal faunas) a high diversity of Buccinidae is not a marked characteristic of New Zealand bathyal faunas; *Aeneator* (*Ellicea*) (Pl. 27i), with distinctive, heavy spiral sculpture, is a good indicator of bathyal depths after it evolved (or arrived in New Zealand?) during Late Miocene time; some *Aeneator* (*Aeneator*) species are bathyal (notably the Pliocene to Recent *A. elegans*; Pl. 37n); and there are a few (some unpublished) records of the largely bathyal buccinid genus *Nassaria* in New Zealand (Cernohorsky 1982, p. 137); (8) the small nassariid *Nassarius* (*Hima*) is particularly abundant in some bathyal faunules (although some species are equally common in shallow-water assemblages); (9) several taxa

of Turbinellidae are bathyal, particularly *Exilia* (Pl. 21e) (in pre-Tongaporutuan rocks) and *Pakaurangia* (= *Teramachia*), and some New Zealand species of Columbariinae occur only in bathyal faunas; (10) a few taxa of Muricidae, mostly small species of *Comptella*, *Pagodula* and *Terefundus*; (11) some taxa of Volutomitridae, particularly species of *Microvoluta* (Pl. 27o) and the large, smooth species *Volutomitra banksi* (Pl. 27k), which is limited to bathyal depths and occurs widely in Late Miocene to Recent faunas, appearing here during Waiauan time; (12) some Marginellidae, particularly *Hiwia amplifcata* (Pl. 27j) and the short, inflated species of *ProtoGINella*(?) such as *P.*(?) *whitecliffensis*, common in North Taranaki in Tongaporutuan bathyal siltstone, and *P.*(?) *bellensis* (Pl. 27l), particularly abundant in mid-Tongaporutuan bathyal siltstone at the Bell's Creek locality in South Wairarapa; (13) a few taxa of Volutidae, particularly *Mauithoe insignis* (Pl. 27p), limited to Waiauan rocks, and the similar *M. strongi*, limited to Tongaporutuan rocks; *Iredalina mirabilis*, the volute without columellar plaits, occurring only in late Pliocene to Recent bathyal faunas; the very prominently costate *Alcithoe* (*Leporemax*) *rugosa*, limited to Wairarapa Tongaporutuan bathyal siltstone; and *Teremelon knoxi*, an elongate, smooth species limited to Tongaporutuan to Recent bathyal faunas; (14) small Cancellariidae, particularly in genera close to *Anapepta* and *Inglisella*, are much more diverse in bathyal rocks than in those deposited in shallower water; (15) diagnostic bathyal groups among the bullomorph opisthobranchs include many Ringiculidae (particularly *Ringicula* (*Ringiculina*) *ngatapa* and other species of *Ringiculina* in Miocene rocks); many Cylichnidae, and many Retusidae. In the enormous family Turridae, genera that particularly characterise bathyal depths of deposition in New Zealand Neogene rocks include *Apiotoma*, *Cosmasyrinx* (Pl. 27s), *Gemma* (Pl. 27m), *Bathytoma* (*Micantapex*), *Paracomitas* (*Macrosinus*), *Splendrillia* (*Hauturua*) and *S.* (*Wairarapa*), *Awateria*, *Awheaturris*, *Antiguraleus* (= *Oenopota* ?), most genera of Daphnellinae including *Mioawateria* (Pl. 27q), and the large, strikingly shaped *Thatcheria* (Pl. 27t).

The areas where deep-water Mollusca occur in Neogene rocks are better discussed in terms of relatively large areas rather than the many individual localities. At Parengarenga Harbour in the far north, much of the Otaian part of the sequence was deposited in bathyal depths. Some characteristic taxa are *Brevinucula*, *Ledella pakaurangiensis*, *Pseudotindaria*, *Propeamussium zitteli*, two taxa of the Seguenziidae (Marshall 1983a), *Uberella cicatrix*, *Mioawateria*, and common *Eubela* (Daphnellinae), a typical bathyal assemblage, although in this section they occur with other shallow-water taxa that have probably slumped into the deposition site. Some parts of the sequences in Waimamaku Valley, Hokianga, and Pakaurangi Point, Kaipara Harbour, probably were deposited in bathyal depths. In the Waitemata and Waitakere Groups (Otaian and Altonian) of Auckland district, the few faunules of sparse, scattered Mollusca (other than the richly diverse, shallow-water, basal Waitemata Group fauna of Waiheke and Kawau Islands) were deposited in bathyal depths. Perhaps the deepest-water molluscan faunule yet recorded from New Zealand

is the mid-Altonian middle bathyal assemblage from near the Scenic Drive in the Waitakere Ranges (Hayward 1979). The faunule consists of only a few taxa, all among those listed above as diagnostically bathyal, and the arcid identified by P.A.M. (in Hayward 1979, p. 216) as *Notogrammatodon* has since proved to belong in the extremely deep-water genus *Bentharca* Verrill and Bush, 1898, the sole fossil occurrence of the genus we are aware of in New Zealand. Foraminifera in the same samples indicate deposition in 1000-2000 m (Hayward 1979). The similar but more diverse faunule described by Powell (1935b) from Altonian volcanic tuffs at Motutara, south of Muriwai Beach, Auckland, also lived at bathyal depths, but probably somewhat shallower than the Waitakere Ranges faunule.

Molluscan faunules—at least those of Miocene age—recorded from a large area of the North Island east coast north of Gisborne by Marwick (1931) are almost entirely bathyal assemblages. The only major exceptions are (1) mixed bathyal and shallow-water Mollusca in thin slumped conglomerate beds ("Tutamoe conglomerate" facies) occurring sporadically throughout the great thickness of bathyal (and deeper-water?) mudstone of Clifdenian to Waiauan age, and (2) towards the top of the sequence, Tokomaru Sandstone facies (Kapitean) contains shallow-water Mollusca near the present east coast at Tolaga, Tokomaru and Anaura bays. The great thickness and relatively large area of the Opoitian sandstone and sandy mudstone in the Tauwhareparae area, inland from Tolaga Bay, contains faunules that include *Struthiolaria*, *Austrofuscus*, and *Amalda* (*Baryspira*), and seems all to have been deposited on the mid to outer shelf, although Opoitian bathyal faunules probably occur in some areas in the district. The relatively well known faunules of Muddy and Island Creeks, Waipaoa River, of the upper Mata River, and of Pangopango Stream and nearby localities (all Clifdenian to Waiauan in age), described by Marwick (1931), are predominantly bathyal but some include taxa of supposed shallower-water provenance, apparently introduced by mass debris flows. The northern east coast region apparently shallowed permanently by Late Miocene time, but further south in Wairoa Syncline, some of the most extensive deposits of bathyal Pliocene rocks exposed on land in New Zealand crop out almost continuously in the banks of major rivers such as Mangapoke River and Wairoa River. Most of the thick mudstone units (e.g. Mangapoke River: a Lillburnian to Waipipian sequence 4000 m thick, interrupted by two minor unconformities and one minor and one major limestone beds) unfortunately contain very sparse Mollusca, apparently as a result of very rapid deposition. The exceptions are the faunules described by Marwick (1965), largely from bathyal or outer shelf mudstone of Pliocene age in southern Wairoa district. Particularly important here is the upper bathyal Nukumaruan (late Pliocene) faunule from the coastal cliffs south of Wairoa River mouth, which includes protobranch bivalves, *Aeneator* (*Ellicea*), the bathyal ranellid *Sassia kampyla*, a diverse fauna of Turridae, and the large opisthobranch *Scaphander flemingi*, and probably lived in water at least 300-400 m deep. A still deeper facies is probably represented by a faunule of protobranch bivalves in Nukumaruan (late Pliocene) mudstone cropping out not far upstream from

the mouth of Mohaka River. This unit underlies the youngest-known sequence of graded sandstone-mudstone interbeds cropping out on land in New Zealand, on the coast north of Mohaka River mouth (Nukumaruan, here still latest Pliocene).

In North Taranaki, most Early Miocene faunules in the Awakino Gorge sequence and in the Mahoenui Mudstone sequences for some tens of km to the south, seem to have lived in the bathyal zone. Mudstone in the long, almost continuous outcrops along the North Taranaki coast from Urenui (Kapitean) to Whitecliffs and north (Tongaporutuan) was also deposited in bathyal depths, and has sparse molluscan faunules dominated by protobranch bivalves, such as *Neilo* and the huge nuculid "*Ennucula*" *otamaringaensis*, and diverse Turridae. This was the source of most Mollusca described by Marwick (1926c), although some shallow-water Tongaporutuan Molluscs named by Marwick seem to be from slumped shallow-water packets within the bathyal sequence. The exceedingly thick sequences of Miocene bathyal rocks of Taranaki are overlain to the south by a very thick Pliocene sequence, bathyal near the base (Opoitian) but little-studied because of its inaccessibility. The southern Hawke's Bay region includes bathyal (or deeper-water) sequences of Late Miocene rocks in some areas (Makara Basin; and the Tukituki River sequence near Tamumu Bridge), but most rocks are flysch facies (sandstone-mudstone interbeds) and all are very sparsely fossiliferous; a few Mollusca occur on the soles of individual sandstone beds in Makara Basin.

In central and southern Wairarapa, extensive areas of Miocene and Pliocene bathyal rocks crop out, and in some areas they contain diverse molluscan faunules. The most diverse faunules are in Tongaporutuan rocks, and were reported by King (1933), Vella (1954) and Beu (1970c). In the Wainuioru Valley, east of Carterton, small areas of Tongaporutuan upper bathyal mudstone underlying the shallow-water Pliocene sequence of the Maungaraki Range contain diverse, scattered Mollusca including *Neilo* and other protobranchs, common *Aeneator* (*Ellicea*), triphorids and cancellariids, *Teremelon knoxi*, *Thatcheria*, and many smaller Turridae. There are surprisingly few taxa in common with the more diverse, upper bathyal, mid-Tongaporutuan faunules of Bell's Creek and McLeod's Stream, tributaries of Mangaopari Stream near White Rock Road, east of Martinborough in South Wairarapa. The Mangaopari faunules are dominated by abundant *Protoginella*(?) *bellensis*, a few large Turridae such as *Comitas*, *Inquisitor*, *Bathytoma* (*Micantapex*), *Lucerapex*(?), and *Apiotoma*, and very diverse smaller Turridae; *Gemmula peraspera* (Pl. 27m) and *Propeamussium zitteli* (Pl. 27e) (or a similar species) are common at McLeod's Stream, but were not collected at Bell's Creek, only two km to the west, a further example of the kind of patchy differences between bathyal faunules remarked on by Maxwell (1988a, p. 24-25) for the Stillwater Mudstone faunules near Greymouth and by Dell (1956c, p. 198) for modern Chatham Rise assemblages. In the Palliser Bay coastal cliffs (southern Wairarapa coast), similar Turridae to those at Mangaopari Stream occur in bathyal mid-late Tongaporutuan mudstone well above the Mesozoic basement to the west of Hurupi Stream, but are much rarer and less diverse than further north. The Palliser Bay

sequence deepened until about Kapitean time, so Kapitean to Waipipian rocks lack Mollusca, but by Mangapanian (or perhaps earliest Nukumaruan) time the deposition site apparently had the ideal combination of depth and sedimentation rate to record some of the most diverse upper bathyal faunules known in New Zealand.

Siltstone cropping out to the east of the mouth of Whangaimoana Stream, and continuously between Whangaimoana Stream and Lake Ferry to the west, contains relatively common Mollusca (Beu 1967a, 1969) including protobranch bivalves, a few small naticids, *Galeodea triganceae*, *Sassia kampyla*, *Pagodula*, *Comptella*, common *Aeneator* (*Ellicea*) *orbitus*, *Nassaria incerta* (Cernohorsky 1982, p. 137), *Volutomitra banksi*, the modern bathyal fascioliariid "*Pleia*" *cryptocarinata*, common small *Alcithoe*, and abundant diverse Turridae ranging from the very large *Comitas onokeana* to the small species of *Splendrillia*. Other taxa with less restricted depth ranges also occur, such as *Chlamys*, the venerid *Marama murdochi* and rare *Pellicaria* specimens, and a depositional depth of about 300-400 m seems likely. A very small (now largely eroded away) coral thicket in the siltstone cliff about one km east of Lake Ferry contains a faunule unique among Pliocene bathyal faunules in New Zealand in being dominated by hard-substrate, epifaunal taxa such as limids (notably the youngest record of *Ctenoides* in New Zealand), *Pododesmus* (*Monia*), *Emarginula*, and *Tugali*.

In the main Neogene sequences in Marlborough, in Upton Brook and Blind River in Awatere Valley, the bathyal mid-regions of sequences (middle Tongaporutuan to Kapitean) contain only very sparse Mollusca, and sequences shallowed to shelf depths by early Pliocene time. The opposite seems to have occurred in southernmost Marlborough and northern North Canterbury, where Miocene bathyal facies are rare but mid-late Pliocene time is represented by bathyal mudstone and an unusual slumped conglomeratic mudstone lithofacies ("Bourne conglomerate") probably emplaced by mass debris flows. The Pliocene bathyal rocks occur in narrow in-faulted depressions between hills of Mesozoic basement and seem to be, at least in part, original submarine canyons in situ, formerly leading into the proto-Hikurangi Trench but now uplifted. The faunule in siltstone exposed on the summit of the hill east of Glenstrae Station, Oaro Valley (Beu 1979) is particularly diverse, and seems to represent a canyon-head accumulation of bathyal and some slumped shallower-water Mollusca. Similar but less diverse Mollusca (including *Chlamys patagonica delicatula*, common *Aeneator* (*Aeneator*) *elegans* and *A. (Ellicea) orbita*, *Falsilunatia ambigua*, *Comitas onokeana*, and diverse small Turridae) occur widely in North Canterbury in the Conway River-Parnassus area in "Bourne conglomerate" facies.

Further south in North Canterbury, Pliocene bathyal facies are almost unknown, but Late Miocene bathyal Mollusca are known in a few places. A zone of Tongaporutuan bathyal mudstone cropping out in the Kaiwara River, and in the Hurunui River and Cobbold's Creek to the south, contains sparse Mollusca including *Neilo sublaevis*, *Mauithoe strongi*, *Galeodea*, *Bathytoma* (*Micantapex*), and *Comitas* aff. *onokeana*. A diverse but sparse molluscan faunule occurs in Waiauian siltstone

cropping out in sea cliffs at Glenafric (mouth of Dovedale Stream), source of the illustrated specimen of *Mauithoe insignis* (Pl. 27p). The large faunule from this locality listed by Fleming (in Wilson 1963, p. 56) came largely from a thin lens of shell collected by Dr B.H. Mason in 1946, and evidently included many slumped shallow-water taxa, but bathyal taxa present include *Jupiteria*, *Uberella cicatrix*, *Mauithoe insignis*, *Hiwia amplificata*, and several taxa of Turridae. Bathyal faunas are almost unknown in the extensive Neogene deposits further to the south in eastern South Island except for some assemblages from the Mount Harris Formation (Waitakian-Altonian) in North Otago and South Canterbury – these, however, probably lived in the uppermost part of the zone, if not at outer shelf depths.

In Westland, the bathyal Stillwater Mudstone of Greymouth district contains widespread, diverse molluscan faunules of Clifdenian to Waiauan age. The diverse Clifdenian faunule of Alexander Street, Greymouth, comes both from a basal zone of slumped blocks, with some included shallow-water fossils, and from the overlying siltstone. The beautifully preserved, diverse fauna of the Karoro area (Waiauan) has been described in detail by Maxwell (1988a). A detailed paleoecological analysis of the Karoro Quarry and Power Road faunules indicated a depth of deposition of about 400–800 m. Common taxa in the fauna are protobranchs (13 species, more than half the total number of bivalves), *Taniella mima*, *Nassarius (Hima) karoroensis* (more than 50% of Karoro Quarry gastropod specimens, but only 20% at Power Road), *Microvoluta*, marginellids (four taxa), and diverse Turridae (16 species) and Cancellariidae (six species), with several opisthobranchs and scaphopods; the gastropods are greatly dominated by carnivorous neogastropods. A moderately diverse Clifdenian assemblage of largely undescribed Turridae, with a few other taxa such as common *Pakaurangia* (= *Teramachia*), occurs in a single outcrop on the (disused) Marsden-Kumara road, representative of widespread, but at other localities much less diverse, Middle Miocene bathyal Molluscan faunules in the Hokitika district. Pliocene rocks of Westland are poorly fossiliferous in most places, and where Mollusca occur they are nearly all of shallow-water facies, although sparsely fossiliferous early Pliocene mudstone with *Galeodea (Galeocorys)* overlying the Kapitean sequence in Kapitea Creek, south of Hokitika, possibly was deposited at a bathyal depth.

Finally, some of the most interesting bathyal molluscan faunules we are aware of in New Zealand are the undescribed Waiauan ones in siltstone cropping out in the western bank of the Waiau River opposite the Monowai power house, in western Southland, on the thick, deep-water limb of the Waiau Syncline. The faunules were discussed in more detail by Maxwell (1988a, p. 11); taxa present include a large turbinid (probably shallow-water), common naticids including *Taniella* cf. *mima*, *Galeodea (Galeocorys)*, neogastropods such as *Microvoluta*, *Exilia*, and common Turridae including *Gemmula*, *Cosmasyrinx* and *Thatcheria*.

Bathyal Neogene molluscan faunas of New Zealand constitute a poorly known field for extensive further study. They offer rich potential rewards in such fields as the origins of the present bathyal fauna, and studies of evolutionary rates, as bathyal faunas seem to have

evolved more slowly than those in shallower water, i.e., Miocene bathyal faunas seem to have more in common with the modern New Zealand bathyal fauna than Miocene shallow-water faunas do with modern shelf faunas; but this impression needs to be tested on the basis of detailed studies.

REPRESENTATIVE NEOGENE BATHYAL MOLLUSCA

Pl. 27 a,c. *Pseudotindaria* n. sp. (Neilonellidae)

Size moderate for genus (length 4.5–6.5 mm), ovate, strongly inflated, rather thick-shelled, anterior end convex, posterior end subangled. No lunule; escutcheon narrow, slightly concave. Commarginal sculpture of narrow, low, rounded ridges with interspaces of similar or somewhat greater width, absent from umbones. Radial sculpture of very weak striae only. Hinge relatively heavy, strongly arched, continuous and considerably thickened beneath beaks, anterior and posterior series of teeth meeting, i.e., not separated by a resilifer. Proximal 5 or 6 posterior teeth excavated dorsally to accommodate very short, external ligament. Adductor muscle scars flush or impressed, anterior one the larger; pallial sinus rounded, deep, extending about 0.33 length of shell. Internal margins smooth; interior highly polished.

Otaian, mouth of Waioha Stream, north shore of Parengarenga Harbour (common).

This new species is one of a group of small taxodont bivalves that previously were referred to either *Jupiteria* Bellardi, 1875 (Nuculanidae) or to *Austrotindaria* Fleming, 1948 (Neilonellidae) but differ markedly from these genera in hinge and ligament characters (Maxwell 1988a, p. 41–42). They are assigned to *Pseudotindaria* Sanders and Allen, 1977, which was proposed for deep-water bivalves resembling species of *Tindaria* Bellardi, 1875 in most shell characters but differing in having a well defined pallial sinus. Modern species of *Pseudotindaria* are from very deep water (abyssal) environments but records of fossil species from New Zealand are from much shallower (mostly bathyal) habitats (Maxwell 1988a, p. 15, 42).

The Parengarenga species differs from *Pseudotindaria kapua* (Opoitian), *P. kouhaiensis* (Tongaporutuan or Kapitean) and *P. nugax* (Tongaporutuan) in having a relatively restricted smooth area on the umbones, and in its finer commarginal sculpture.

Figured specimen (Pl. 27a, c): GS 13105, NO2/f67, mouth of Waioha Stream, north shore Parengarenga Harbour, Northland, Otaian (NZGS) x 6.

Pl. 27 e. *Propeamussium zitteli* (Hutton, 1873) [*Pecten zitteli* Hutton 1873b, p. 32; *P. (Amusium) zitteli*; *Parvamussium zitteli*] (Propeamussiidae).

Moderately large for family (height 20–30 mm), little-inflated, subcircular to oval, typically higher than long. Ears relatively small, subequal, no byssal notch. Exterior smooth except for very fine commarginal ridges. Interior with 8–10 prominent radial costae, in many specimens reaching only 0.67 distance across disc. Each ear with prominent auricular crus at base.

Whaingaroan-Tongaporutuan(?); Whangape Lake, Waikato district, Whaingaroan (type); numerous localities throughout New Zealand, mainly in siltstone or mudstone.

The status of *Propeamussium papakurense* (Otaian, Papakura, Auckland) is uncertain (Beu 1970c, p. 214) – it may be a synonym of *P. zitteli*. However, because of the great fragility of specimens of *Propeamussium* and

because much fossil material consists of steinkerns (internal moulds), it is very difficult to know how many species are represented and whether *P. zitteli* really has the very long stratigraphic range adopted here.

P. zitteli was assigned to *Parvamussium* Sacco, 1897 by Marwick (1928, p. 452) but the oval shape and the absence of a byssal notch indicate that it belongs in *Propeamussium* (Maxwell 1988a, p. 44). On the other hand, the generally much smaller, internally ribbed species that Marwick (1928, p. 452) assigned first to *Variamussium* Sacco, 1897 and later (Marwick 1931, p. 64) to *Ctenamussium* Iredale, 1929 are of more nearly circular shape and have a well developed notch, and may be included in *Parvamussium* (Maxwell 1988a, p. 44). Species of *Parvamussium* typically have more prominent external sculpture than those of *Propeamussium*.

Although *Propeamussium* and *Parvamussium* superficially resemble internally ribbed pectinids such as *Amusium*, they differ sufficiently from the Pectinidae in anatomy and shell structure to warrant inclusion in a separate family Propeamussiidae (Waller 1972). Pectinids are most common in depths of less than 200 m (although some species occur as deep as 6000 m) whereas propeamussiids are rare in depths less than 60 m and are most common below 150 m. The most dramatic difference between Pectinidae and Propeamussiidae, however, is in feeding habits—the former are suspension feeders, whereas the latter are carnivores living on small crustaceans (mostly copepods and ostracodes) (Knudsen 1967, p. 327-329). Hicks and Marshall (1985) have demonstrated that bathyal propeamussiids capture male copepods to the exclusion of females, greatly influencing the sex ratio of the copepods, and suggested that propeamussiids have mantle-margin luminescent organs with which they lure male copepods seeking luminescent females.

Figured specimen (Pl. 27e): GS7862, NO2/f7554, mouth of Waioha Stream, north shore Parengarenga Harbour, Northland, Otaian (NZGS) x 1.

Pl. 27 d,f. *Bartrumia tenuiplicata* (Bartrum, 1919) [*Raeta tenuiplicata* Bartrum 1919, p. 97; *Macoma tenuiplicata*]. Type species of *Bartrumia* Marwick, 1934 (Tellinidae: Macominae).

Moderate-sized for family (length 30-40 mm), ovate-trigonal, strongly inflated, thin-shelled; umbones sloping backwards; beaks orthogyrous or slightly prosogyrous, at or somewhat behind middle of length. Low, broadly rounded ridges extend from umbo to antero-ventral and postero-ventral junctions. Anterior margin strongly and broadly convex, posterior end with short, narrowly rounded and weakly twisted rostrum. Commarginal sculpture of fine, low, well spaced ridges; radial sculpture of feeble striae. Hinge narrow, left valve with lamellar anterior and posterior cardinal teeth; right valve with narrowly triangular anterior cardinal and larger, bifid median cardinal; no lateral teeth. Ligamental groove long and narrow, attachment area for inner ligament narrowly triangular, slightly concave. Anterior adductor muscle scar very elongated parallel to anterior margin of shell, posterior scar much smaller, subrectangular. Pallial sinus moderately deep, extending beyond middle of shell, ventral margin partly confluent with pallial line.

Altonian-Tongaporutuan; western end of Okahukura tunnel, Taranaki, Lillburnian? (type) and other localities in Taranaki and southwest Auckland; Awamoa Creek, Oamaru; Stanton River, North Canterbury.

Bartrumia tenuiplicata is distinguished from other New Zealand tellinids by its relatively short shell, its strong

inflation, its weak rostral twist and its very long anterior adductor muscle scar. The holotype and topotypes of *B. tenuiplicata* are articulated and largely decorticated specimens and are therefore difficult to compare with shells from other localities, so the limits of the species (and its stratigraphic range) must be uncertain. The only other species named to date, *B. oneroaensis* (Otaian, Oneroa, Waiheke Island), has more erect umbones than *B. tenuiplicata* and is probably distinct. Specimens from the Mount Harris Formation (Otaian), Tengawai River near Sutherland's, South Canterbury, are more elongate and have more widely spaced commarginal sculpture than either *B. tenuiplicata* or *B. oneroaensis* and probably represent a third species.

Bartrumia is known definitely only from New Zealand, where it ranges from at least Duntroonian to Tongaporutuan. It may be represented in the modern West African fauna by *Macoma cancellata* (Sowerby, 1873), type species of *Rostrimacoma* Salisbury, 1934. *Bartrumia* seems to be closely related to *Leporimetus* Iredale, 1930 (type species: *L. spectabilis* (Hanley, 1844), Recent, Australia), which has a similar anterior adductor muscle scar but differs in having a much stronger rostral twist. *Bartrumia* occurs commonly in massive siltstone and mudstone of probably bathyal environment, but it is also present in much shallower-water faunules.

Figured specimen (Pl. 27d, f): GS 9520, J41/f8029, Awamoa Creek, North Otago, Altonian (NZGS) x 1.5.

Pl. 27 b. *Pholadomya neozelanica* Hutton, 1885b [p. 330] (Pholadomyidae).

Moderately large for family (to 80 mm long), highly inflated, with very thin, fragile, highly nacreous shell, and umbo close to anterior end. Sculpture of many rather indistinct commarginal ridges and, on central region, about 17 to 20 low, widely spaced radial costae, forming weak nodules at sculptural intersections; anterior eighth and posterior fifth of length lack obvious radial sculpture. Escutcheon weakly defined, a narrow, smooth, weakly concave area on each side of dorsal margin. Anterior end short, inflated, bearing very weakly defined, pouting lunule, occupying third of shell height, bounded by very shallow, wide depression. Interior not seen in any New Zealand material of the genus; modern species lack hinge teeth. Almost all specimens distorted in a variety of ways.

(Duntroonian ?) Otaian(?) to Tongaporutuan; rare in bathyal siltstone and some shelf assemblages throughout New Zealand.

Hutton's (1885b, p. 330) holotype of *Pholadomya neozelanica*, illustrated by Suter (1915, p. 62, pl. 7, fig. 1), is said to be from "Oamaru"; the sole specimen we are aware of subsequently collected in Oamaru district is from Mount Harris Formation in South Oamaru (Altonian) and this could well be the horizon of Hutton's type. *P. neozelanica*, of large size and very inflated form, with the umbo very near the front, is the most commonly encountered of at least five species of pholadomyacean bivalves recorded from the New Zealand Cenozoic. Until recently these were all included in the Pholadomyidae and assigned to either *Pholadomya* itself or to *Procardia* (Pl. 9h, i), but some modification to this classification is necessary in the light of work by Morton (1982). He proposed a new family Parilimyidae for anomalodesmatans that resemble pholadomyids in most shell characters, but differ significantly in anatomical details. In particular, parilimyids have "taenioid" (i.e. tape-like) siphonal retractor muscles, which leave

prominent scars on the inside of the shell (a single scar near the centre of each valve), whereas pholadomyids have only greatly reduced siphonal muscles. On the other hand, parilimyids lack pedal retractor muscles, whereas these are well developed in Pholadomyidae. Unfortunately, fossil pholadomyaceans are rarely well enough preserved to discern muscle scar details, so assignment to one or other of these families normally depends on their similarity to extant species.

Pholadomya neozelanica resembles the type species of the genus (*P. candida* Sowerby, 1823; Recent, Caribbean) in having umbones close to the anterior end, and in its sculptural plan, and is probably congeneric, but *P. waitotarana* (Opoitian-Waipipian) and *P. warrenae* (Tongaporutuan) have more centrally placed umbones and have much weaker radial sculpture than *Pholadomya neozelanica*. In these respects they are much closer to the extant New Zealand species *P. maoria* Dell, 1963, which Morton (1982, p. 167) assigned to *Parilimya* Melvill and Standen, 1889, and although there is only limited similarity to *P. haddoni* Melvill and Standen, 1889 (Recent, Torres Strait), the type species of the genus, we have provisionally assigned them here. The problematic *Thracia neozelanica* (Pl. 46g, i) is also provisionally included in *Parilimya*, but like *P. waitotarana* and *P. warrenae* it almost certainly requires a new genus. *Procardia*, which is represented in the New Zealand Cenozoic by *P. dolicha* (Pl. 9h, i), has previously been regarded as a pholadomyid, but it is very similar to *Panacca* Dall, 1903, which Morton (1982, p. 161-163) included in the Parilimyidae.

"*Parilimya*" *warrenae* is considerably smaller than *Pholadomya neozelanica* (length up to about 55 mm), is lower and less inflated, has a less convex ventral margin, has umbones situated at about a third of the length from the anterior end, and has less prominent radial sculpture. There are few obvious differences, however, between *P. warrenae* and *P. waitotarana*, and their relationship needs further study; specimens of *P. waitotarana* are known from Waipipi, Waverley Beach (Waipipian; type only), and from GS 1548, Mangaone Crossing, Wairoa district, Hawkes Bay (Opoitian). *P. maoria* differs from *P. waitotarana* in having stronger radial costae and a more convex ventral margin.

An unnamed pholadomyacean, probably a parilimyid, is represented by a specimen in NZGS from Whitewater Creek, Castle Hill Basin, Canterbury (Duntroonian) with a nearly central umbo, a relatively thick shell, and prominent radial costae with no obvious commarginal sculpture; this may be the second species illustrated by Suter (1915, pl. 6, fig. 2) as *Pholadomya neozelanica* as, although Suter's specimen is unlocalised, the preservation appears to match that of the Whitewater Creek shell. It is not a typical *Pholadomya*, but has considerable similarity to *P. pacifica* Dall, 1907 (Recent, Japan), referred by Morton (1982, p. 172) to *Parilimya* although, like the other species he assigned there, it has little similarity to the type species. Another possibly distinct species is represented by an internal mould of a small (length 40 mm), evenly oval specimen from "GS 945, breccia below Kakanui limestone, Kakanui" collected and listed by Park (1918, p. 68); the specimen is almost certainly from the top of the Deborah Volcanic Formation (Whaingaroan).

Procardia dolicha (Pl. 9h, i) is readily distinguished from all other New Zealand pholadomyaceans by its extremely short anterior end and almost flat anterior area.

Although pholadomyaceans are often considered to be characteristic of deep waters they are also recorded from much shallower environments. *Pholadomya candida* itself apparently lives at depths of about three to six metres in the Virgin Islands (Runnegar 1979) and at least one of the records of *P. neozelanica* (Tongaporutuan, Kaiwara River, North Canterbury) is from a very shallow water assemblage. "*Parilimya*" *maoria* is known only from the upper bathyal zone, but *P. warrenae* is apparently limited to shallow-water "Hurupi facies" faunules in Palliser Bay (Tongaporutuan). Powell (1931a, p. 90) concluded that the fossiliferous beds at Waipipi—the type locality of "*Parilimya*" *waitotarana*—were deposited at inner-shelf depths.

Figured specimen (Pl. 27b): GS 4454, U25/f6483, tributary of Waikohi Stream, east of Waikohi Valley Rd, east of Puketoi Range, southern Hawke's Bay, Tongaporutuan (NZGS) x 1.

Pl. 27 g,h. *Uberella cicatrix* Marwick, 1931 [p. 100] (Naticidae: Poliniceinae).

Very small for family (height 6.4 mm, diameter 5.5 mm), oval with whorl outlines slightly flattened, almost smooth, with very low spire. Sculpture of consistent, short, shallow axial grooves below suture on spire, becoming weak on last whorl, parallel to outer lip, which is prosocline below, then curves in to suture at little more than a right angle. Inner lip with moderately thickened callus, bearing single central denticle; umbilicus almost completely closed in most specimens, a few specimens with an extremely narrow chink.

Otaian-Tongaporutuan; Kapitean?, Te Karaka, Gisborne, Clifdenian (type). Present in most Miocene bathyal faunules throughout New Zealand, of Otaian (Parengarenga Harbour only) and Altonian to Tongaporutuan age, but not in the Waiauan faunules from the Stillwater Mudstone described by Maxwell (1988a).

Uberella cicatrix was apparently succeeded by *U. cicatricella* (Opoitian-Mangapanian), which differs in its slightly higher spire, its less laterally flattened whorls, its finer, more numerous and more closely spaced subsutural axial grooves, and its more consistently (if very narrowly) open umbilicus. *U. cicatricella* appears to be intermediate between *U. cicatrix* and the Nukumaruan to Recent *U. denticulifera*, which differs from its presumed ancestors in its slightly larger size (to 9 mm high), its taller spire, its only weak signs of axial subsutural grooves, and its slightly more open umbilicus. Although *U. cicatrix* seems to be exclusively a bathyal species, its apparent descendants seem both to be both shelf and upper bathyal species, and *U. denticulifera*, for example, is much more common at Castlecliff, Wanganui, in offshore siltstone of the Okehu and Kai-Iwi Groups (Castlecliffian, shelf facies) than is the modern shallow-water species *U. vitrea*.

Figured specimen (Pl. 27g, h): holotype, GS1366, Y17/f6486, alternating sandstone and siltstone in cutting on highway (now State Hwy 2) one to two km west of Te Karaka, Gisborne, Clifdenian (TM3783, NZGS) x 6.

Pl. 27 i. *Aeneator (Ellicea) willetti* (Fleming, 1955) [*Ellicea willetti* Fleming 1955, p. 1057] (Buccinidae).

Small for genus (30 mm high), robust, with rather short spire, rather

short siphonal canal directed slightly to left, and evenly rounded whorls. Sculpture of prominent, narrow, flat-topped, widely and evenly spaced spiral cords only; 3 prominent cords (plus 2 weaker on sutural ramp) on spire whorls, and 10 on last whorl, with 3-4 low cords decreasing in prominence down neck. Aperture with thickened, lightly reflected lips; columellar callus bearing several low denticles. Protoconch low, dome-shaped, of 2 smooth whorls.

Kapitean, Bluecliff, Te Waewae Bay (type) and middle Tongaporutuan, Wainuioru Valley, Wairarapa.

Aeneator willetti is easily distinguished from other *A. (Ellicea)* species by its particularly prominent spiral cords. The type population completely lacks axial costae, but the middle Tongaporutuan population in southern Wairarapa referred to this species includes specimens with no axial costae and a range of specimens with weak to moderately prominent costae; possibly the Wairarapa population is intermediate between the typical *A. willetti* and a species resembling *A. conformatus*.

The Kapitean *A. (Ellicea) antorbitus* has weaker spiral cords and consistent, prominent, axial costae; it is common in outcrops near the mouth of Waikoau River, Te Waewae Bay, close to the type locality of *A. willetti*, and as there are few apparent differences in facies between these localities the reason for two such distinct species of *A. (Ellicea)* occurring in rocks of the same age is not obvious. The rare Tongaporutuan species *A. (Ellicea) henchmani* and *A. conformatus* differ from *A. willetti* in being smaller, having lower, narrower spiral cords, and having prominent axial costae on early spire whorls. The poorly known *A. (Ellicea) perobtus* (Opoitian, Dannevirke) is similar to *A. willetti*, but has axial costae. The common Pliocene bathyal index species *A. (Ellicea) orbitus* (= *Ellicea carinata* Powell, 1929; Beu 1967a, p. 106), the possibly synonymous *A. wairoanus*, and the closely similar Recent species *A. recens* (Dell, 1951) differ

from *A. willetti* in their larger size (to more than 50 mm high), their slightly less prominent sculpture of narrower, more numerous spiral cords, and in bearing short axial costae below the suture on spire whorls, descending as low as the last whorl on at least some specimens in almost all faunules. Finally *A. validus* (Pl. 37j) is similar to *A. antorbitus*, differing in its larger size, its slightly thinner shell, its more prominent axial costae, and its prominent, horizontal, channelled sutural ramp.

Figured specimen (Pl. 27i): holotype, GS2944, C46/f9487, Bluecliff, Te Waewae Bay, Southland, Kapitean (TM6795, NZGS) x 1.5.

Pl. 27 j. *Hiwia amplificata* (Marwick, 1931) [*Marginella (Hiwia) amplificata* Marwick 1931, p. 129]. Type species of *Hiwia* Marwick, 1931 (Marginellidae).

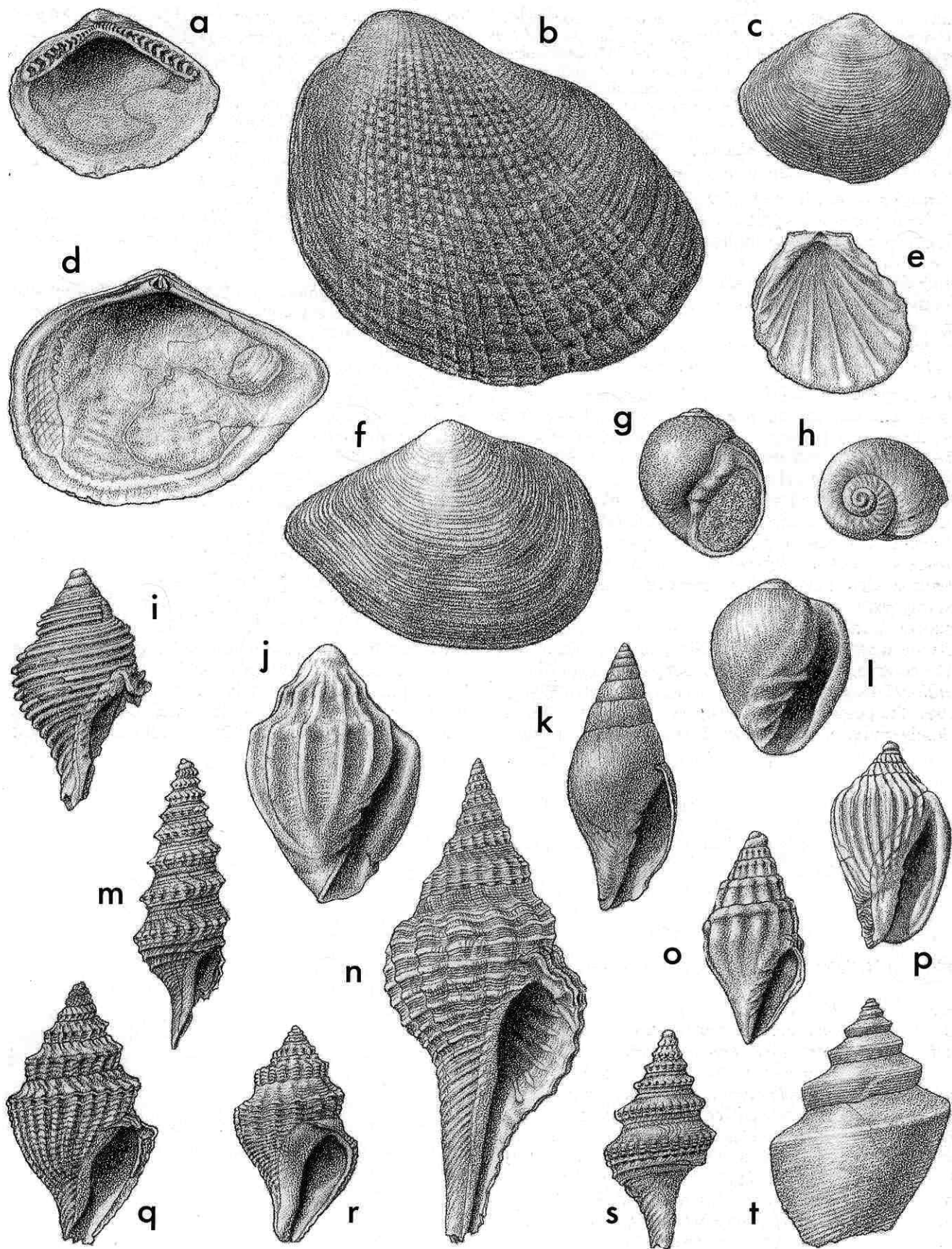
Small for family (5.1 x 3.3 mm) and very wide, with smoothly rounded apex and prominent, concave sutural ramp. Protoconch and sutures hidden by smooth callus; exterior smooth and glossy except for prominent, narrowly rounded, widely spaced axial costae that commence abruptly as shoulder nodules, extend to lower suture on spire whorls and extend down over most of last whorl. Outer lip thick, bevelled to thin, smooth inner margin. Inner lip not thickened; bearing 4 prominent plaits increasing in obliquity down columella, lowest bordering anterior canal; anterior end of aperture unnotched, weakly thickened.

Otaian-Tongaporutuan; Te Karaka, Gisborne, Altonian or Clifdenian (type); Northland, Nelson, Westland, many localities in Gisborne district, but not known in Wairarapa district, and nowhere common. A very useful indicator of Miocene bathyal facies.

Marwick (1931) compared *Hiwia* with the Recent tropical American *Glabella* Swainson, 1840, which differs from *Hiwia* in having prominent denticles inside the outer lip, and in having a distinct anterior notch, as well as in its much larger size. Coan (1965) published a revised

Plate 27 Bathyal Miocene (Otaian-Tongaporutuan) Mollusca.

- a,c. *Pseudotindaria* n.sp., x 6.
- b. *Pholadomya neozelanica* Hutton, x 1.
- d,f. *Bartrumia tenuiplicata* (Bartrum), x 1.5.
- e. *Propeamussium zitteli* (Hutton), x 1.
- g,h. *Uberella cicatrix* Marwick, x 6.
- i. *Aeneator (Ellicea) willetti* (Fleming), x 1.5.
- j. *Hiwia amplificata* (Marwick), x 10.
- k. *Volutomitra (Volutomitra) banksi* (Dell), x 1.5.
- l. *Protoginella (?) bellensis* (Beu), x 6.
- m. *Gemmula peraspera* Marwick, x 2.
- n. *Falsiculus tangituensis* (Marwick), x 2.
- o. *Microvoluta marwicki* (Vella), x 6.
- p. *Mauithoe insignis* (Marwick), x 1.
- q. *Mioawateria personata* (Powell), x 6.
- r. *Marshallena curtata* (Marwick), x 2.
- s. *Cosmasyrinx monilifera* Marwick, x 4.
- t. *Thatcheria pagodula* (Powell), x 1.5.



classification of the Marginellidae in which *Hiwia* is regarded as a full genus distinct from *Glabella*. *Hiwia* seems to be represented in the southern Australian Late Eocene fauna by *Marginella aldingae* Tate, 1878, which was referred to *Plicaginella* Laseron, 1957 by Laseron (1957, p. 285). The type species of *Plicaginella*, however, has a strong anterior notch, whereas *M. aldingae* apparently lacks such a notch.

Figured specimen (Pl. 27j): holotype, GS 1295, Y17/f7474, 3.2 km up Mangaruke Stream [Mangaruaki Str. on Y17] from Waipaoa River, east of Te Karaka, Gisborne, Altonian or Clifdenian (TM 6843, NZGS) x 10.

Pl. 27 l. *Protoginella(?) bellensis* (Beu, 1970) [*Euliginella bellensis* Beu 1970c, p. 226] (Marginellidae).

Small for family (5.5 x 4.3 mm), short and very inflated, with low spire, rounded, polished whorls, no sculpture other than faint growth lines, and only thin external glaze, with clearly visible suture and distinct, thickened, relatively wide inner lip callus. Outer lip thickened, bevelled to thin, smooth inner edge. Inner lip callus extending full height of aperture, smooth except for 4 prominent plaits, highest plait slightly above centre of columella; plaits increase in obliquity downwards. Some specimens with shallow indistinct groove around outer (left) edge of basal area of inner lip callus.

Tongaporutuan, Opoitian?; Bell's Creek, Mangaopari Stream (type); common at all southern Wairarapa bathyal mollusc localities (middle Tongaporutuan) and much the most common mollusc at the locality with the most diverse assemblage, Bell's Creek, a tributary of Mangaopari Stream.

Specimens from several Opoitian localities in Mangapoike River, Wairoa district, Hawke's Bay have been identified by Dr J. Marwick as "*Marginella whitecliffensis*" and appear inseparable from *Protoginella(?) bellensis* (although they were not recorded by Marwick 1965). The similar *P.(?) whitecliffensis* (Tongaporutuan, North Taranaki) has a slightly more conical spire, a shorter inner lip callus (extending only half the height of the lip), less prominent plaits, and a more marked basal groove than *P.(?) bellensis*. This species group appears to be widespread in Late Miocene-early Pliocene bathyal facies.

These species have previously been placed in *Euliginella* Laseron, 1957 (synonymised by Coan (1965, p. 190) with *Cystiscus* Stimpson, 1865, although in our opinion *Euliginella* and *Cystiscus* are distinct) but *Euliginella* species are markedly smaller and have many small denticles inside the outer lip that are lacking from the *P. bellensis-whitecliffensis* group.

Figured specimen (Pl. 27l): paratype, GS10200, S27/f8945, Bell's Creek, Mangaopari Stream, South Wairarapa, middle Tongaporutuan (TM 4616, NZGS) x 6.

Pl. 27 k. *Volutomitra (Volutomitra) banksi* (Dell, 1951) [*Proximitra banksi* Dell 1951, p. 54] (Volutomitridae).

Largest New Zealand member of family (30-55 mm high), most specimens almost smooth apart from faint growth lines, with weakly inflated whorls, thin apertural lips, moderately long, almost straight, widely open anterior canal, and 3 prominent, narrow columellar plaits. Outer lip with long, very shallow sinus occupying upper half of lip, swinging forward weakly opposite neck, then contracted sharply ("cut away") to canal tip (slightly incomplete on figured specimen). Well preserved specimens with sculpture of low axial costae and 7 spiral grooves on first 3 spire whorls, fading out down spire, and about 10 low spiral cords around neck, but these are not seen on most fossils. Protoconch not well preserved, dome-shaped, of about 2 apparently smooth whorls.

Waiauian-Recent; Recent, New Zealand (type); not uncommon in the bathyal zone around New Zealand, especially off south-eastern South Island. Fossil specimens have been examined from Glenafric, North Canterbury (Waiauian), southern Wairarapa (Tongaporutuan; Beu 1970c), Palliser Bay (Mangapanian-Nukumaruan; Beu 1967a), Oaro, Marlborough (Nukumaruan; Beu 1979) and nearby Nukumaruan localities in North Canterbury, the illustrated Pitt Island specimen (Waipipian), and GS8310, rail cutting, Kapara, Blenheim, Marlborough (Mangapanian?), so the species is apparently uncommon but widespread in late Middle Miocene to Recent bathyal facies.

The superficial lack of sculpture, the elongate fusiform shape, and the large size among New Zealand late Neogene mitriform gastropods make *Volutomitra banksi* easily recognised. Cernohorsky (1970a, p. 100) showed that *V. banksi* is a typical species of *Volutomitra* closely resembling the type species, *V. groenlandica* (Beck in Möller, 1842) and the northern Pacific *V. alaskana* Dall, 1902. Cernohorsky (1981c, p. 1000) further considered the New Zealand taxon *Waimatea* Finlay, 1926 to be a subgenus of *Volutomitra*, presumably differentiating the two by the prominent sculpture present on many *V. (Waimatea)* species. However, the type species of *Waimatea*, *Mitra inconspicua* Hutton (Pl. 8i), is almost smooth and closely resembles species of *Volutomitra* (sensu stricto). We doubt that these are distinct taxa, although not all the coarsely sculptured species assigned at present to *Waimatea* necessarily belong in *Volutomitra*. For the time being, our list follows Cernohorsky's classification.

Figured specimen (Pl. 27k): GS 12161, CH/f23A, Whenuataru Tuff, cliff-top outcrop north of "The Point" homestead, west of Flowerpot Harbour, Pitt Island, Chatham Islands, Waipipian (NZGS) x 1.5.

Pl. 27 o. *Microvoluta marwicki* (Vella, 1954) [*Vexillitra marwicki* Vella 1954, p. 544; *Austromitra marwicki*] (Volutomitridae).

Small for family (6.4 x 3.2 mm), glossy, with moderately tall, weakly stepped spire, spiral row of low nodules below suture (as in most *Microvoluta* species), and sculpture of 13 prominent, rounded axial costae per whorl. Costae extend well down onto base of last whorl, but fade out over last quarter to half whorl on most specimens. No spiral sculpture, other than subsutural nodule row. Inner lip bearing 4 low, narrow, oblique plaits, increasing in obliquity down columella. Protoconch dome-shaped, of 1.5 apparently smooth whorls.

Tongaporutuan; Bell's Creek, Mangaopari Stream (type); common at South Wairarapa bathyal siltstone localities (middle Tongaporutuan), but not known to us from elsewhere.

Microvoluta marwicki is a typical representative of a group of similar small *Microvoluta* species occurring in many Miocene bathyal siltstone faunules throughout New Zealand, although not known in Pliocene or younger bathyal faunules. The larger and more elongate, more weakly sculptured *M. marginata* occurs in Opoitian—Recent shallow-water faunules. The bathyal *M. fracta* (Tongaporutuan, North Taranaki) has a much shorter spire than *M. marwicki*, but is otherwise similar, and the bathyal *M. wainuioruensis* (Tongaporutuan, southern Wairarapa) has axial sculpture on early spire whorls only. Cernohorsky (1970c) regarded *Vexillitra* Marwick as a

disparate group, assuming some species were based on juvenile specimens of species in other genera, and divided the species between *Austromitra*, *Conomitra* and *Proximitra* (*Parvimitra*). Comparison of the holotypes and other specimens leaves no doubt that *Vexillitra* species are based on adult shells, and are closely related species of *Microvoluta*. We regard *Vexillitra* as simply a synonym of *Microvoluta* (Maxwell 1988a, p. 55-56).

Figured specimen (Pl. 27o): holotype, S27/f8507, Bell's Creek, Mangaopari Stream, southern Wairarapa, middle Tongaporutuan (TM 6796, NZGS) x 6.

Pl. 27 n. *Falsiculus tangituensis* (Marwick, 1926) [*Euthriofusus tangituensis* Marwick 1926c, p. 320; *Falsiculus waiauensis* Finlay 1930e, p. 265] (Fasciolaridae).

Size moderate for genus (height 40-70 mm), robust, broadly fusiform, spire 0.3 total height. Protoconch conical, of 3 convex whorls; last quarter-whorl with narrow axial costellae crossed by 4 narrow spiral cords, remainder very finely granulate. Teleoconch of up to 8 whorls, shouldered at or near middle of whorl on spire, sutural ramp concave, particularly on later whorls. Last whorl excavated, with long almost straight neck. Axial sculpture commencing at beginning of teleoconch as rounded costae extending from suture to suture but becoming obsolete on ramp on later whorls; costae varying considerably in strength, in some shells becoming obsolete on last whorl, in others persisting to outer lip; 11-15 costae on penultimate whorl. Spiral sculpture commencing as 3 subequal cords, topmost on shoulder angulation; fine threads appear between primaries and on ramp during growth, last whorl with 13-17 additional cords on base and neck, those on posterior half with interstitial threads. Aperture pyriform, columella bearing weak rounded ridge at inception of long, straight, narrow siphonal canal; outer lip with 8-14 lirae within.

Waiauan-Tongaporutuan; Tangitu River, North Taranaki (Tongaporutuan) (type of *E. tangituensis*); Clifden ("Band 7c", probably Nissen "no. 1" shellbed, Park Bluff, Waiauan) (type of *F. waiauensis*); common at Karoro Quarry, Greymouth, and nearby Stillwater Mudstone bathyal localities (Waiauan); Kapitea Creek, Westland; Cape Foulwind, Westport (Tongaporutuan).

Falsiculus tangituensis is apparently most closely related to *F. eoaffinis* (Altonian, Clifden) and *F. excellens* (Clifdenian, Clifden) but differs in having a less well defined shoulder angulation (and hence more evenly convex teleoconch whorls) and coarser spiral sculpture. Most species of *Falsiculus* are recorded from probable middle or outer shelf faunules, but *F. tangituensis* ranged down into the upper bathyal zone (Maxwell 1988a, p. 17). It is the only common large mollusc in the upper part of the Stillwater Mudstone in the Greymouth district. *F. waiauensis*, from shallow-water assemblages in Southland, does not differ significantly from *F. tangituensis* (Maxwell 1988a, p. 54-55).

Figured specimen (Pl. 27n): GS3341, J32/f7585, abandoned brickworks quarry, Karoro, near Greymouth, Westland (Waiauan) (NZGS) x 2.

Pl. 27 p. *Mauithoe insignis* (Marwick, 1926) [*Mauia insignis* Marwick 1926a, p. 274]. Type species of *Mauithoe* Finlay, 1930 (Volutidae: Zidoninae).

Small for family and wide (38 x 23 mm; but a few individuals reach 70 mm high), with low conic spire, weakly concave sutural ramp, relatively short, inflated last whorl, and very prominent sculpture. Sculpture of narrowly crested, closely spaced axial costae, 20-22 per whorl, extending well down last whorl and persisting to end of last whorl on almost all specimens; crossed by few faint spiral threads. Outer lip smooth, strongly thickened, produced into wide, greatly thickened flare

in a few large individuals. Inner lip a thin glaze not masking sculpture of previous whorl, bearing 5 prominent columellar plaits on most specimens, but uppermost plait weak on a few specimens. Anterior end widely but shallowly notched, producing fasciole that is not raised above remainder of surface but is clearly bounded by line (a low ridge on some specimens). Protoconch large, strongly protruding, wide, of at least 2 low, apparently smooth whorls, but incomplete on all available material.

Waiauan; not uncommon at the type locality, Glenafric, mouth of Dovedale Stream, North Canterbury, and a few specimens known from bathyal siltstone in the Gisborne district.

Most specimens of *Mauithoe insignis* are markedly shorter and wider than Marwick's holotype (which, however, lacks the outer lip); a single very large shell from Glenafric shows that large, old shells develop a very wide, thick outer lip. The short, wide form usually collected (illustrated) closely resembles the Tongaporutuan *M. strongi* (Gisborne district, type; Bell's Creek, South Wairarapa; Hurunui River, North Canterbury) which differs in having shorter, weaker, closer and more numerous axial costae. These two species appear to be closely related phylogenetically and to constitute a brief, minor offshoot of *Alcithoe* (of dubious generic rank), but the other two species included in *Mauithoe* by Finlay (1930d, p. 252) (*Alcithoe parva*, = *A. propearabacula* Bartrum and Powell, 1928; Opoitian, Kaawa Creek, southwest Auckland; and *A. dilatata*, Tongaporutuan, "Hurupi facies" shallow-water faunules in South Wairarapa) only superficially resemble *M. insignis*; we include them in *Alcithoe* (*Alcithoe*).

Figured specimen (Pl. 27p): GS3840, N34/f6222, Glenafric, mouth of Dovedale Stream, North Canterbury, Waiauan (NZGS) x 1.

Pl. 27 m. *Gemmula peraspera* Marwick, 1931 [*Gemmula peraspera* Marwick 1931, p. 133; ? = *Gemmula orba* Marwick 1931, p. 133] (Turridae: Turrinae).

Moderate-sized for genus (27-33 mm high), tall and narrow, with narrow spire 0.5-0.6 total height; whorls prominently keeled at about mid-height on spire, forming narrow, strongly concave sutural ramp. Sculpture of peripheral row of small nodules, quite sharply pointed on most specimens, 16-20 per whorl; nodules are formed at apex of anal sinus, where growth lines curve sharply forward after their backward inclination over sutural ramp; spiral sculpture of 2 or, in most specimens, 3 prominent, widely spaced cords on base, narrow, weakly gemmate subsutural cord, 3 to 5 low threads on sutural ramp, 3 narrow threads over peripheral nodules, and about 20 low, closely spaced cords on anterior canal. Anterior canal long and narrow, deflected weakly to left, but incomplete on all known specimens. Protoconch presumably as in other *Gemmula* species, narrowly conical, of 5 or 6 whorls, smooth near apex but with regular axial costae lower down.

Tongaporutuan-Opoitian; Totangi Stream, Ngatapa, Gisborne district, Tongaporutuan (type); widespread in bathyal siltstone in Gisborne district, Wairoa district, and southern Wairarapa. Curiously, although it is common at most southern Wairarapa Tongaporutuan localities, specimens have not been collected at Bell's Creek, Mangaopari Stream, the locality with the most diverse faunule (Beu 1970c, p. 232).

Marwick (1931, p. 133) named both *Gemmula peraspera* and *G. orba* from GS1322, Totangi Stream, Ngatapa, Gisborne, and other specimens resembling the holotype of *G. orba* have not been collected subsequently. Comparison of the holotypes showed few differences other than the lower spire and more prominent subsutural

cord of *G. orba*, and it seems likely that the holotype of *G. orba* is a broken, low-spined specimen of the species also named *G. peraspera*. Fleming (1966b, p. 114, caption to *Bathyarca crenulifera*) noted that although matrix supposedly from GS1322 contained Lillburnian foraminifera, the nearby GS1332 is Tongaporutuan, the faunas of GS1322 and GS1332 are almost identical, and it seems likely that GS1322 is really Tongaporutuan. The subsequent collection of *G. peraspera* from rocks of Tongaporutuan to Opoitian (not Middle Miocene) age helps to confirm Fleming's conclusion.

G. peraspera is a member of a group of small to moderate-sized, tall-spined, finely sculptured *Gemmula* species that is common in New Zealand Neogene rocks. The most closely similar species are *G. kaiparaensis*, with two cords around the peripheral keel, and the smaller, narrower, very finely sculptured *G. clifdenensis* (Pl. 26g), with two or three relatively prominent cords around the peripheral keel.

Figured specimen (Pl. 27m): holotype, GS1322, X17/f9474, small tributary of Totangi Stream 1.6 km north of major bend in Totangi Road, Ngatapa, northwest of Gisborne, Tongaporutuan (TM 6797, NZGS) x 2.

Pl. 27 s. *Cosmasyrinx monilifera* Marwick, 1931 [p. 138]. Type species of *Cosmasyrinx* Marwick, 1931 (Turridae: Turrinae).

Small for family (12-15 mm high), with moderately tall, weakly stepped spire, long straight unnotched anterior canal, wide almost smooth sutural ramp, and wide, moderately deep posterior sinus occupying sutural ramp, with its rounded apex near centre of ramp. Sculpture dominated by row of small nodules around prominent peripheral band of three closely spaced spiral cords, by 2 or 3 prominent smooth cords lower on last whorl, and by low, almost smooth subsutural cord; neck and canal bearing a further 14 low spiral threads. Protoconch dome-shaped, of 2 apparently smooth whorls with large, bulbous apex.

Altonian-Clifdenian; Akiripuraho Stream, Waihora River, Gisborne district, Altonian or Clifdenian (type); rare in bathyal siltstone of the Gisborne district.

Cosmasyrinx monilifera is illustrated as an example of a widespread genus of Miocene bathyal faunas in Gisborne district, Wairarapa and Westland. "*Cosmasyrinx*" *semilirata* (Duntroonian, coast near Orepuki, Southland) has a daphnelline protoconch (with characteristic decussate (diagonally reticulate) sculpture) and is placed here in *Cryptodaphne*; all remaining species of *Cosmasyrinx* are Miocene. Several lots of *Cosmasyrinx* collected in the Gisborne district in recent years show that there are probably several unnamed species, and shells reach 20-25 mm in height. Unnamed, relatively narrow species from the Stillwater Mudstone (Clifdenian-Waiarau) in Westland resemble *Gemmula* species, but differ in their low, dome-shaped (rather than narrowly conical) protoconch, and in the anal sinus occupying the sutural ramp, not the peripheral keel. Typical Gisborne species of *Cosmasyrinx* differ further from *Gemmula* in their wide, almost smooth subsutural ramp. *C. ardua* is narrower than *C. monilifera*, with a more steeply sloping sutural ramp; *C. latior* has a strongly beaded subsutural cord; *C. tereumera* has larger peripheral nodules and more numerous spiral cords on the base than on *C. monilifera*; and *C. marwicki* (Tongaporutuan, southern Wairarapa) is similar to but more finely sculptured than *C. tereumera*.

Figured specimen (Pl. 27s): holotype, GS1293, Y17/f7472, Akiripuraho Stream, tributary of Waihora River, near Kanakanaia Road, 4 km northeast of Te Karaka, Gisborne, Altonian or Clifdenian (TM 6801, NZGS) x 4.

Pl. 27 r. *Marshallena curtata* (Marwick, 1926) [*Turricula curtata* Marwick 1926c, p. 325] (Turridae: Pseudotominae).

Moderate-sized for genus (height c. 20 mm), broadly fusiform, spire 0.45 total height. Protoconch bluntly conical, of about 3 whorls; last quarter-whorl with narrow axial costellae, remainder smooth. Teleoconch of 4-4.5 whorls, somewhat glazed, sharply angled at or slightly below middle on spire whorls, last whorl broadly excavated with a short neck. Axial sculpture of narrow, rather sharp-crested costae with concave interspaces, reaching from shoulder angle to lower suture on spire and dying out over upper part of base on last whorl; 15-18 on penultimate whorl. Sutural ramp bearing a row of weak nodules corresponding to costae, bordering suture. Spiral sculpture commencing as 2 weak cords, 1 on shoulder, the other between shoulder and lower suture; additional cords appearing during growth, adult whorls covered with closely spaced, flattened cords and interstitial threads, those on sutural ramp noticeably weaker than those below. Penultimate whorl with 4 or 5 cords below shoulder; last whorl with 12-16 additional cords, some with interstitial threads, on base and neck, becoming crowded anteriorly. Peripheral cord slightly thickened where it crosses costae, other cords virtually unaffected. Aperture pyriform, siphonal canal short, slightly oblique; columella gently convex. Outer lip with shallowly arcuate anal sinus, its apex closer to suture than to periphery.

Tongaporutuan; coast south of Wai-iti Stream, North Taranaki (type); also Bell's Creek and nearby tributaries of Mangaopari Stream, southern Wairarapa.

Marshallena curtata differs from *M. neozelanica* (Pl. 8v)—the only other named New Zealand species considered to belong in the genus—in its less elongate shape and in having more sharply shouldered teleoconch whorls and stronger axial sculpture. Its closest relative is a very rare, undescribed species from the Mount Harris Formation at Pareora River, South Canterbury (Otaian), which differs primarily in having a flattened apex to the protoconch.

M. curtata occurs only in bathyal siltstone in both North Taranaki and southern Wairarapa, and the Recent Indo-West Pacific species referred to *Marshallena* by Powell (1969) are recorded from the upper bathyal zone only. However, the other New Zealand "*Marshallena*" species (see discussion under *M. neozelanica*) occur in inner to outer shelf faunules.

Figured specimen (Pl. 27r): holotype, GS1141, Q18/f8493, coast south of mouth of Wai-iti Stream, North Taranaki, Tongaporutuan (TM 5606, NZGS) x 2.

Pl. 27 q. *Mioawateria personata* (Powell, 1942) [*Awateria personata* Powell 1942, p. 130; *A. (Mioawateria) personata*]. Type species of *Mioawateria* Vella, 1954 (Turridae: Daphnellinae).

Small for family (height 5-7 mm), biconic, spire strongly gradate, about half total height. Protoconch conical, probably about 4 whorls when complete, decussately sculptured (i.e., by diagonally reticulate threads). Teleoconch of up to 4 whorls, which are strongly shouldered at or near middle on spire, sutural ramp with prominent subsutural fold; last whorl broadly excavated, with short neck. Axial sculpture of narrow, opisthocline costae extending from shoulder angle to lower suture on spire whorls, and across base (but not onto neck) on last whorl. Costae of rounded-triangular cross-section, with interspaces considerably wider than one costa; 15-22 costae on penultimate whorl. Sutural ramp with narrow, prosocline costellae reaching from upper suture to shoulder angle on early whorls but largely confined to subsutural fold on later whorls, costellae more numerous than axial costae. Spiral sculpture

commencing as narrow cord on shoulder, joined during growth by low, flat-topped cords on sides, penultimate whorl with 3-4 cords, last whorl with additional 15-17 cords. Some specimens have 1-3 weak cords on sutural ramp between subsutural cord and shoulder. Aperture pyriform, columella almost straight above, curved to left below, forming short siphonal canal. Inner lip thinly callused; outer lip with very shallow, arcuate anal sinus, its apex below middle of ramp.

Waiauian-Opoitian; Mangawhero Stream, Wairoa district, Opoitian (type); Karoro quarry, Greymouth (Waiauian); Kapitea Creek, Westland (Waiauian); Bell's Creek, Mangaopari Stream, southern Wairarapa (Tongaporutuan). Moderately common in Stillwater Mudstone at Karoro quarry, rare elsewhere.

Mioawateria personata is distinguished by its small size, its biconic shell with strongly angled teleoconch whorls, its very shallow anal sinus, and its decussate daphnelline protoconch. Several New Zealand turrids have previously been assigned to *Mioawateria*, but the only ones currently accepted here are *M. personata*, *M. expalliat*a (Otaian, Hokianga district) and *M. aitanga* (Haweran, Te Piki, Cape Runaway) (Maxwell 1988a, p. 66-68). An unnamed species is present in Otaian rocks at Parengarenga Harbour.

Mioawateria is very similar to *Gymnobela* Verrill, 1884, which is widely recorded from bathyal and abyssal depths in the Atlantic Ocean (Bouchet and Warén 1980, p. 48-59). Further study may show that *Mioawateria* is not separable from *Gymnobela*, although the type species of *Gymnobela* (*G. engonia* Verrill, 1884; Recent, Western Atlantic) is much larger than *M. personata* and differs in sculptural style.

Mioawateria is not recorded from the modern New Zealand fauna, although it seems to be represented in Indonesia and Japan by *Pleurotomella extensaeformis* Schepman, 1913, which occurs at depths of 460 to 730-760 m (Maxwell 1988a, p. 68). Most New Zealand records of the genus are from upper bathyal assemblages, but *M. aitanga* occurs in the Te Piki bed, with a shallow-water faunule of apparently mixed mid-shelf to shallow bay assemblages.

Figured specimen (Pl. 27g): GS3341, J32/f7585, abandoned brickworks quarry, Karoro, near Greymouth, Westland, Waiauian (NZGS) x 6.

Pl. 27 t. *Thatcheria pagodula* (Powell, 1942) [*Waitara pagodula* Powell 1942, p. 168] (Turridae: Thatcheriinae).

Large for family (probably reaching at least 80 mm x 45 mm; dimensions of holotype of *T. liratul*a), biconic, wide, with short pagodiform spire (probably about 0.3 total height), wide, almost smooth, gently sloping, almost flat sutural ramp, narrow smooth keel around shoulder, and wide, long last whorl tapering very gradually to straight, widely open siphonal canal. Spiral sculpture of very weak, low, wide spiral cords, about 6 below shoulder on spire whorls and many closely spaced below shoulder on last whorl, and few weak threads on outermost sutural ramp. Axial sculpture of growth lines only, defining an exceedingly deep anal sinus on sutural ramp, with widely rounded apex over inner half of ramp and long, forward-swinging limb over outer half of ramp. Aperture long, narrow, subrectangular, with thin lips. Protoconch not

preserved on New Zealand fossils, but presumably daphnelline (conical, with decussate fine diagonal threads) as on the modern species, *T. mirabilis* Angas, 1877.

Tongaporutuan; Moutara Point, coast between Whangara and Tolaga Bay, north of Gisborne (type); uncommon in bathyal siltstone in Wainuioru Valley, southern Wairarapa (Tongaporutuan) and in road cuttings on the hill south of Te Araroa, East Cape (Tongaporutuan), so probably widespread in bathyal facies.

The equally widespread Opoitian bathyal species *Thatcheria liratul*a differs from *T. pagodul*a in its coarser spiral cords, its more nearly horizontal sutural ramp, and its consequently much more strongly stepped spire. Specimens have been seen from Mangawhero Stream, Wairoa district, Hawke's Bay (the large incomplete holotype, 79 mm high, and Powell's illustrated paratype), Castlepoint, eastern Wairarapa (another large shell, 71 mm high) and the head of Waihua Valley, Wairoa. The unique holotype of *T. waitaraensis* is an incomplete large specimen of a narrow species with a more steeply sloping sutural ramp than on *T. pagodul*a or *T. liratul*a, and the doubtfully significant subgenus *T. (Waitara)* Marwick, 1931 has been retained for it at present. An unnamed *Thatcheria* species with early whorls prominently keeled, as on the Recent type-species *T. mirabilis* Angas, 1877, is represented by small spires from the Stillwater Mudstone on the old Marsden-Kumara Road, Hokitika, Westland (Clifdenian) and probably other species will come to light in Neogene bathyal facies. We refer tentatively to *Clinura* Bellardi, 1875 the unique holotype of *Waitara generosa* (Altonian ?, Mangatutae Creek, Waikohu, Gisborne), which resembles *Thatcheria* species but has a taller spire, a much more strongly concave sutural ramp and a more strongly protruding peripheral keel than in *Thatcheria*. *C. generosa* is similar in shape to *Clinura calliope* (Brocchi, 1814) (type species of *Clinura*; Charig 1963, pl. 47, fig. 9, 10) but has much weaker spiral sculpture and lacks the prominent peripheral nodules of *C. calliope*.

Charig (1963) reviewed the relationships of *Thatcheria*, *Waitara* and *Clinura* in some detail, with a long historical introduction. He concluded these three taxa are closely related, and belong in a subfamily of Turridae closely related to the Daphnellinae. He reillustrated Powell's (1942) figured paratype of *T. liratul*a. We agree with Charig's conclusions and, although we largely follow the generic classification adopted by Fleming (1966b), it seems possible that *T. (Waitara) waitaraensis* and *Clinura generosa* will prove to belong in *Thatcheria* (sensu stricto) when more complete material is collected.

Figured specimen (Pl. 27t): holotype, GS 1975, Z17/f7499, Moutara Point, coast between Whangara and Tolaga Bay, north of Gisborne, Tongaporutuan (TM6803, NZGS) x 1.5.

CHAPTER 13. LATE MIOCENE FAUNAS (WAIUAN, TONGAPORUTUAN AND KAPITEAN STAGES): PLATES 28-30

INTRODUCTION

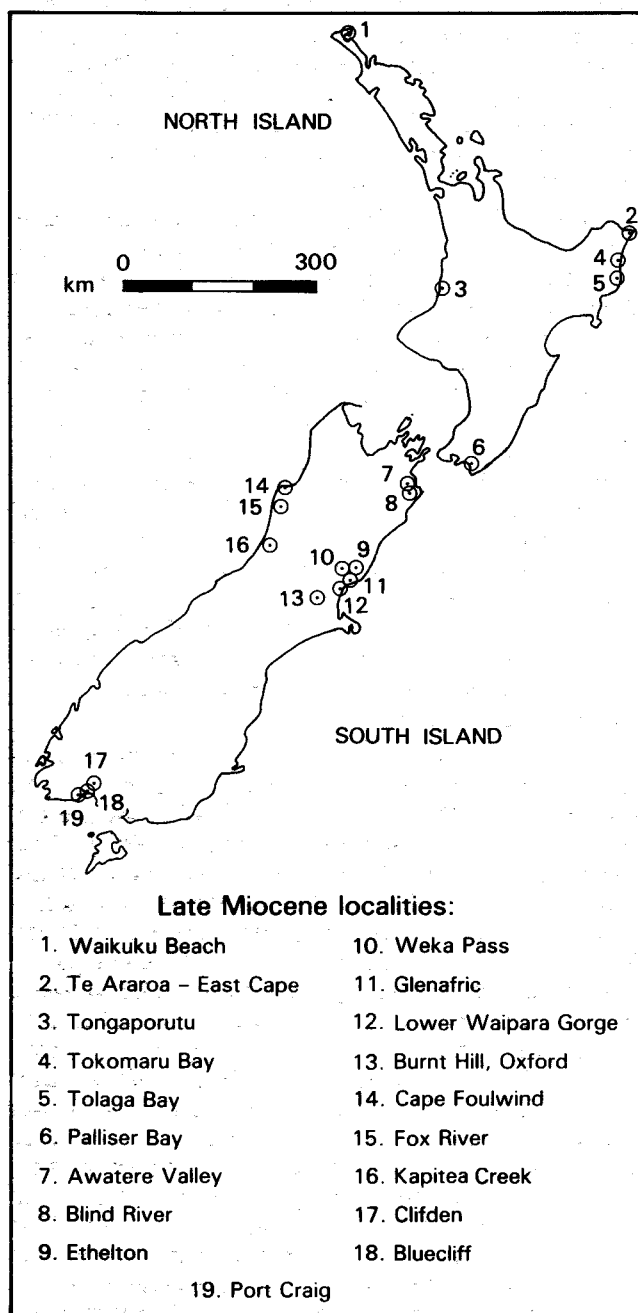


Figure 20 The main molluscan fossil localities of Waiauan to Kapitean (late Middle Miocene and Late Miocene) age.

Note that, although we have considered Waiauan Mollusca in with the similar Tongaporutuan fauna here, the Waiauan Stage is now included in the Middle Miocene (see Figure 1, 2).

Fossiliferous rocks of Waiauan, Tongaporutuan and Kapitean age occur widely in New Zealand, but in relatively small areas (Fig.20). Significant Waiauan shelf-facies rocks with at least reasonably common macrofossils occur at Waikuku Beach, near North Cape (Leitch et al. 1969); the Hinnites Shellbed and Glenmark Limestone

at Weka Pass, the Double Corner Shellbeds (Gregg 1959) in Lower Waipara Gorge (for both see Wilson 1963), and Burnt Hill, near Oxford (Marwick 1932), all in North Canterbury; a debris flow near the base of O'Keefe Formation, overlying Welsh Formation (Otaian-Altonian) and in turn overlying the thick Potikohua Limestone (Duntroonian-Waitakian) in Fox River, Westland; a greensand bed with *Mesopeplum* and *Septifer* at Cape Foulwind, Westport; and, the most important, the Nissen Shellbeds (and the overlying sands on the north bank), in the eastern limb of the Waiau Syncline on the Waiau River at Clifden, Southland (Fleming in Wood 1969, p. 93-95), type section of the Waiauan Stage. Bathyal Waiauan molluscan faunas are described above (introduction to Pl. 27).

Important occurrences of richly fossiliferous, near-shore to outer shelf facies, Tongaporutuan rocks occur in some localities along the coast near Tongaporutu in North Taranaki (Marwick 1926c), although most faunules in this area are bathyal; most importantly, the diverse fauna of the Hurupi Stream area in eastern Palliser Bay (King 1933, Dell 1952; many taxa at Hurupi were not recorded by these authors) and at many other localities in southern Wairarapa; in the Kaiwara River near the former Ethelton School, North Canterbury, and several nearby localities; and in Callaghans Greensand, underlying Kapitean sequences in the Hokitika district, Westland. Sparser faunules (most in deep-water facies) occur widely in North Taranaki, the Gisborne-East Cape district, eastern and southern Wairarapa, North Canterbury, Marlborough, Westland, and Southland. In many areas, particularly in Wairarapa, Marlborough and Westland (near the Alpine Fault zone), basinal eversion and the deposition of new sequences commenced during Tongaporutuan time, and so Tongaporutuan rocks occupy the basal parts of basins, resting unconformably on basement or early-mid Cenozoic rocks and overlain by thick Pliocene sequences. For this reason Tongaporutuan rocks are among the most tectonised and cemented of New Zealand Neogene rocks, and most Tongaporutuan faunules are more poorly preserved and more difficult to collect than those from either Pliocene or older Miocene rocks.

Kapitean rocks are widespread in New Zealand but in most places are thin and contain sparse Mollusca. The localities with the most diverse faunules occur on the coast between Te Araroa and East Cape, particularly in the coastal erosion platform just east of Te Araroa and at Maruhou Point. Other useful localities are in Kapitea Creek and nearby streams in the Hokitika district, Westland; and at Bluecliff, Port Craig, and the mouth of the Waikoau River, in western Te Waewae Bay, Southland (Fleming 1955). As far as we are aware, all diverse Kapitean macrofossil faunules fall into the early Kapitean *Globorotalia conomiozea* foraminiferal zone, whereas the overlying *G. sphericomiozea* zone contains only sparse, undiagnostic Mollusca.

Waiauan Mollusca can usually be distinguished only with difficulty from Lillburnian molluscs. In particularly diverse inner shelf facies (notably at Clifden) some

distinctions are possible. At Clifden, an apparent warming from Lillburnian to Waiauan is recorded by the return of *Struthiolaria* (*Callusaria*) *spinosa* (presumed ancestor of the Clifdenian-Tongaporutuan *S. callosa*) in the Nissen Shellbeds, after its apparent retreat from the area at the end of Altonian time. Distinct taxa of *Zeacolpus* occur in Clifdenian-Lillburnian and Waiauan rocks, some warm-water taxa such as *Glyptoactis subintermedia* and *Rugotyphis* are known in Lillburnian rocks but are absent from Waiauan ones, and *Falsiculus tangituensis* (Waiauan-Tongaporutuan) appears first in the Nissen Shellbeds and is not known in older rocks. The genus *Sectipecten* first appears in Waiauan rocks, as *S. diffusus*, but this species is almost unknown away from the Hinnites Shellbed at Weka Pass. The Double Corner Shellbeds in Lower Waipara Gorge contain abundant, diverse Waiauan faunules that lived in shallow water off a sandy ocean beach, including such distinctive Waiauan species as *Zelandiella fatua* (Pl. 30c, e) and *Austrotoma obsoleta* (Pl. 30i).

Tongaporutuan rocks are just as difficult, at most localities, to distinguish from Waiauan ones as Waiauan ones are from Lillburnian, not least because of the poor preservation of most Tongaporutuan faunules. Recent study of Waiauan and Tongaporutuan rocks of similar "Hurupi facies" sandstone lithology in eastern Wairarapa (M. Crundwell, Victoria University, pers. comm.) has shown that Waiauan faunules with *Zeacolpus* aff. *nissenii* and both *Zelandiella fatua* and *Z. calcarata* are succeeded by typical Tongaporutuan Hurupi faunules containing *Zeacolpus taranakiensis* and only *Zelandiella calcarata*. In most reasonably diverse faunules, *Struthiolaria praenuntia* (Pl. 29i; with a median cord on spire whorls) in Tongaporutuan rocks replaces the Altonian-Waiauan *S. calcar*. In shallow-water or other high-energy or low-deposition rate environments (e.g., Callaghan's Greensand, Westland), Tongaporutuan rocks are recognisable by containing *Sectipecten grangei* (Pl. 28c), with many narrow ribs over the whole disc, whereas early Kapitean rocks of a wider variety of facies contain *S. wollastoni* (Pl. 28f), on which riblets are gathered together into large, square-edged folds.

The classical Kapitean fauna, occurring over much of New Zealand in a well defined zone for which the stage was originally proposed, is the combination of *Sectipecten wollastoni* (Pl. 28f) with *Austrofusus coerulescens* (Pl. 30d). *Cucullaea*, *Polinices*, *Zeacolpus*, and large, coarsely ribbed scaphopods related to *Dentalium otamaringaense* commonly accompany the diagnostic pair of taxa, but in many localities few other taxa are found. This association occurs widely in blue-grey shelf siltstone and sandy siltstone, and it appears that *Sectipecten* occupied a greater range of facies during early Kapitean time than it did before or after. Study of planktonic foraminifera (pers. comm. N. de B. Hornibrook and G.H. Scott) in conjunction with Mollusca in several key sections (notably Kapitea Creek, near Hokitika; Blind River, Awatere Valley; and the coastal sequence from Te Araroa to East Cape) has demonstrated that the typical Kapitean molluscan fauna occurs only in the lower foraminiferal zone (*Globorotalia conomiozea* zone) of rocks customarily included in the Kapitean Stage. Apparently *all* the Kapitean index molluscs and the Miocene lineages that became extinct during this period

(including *Cucullaea*, *Lentipecten*, *Kuia*, *Notocorbula*, *Falsiculus*, *Cypraea clifdenensis*, large *Conus*, and *Aturia*) did so at the end of the *G. conomiozea* zone. The later *G. sphericomiozea* zone contains a very impoverished fauna lacking age-diagnostic Mollusca, and such common, widespread taxa as *Sectipecten*, *Struthiolaria* (sensu lato), *Polinices*, *Maorimactra chrydaea*, and *Austrofusus* (*Neocola*) are not recorded from the zone to our knowledge. With the beginning of the *Globorotalia puncticulata* – *G. crassaformis* zone (Hornibrook 1981), more normal, diverse molluscan faunas reappear, recognisable as Opoitian.

Opoitian rocks are distinguished from Kapitean ones in shallow facies by containing *Sectipecten allani* (Pl. 33c), with still more markedly flat-topped, smooth, major radial folds than those of *S. wollastoni*, by containing the larger and less oblique *Phialopecten ongleyi* rather than its presumed ancestor *P. tolagaensis* (common in Tokomaru Sandstone facies of the Gisborne district, particularly at Anaura Bay, but rare elsewhere), and by lacking the distinctive Miocene (or older) taxa *Cucullaea*, *Lentipecten*, *Kuia*, *Notocorbula humerosa*, *Falsiculus*, large *Conus* and *Cypraea*, *Austrofusus coerulescens*, and *Aturia*. Distinct Opoitian species are known in many genera such as *Glycymeris*, *Nemocardium* (*Pratulium*), *Eumarcia*, *Zeacolpus*, *Polinices*, *Semicassis* (*Kahua*), *Pellicaria*, *Struthiolaria* and *Austrofusus* (*Neocola*), but of these only *Pellicaria parva*, *Zeacolpus kanieriensis* and *A. (Neocola) ngatuturaensis* have proved of much value in practical biostratigraphy.

The overall character of Late Miocene faunas is of extinction of the warm-water genera that appeared in New Zealand during the Early and Middle Miocene thermal maximum – a progressive descent from the heights of late Early Miocene diversity to an extremely impoverished terminal Miocene (*G. sphericomiozea* zone) fauna that contains far fewer taxa than any Pleistocene glacial fauna. As noted by Beu (1987b), this was not a completely gradual descent, but largely occurred in a series of steps, at the stage boundaries. Beu (1987b) pointed out that the largest such step was at the end of Tongaporutuan time (but this is probably largely an artefact of the way time ranges are recorded; the real extinction event was probably at the end of the *G. conomiozea* zone), when 23% of molluscan genera became extinct, much the most marked extinction during Neogene time in New Zealand. The diversity minimum was followed closely by Opoitian warm-water faunas (discussed below) broadly similar in generic composition to Lillburnian-Waiauan faunas, although lacking the genera extinguished by the terminal Miocene cooling. Two different causes seem to have contributed to the terminal Miocene diversity minimum. The first is the fact that rocks of the *G. sphericomiozea* zone appear everywhere to be off-shore siltstone or silty sandstone, so the foraminiferal zone change was apparently accompanied, in all sections we are aware of that contain diverse Mollusca, by a marked deepening of the deposition site. This and the complete lack of preservation of near-shore, high-energy environments in rocks of this age would alone account for a large proportion of the disappearance of shelf and near-shore taxa that constitute the Kapitean (*G. conomiozea* zone) index fossils; but an apparently New Zealand-wide

deepening and absence of shelf facies is itself a noteworthy feature.

The second cause of terminal Miocene impoverishment is presumably the now well established terminal Miocene glaciation of West Antarctica. Kennett (1967) attributed a general impoverishment of New Zealand Kapitean faunas to this terminal Miocene event, but the occurrence of common large *Conus hendersoni* (Pl. 30 m), of a large specimen of *Cypraea clifdenensis* (Pl. 24e, f; specimen in NZGS), and of the tropical echinoid *Phyllacanthus* (Fell 1954, p. 51) near East Cape during the *G. conomiozea* zone, and occurrences of the nautiloid *Aturia* in North Canterbury and at Te Waewae Bay in the far south of Southland (Beu 1973a), effectively rule out any possibility of a marked glaciation in New Zealand during the *G. conomiozea* zone. However, it is now acknowledged by most paleoceanographers (e.g., Kennett 1985, Kennett and von der Borsch 1985) that a marked terminal Miocene glaciation of West Antarctica strongly increased the circulation of cold water in the circum-Antarctic current, pushing the Humboldt Current much further northward up western South America than previously, causing the terminal Miocene revolution in Chilean molluscan faunas (Zinsmeister 1977, 1978), and allowing the first marked circum-Antarctic dispersal of molluscan planktonic larvae from South America to New Zealand (Beu 1985a, p. 9). It also seems likely to have contributed substantially to the coeval Mediterranean Messinian "salinity crisis" (Ryan et al. 1974; Hodell et al. 1986). It now appears that this terminal Miocene event (or closely spaced series of events) occurred in the later part of Kapitean time (the *G. sphericomiozea* zone) in New Zealand, causing the marked terminal Miocene molluscan extinction. The association of this paleoceanographic event with apparently universal deepening (rather than the shallowing expected during a major glaciation) in New Zealand sequences suggests that, rather than a marked terrestrial glaciation in New Zealand, it was the strong increase in circum-Antarctic cold-water circulation during the terminal Miocene event that affected New Zealand faunas.

REPRESENTATIVE LATE MIOCENE MOLLUSCA

Pl. 28 a. "*Ennucula*" *otamaringaensis* (Marwick, 1926) [*Nucula otamaringaensis* Marwick 1926c, p. 327] (Nuculidae: Nuculominae).

Very large for family (23-31 mm long), thick but nacreous and fragile, highly inflated, oval; umbones strongly incurved and directed backward (opisthogyrus), situated at posterior quarter of length. Antero-dorsal margin strongly convex, with well defined, large lunule bounded by shallow, wide groove that forms shallow depression in valve margin; postero-dorsal margin excavated below umbones, then weakly convex above narrowly rounded posterior end. External sculpture of many fine radial threads crossing many slightly more prominent commarginal ridges. Valve margins smooth; hinge not seen (all specimens articulated).

Tongaporutuan-Opoitian; coast near mouth of Waiau Stream, North Taranaki, Tongaporutuan (type); widespread in bathyal siltstone facies in Taranaki, Gisborne district, Wairoa district, southern Wairarapa, North Canterbury, and Westland.

The very large size, the smooth margin, and the unique combination of fine radial and commarginal sculpture of almost equal prominence show that "*Ennucula*"

otamaringaensis belongs in an unnamed genus of Nuculidae Nuculominae, and effectively distinguish it from all other New Zealand nuculids. Other, probably unnamed species of the group occur in Runangan to Otaian rocks.

Figured specimen (Pl. 28a): an unlocalised, complete specimen, from collection of H. Evans (probably from North Taranaki Tongaporutuan; NZGS) x 2.

Pl. 28 b. *Neilo sublaevis* Marwick, 1926c [p. 329] (Malletiidae).

Large for family (25 to 57 mm long; largest New Zealand malletiid), long and moderately narrow, with dorsal and ventral margins both lightly down-curved, subparallel; anterior end evenly rounded, posterior end markedly longer than anterior, drawn out into weakly sinuate rostrum (variable in length and protrusion); umbo at anterior 0.3-0.4 of length. Low ridge extending from umbo to postero-ventral margin, marking off posterior area. Sculpture of weak, rather irregular commarginal ridges and grooves on posterior area and, more weakly, on anterior end; most specimens almost completely smooth medially. Margins smooth. Hinge thick, with many similar, shallowly V-shaped teeth; about 22 posterior and 30 anterior teeth in shell 43 mm long. Adductor scars small, deeply impressed; pallial sinus deeply U-shaped, directed slightly downward anteriorly, extending only to posterior third of length.

Clifdenian-Kapitean; fairly common, North Taranaki coast, Tongaporutuan (type); widespread in North Taranaki, Gisborne district, southern Wairarapa and North Canterbury, in siltstone of outer shelf and upper bathyal facies.

The very large size for a New Zealand malletiid, the thick shell, and the largely smooth and, in many specimens, lightly polished exterior make *Neilo sublaevis* easily recognised.

Marshall (1978b) showed that *Neilo sublaevis* differs little from its presumed descendant *N. annectens* (= *N. rugata* Dell, 1956) (Opoitian-Recent), the older species having a slightly thicker shell and consequently a wider hinge plate than the younger one. *N. annectens* occurs now in water 100-700 m deep (Marshall 1978b) and this provides good corroborating evidence for the ecology of the fossils, which occur widely but uncommonly in siltstone with sparse Mollusca. However, Marshall (1978b) also showed that *N. annectens* occurred in shallower water during cool periods than during warm periods and, for example, is not uncommon in shelf assemblages with common Mollusca in the Kai-Iwi and Okehu Groups in the Castlecliffian type section, Wanganui, deposited in about 50-60 m of water.

The shallow-water species *N. australis* is the most common *Neilo* species in Nukumaruan to Recent faunas, and is easily distinguished from *N. annectens* by its smaller size, its thinner shell, and its sculpture of regular, thin, commarginal lamellae. *N. australis* occurs commonly in inner to mid-shelf siltstone in Wanganui, Hawke's Bay, and Wairarapa.

Figured specimen (Pl. 28b): holotype, GS1125, Q18/f9020, coast between Waikiekie and Maungapukatea streams, North Taranaki, Tongaporutuan (TM4091, NZGS) x 1.5.

Pl. 28 g,h. *Glycymerita* (*Glycymerita*) *rangatira* (King, 1934) [*Glycymeris rangatira* King 1934, p. 27] (Glycymerididae: Glycymeridinae).

Largest New Zealand glycymeridid, an enormous, thick, *Cucullaea*-like

shell 85-114 mm high and 80-105 mm long, very strongly inflated (inflation of 2 valves to 90 mm), with relatively small umbo slightly behind centre of length, lightly convex dorsal margin, long, straight posterior margin, and strongly trigonal shape produced by extended antero-dorsal and postero-ventral margins. Very low, indistinct ridge from umbo to mid-posterior margin (opposite posterior adductor scar) marks off small postero-dorsal area. Whole exterior sculptured with 55-58 very shallow, widely spaced radial grooves, many fine radial threads, and many fine, irregular growth ridges. Ligamental area deep, bearing up to 10 wide, prominent chevron grooves. Hinge wide at ends but obliterated by growth of ligament medially, bearing many similar, long, curved teeth on each end. Adductor scars relatively small, roughened, elevated, dark brown in most specimens (calcitic?); pallial line without sinus. Ventral margin coarsely crenulate.

Clifdenian-Opoitian; Colonel Gully, Medway River, Awatere Valley, Tongaporutuan (type); widespread in Gisborne district, Hawke's Bay, Wairarapa, Marlborough, and the Karamea district, northern west coast of South Island, in shallow-water shellbeds with other diverse Mollusca, but nowhere common.

This spectacular shell is much the largest of its family in New Zealand (if not the world), and is easily recognised by its weakly trigonal shape, by being higher than long, by its very wide ligamental area, and by its weak sculpture. *Glycymerita rangatira* seems likely to have descended from *G. robusta* (Altonian and Clifdenian), from which it differs in its larger size, greater height, and weaker umbonal-posterior ridge.

Figured specimen (Pl. 28g, h): GS4751, L27/f7520, Oparara River, Karamea district, southwest Nelson, Lillburnian (NZGS) x 0.67.

Pl. 28 d. *Xenostrobus altijugatus* (Marwick, 1931) [*Modiolus altijugatus* Marwick 1931, p. 66] (Mytilidae: Modiolinae).

Large for genus (60-68 mm long), with prominent, narrowly rounded umbones projecting well above dorsal margin, and situated almost at anterior end; dorsal margin long and straight, then curving strongly around to equally long, straight posterior margin; postero-ventral margin narrowly rounded; antero-ventral margin shallowly concave. Very prominent, narrow umbonal ridge widens down shell; shell surface shallowly concave above and below ridge, forming wide posterior "wing". Surface smooth and highly polished, with weak growth ridges. Interior not seen (all specimens articulated).

Tongaporutuan-Opoitian; Mokau Road, North Taranaki, Tongaporutuan (type), from a shallow-water "Hurupi facies" faunule that includes *Amalda* (*Alocospira*) *subhebra* and *Marama hurupiensis*; uncommon but widespread in North Taranaki, Gisborne district, Wairarapa, Marlborough, North Canterbury, and Campbell Island, in shallow-water shellbeds with diverse Mollusca.

Marwick understandably referred *Xenostrobus altijugatus* to the ubiquitous genus *Modiolus*, but Wilson's (1967) demonstration of the distinctive anatomy of the strongly ridged modern species he assigned to *Xenostrobus*, his assignment of the large Plio-Pleistocene *X. huttoni* (Pl. 39b) to *Xenostrobus*, and the similarity in shape of *X. altijugatus* to *X. huttoni* suggest that a position in *Xenostrobus* is more reasonable than one in *Modiolus* for *X. altijugatus*; the position must always be tentative because of the lack of knowledge of the anatomy of the extinct *X. altijugatus*. Huge specimens (to 120 mm long) from the mouth of Upton Brook, Awatere Valley (Opoitian) are similar to *X. altijugatus* but are less strongly curved; they appear to be intermediate between *X. altijugatus* and *X. huttoni*.

Figured specimen (Pl. 28d): holotype, GS1153, Q18/f9045, Mokau Road downstream from Mangapepeke Stream, north of Mt Messenger, North Taranaki, "from the Tongaporutuan beds" (Marwick 1931, p. 66), Tongaporutuan (TM4183, NZGS) x 1.

Pl. 28 f. *Sectipecten wollastoni* (Finlay, 1927) [*Pecten sectus* Hutton 1873b, p. 30 (not of Goldfuss, 1836); *Pecten wollastoni* Finlay 1927b, p. 526 (new name for *P. sectus* Hutton, preoccupied)]. Type species of *Sectipecten* Marwick, 1928 (Pectinidae).

Large for family (95-110 mm high), equidimensional to slightly longer than high; 2 valves almost equally inflated (right valve slightly more inflated than left in some specimens). Ears almost square; posterior edge of posterior ears slopes slightly backward, anterior edge of anterior ears weakly sinuous, with wide, shallow byssal sinus in right anterior ear. Right valve sculpture of 6 prominent, square-edged, flat-topped, radial costae, smooth or weakly grooved over umbonal 0.3-0.5 of disc but becoming progressively subdivided by widening grooves over outer 0.5-0.7 of disc, with lower, narrower costae on each end of disc and a prominent, narrow, median costa in each major interspace, each flanked over outer half of disc by narrow tertiary costellae. Left valve sculpture a mirror image of right, i.e., prominent, narrow, deeply grooved major costae, with 2-4 narrow costellae strengthening out over disc in each wide interspace. Interior not seen; all specimens articulated.

Kapitean; Callaghan's Creek, a tributary of Kapitea Creek, Hokitika district, Westland (lectotype), and widespread from East Cape to southern Southland, in level-bottom environments in near-shore to mid-shelf depths. Most common in rock types with low deposition rates (particularly greensand) but, unlike other *Sectipecten* species, *S. wollastoni* occurs sparsely in normal shelf blue-grey mudstone, as well as in the shallower facies that other *Sectipecten* species seem to have preferred.

Sectipecten wollastoni is the traditional Kapitean index fossil, but unfortunately its lineage evolved very gradually, and has proved difficult to use in biostratigraphy. The putatively ancestral *S. diffusus* is a rare species occurring in only a few Waiauian shellbeds (mainly the *Hinnites* Shellbed at Weka Pass, North Canterbury); it has strongly unequal ears, a deep, perhaps functional byssal notch in the right anterior ear, five radial folds (like those of *Mesopeplum* (*Borehamia*)) in the umbonal area of the disc, and about 30 similar, relatively narrow, raised, flat-topped radial costae with finely serrated edges; it seems likely to have evolved from *M. (Borehamia)*. *S. grangei* (Pl. 28c) is an uncommon Tongaporutuan species occurring in shallow-water, near-shore greensand, sandstone, limestone and shellbeds, but never in the widespread early Tongaporutuan "Hurupi facies" with diverse shelf molluscs. *S. grangei* has much more subdivided sculpture than *S. wollastoni*, early to late Tongaporutuan shells having no smooth-topped, undivided area of main costae. Through the Kapitean, the area of the disc of the right valve over which major costae remain undivided increased progressively over the disc (but quite irregularly in different proportions of different populations), culminating in the early Opoitian type population of *S. allani* (Pl. 33c; Momoe-a-Toa Shellbed, Chatham Island), in which about 30% of the population has completely undivided, smooth-topped costae over the whole disc of the right valve. However, the population is exceedingly variable (see under *S. allani*, Pl. 33 c). The lectotype of *Pecten sectus* Hutton (= *S. wollastoni*), from Callaghan's Creek, a tributary of Kapitea Creek, has the major costae on the right valve

a little more deeply subdivided than most specimens in the *S. wollastoni* bed in greensand at the base of the sequence in Kapitea Creek itself, suggesting that the lectotype may have come from a little lower in the sequence. The sequence of *Sectipecten* species is therefore:

1. The Waiauan *S. diffusus* has about 30 narrow, square-edged costae with finely serrated edges; but almost unknown away from the *Hinnites* Shellbed, Weka Pass.
2. Early-late Tongaporutuan *S. grangei* is easily recognised, as no area of undivided costae occurs on either valve.
3. Early Kapitean (*Globorotalia conomiozea* zone) specimens of *S. wollastoni* occur in highly variable populations in which at least some right valves have smooth, flat-topped costae over the proximal third to half of the disc. No specimens are known from the *G. sphericomiozea* zone (late Kapitean).
4. Pliocene (Opoitian-Mangapanian) specimens are recognisable as *S. allani* by at least some members of the population having undivided costae on the right valve (but most material, other than at Momoe-a-Toa, consists of poorly diagnostic left valves resembling *S. grangei*). A deep, prominent, second subdivision of the right valve costae began in the Waipipian, but the genus became extinct during Mangapanian time.

Figured specimen (Pl. 28f): Lectotype of *Pecten sectus* Hutton, 1873 (not of Goldfuss) = *Pecten wollastoni* Finlay, 1927, GS103, K36/f6009, greensand, Callaghan's Creek, tributary of Kapitea Creek, Hokitika District, Westland, Kapitean ? (specimen is presumably from high in Callaghan's Greensand, and could be either latest Tongaporutuan or early Kapitean) (TM2761, NZGS) x 0.67.

Pl. 28 c. *Sectipecten grangei* Boreham, 1961 [p. 660] (Pectinidae).

Most characters as in *S. wollastoni* (above); differs from *S. wollastoni* in being a little smaller, in being slightly more obliquely elongate postero-ventrally, in being a little less inflated, in having a slightly deeper byssal sinus and, principally, in having much more complexly subdivided sculpture, lacking any undivided, smooth-topped major costae.

Tongaporutuan; Te Wera Quarry, central Taranaki, late Tongaporutuan (type; Boreham 1961, p. 661); widespread in facies where fine sediment was being bypassed during

deposition (greensand, conglomerate, a few limestone beds), mostly in very near-shore facies, in North Taranaki, the Ngamatea Plateau (Napier-Taihape Road), northern Ruahine Range near Kuripapango, northern Wairarapa near Mount Bruce, the Kaiwara River in North Canterbury, and in Callaghan's Greensand in Westland.

Figured specimen (Pl. 28c): GS9478, N33/f9804, Kaiwara River near "Athol Glen", North Canterbury, late Tongaporutuan (NZGS) x 0.67.

Pl. 29 b,c. *Marama (Marama) hurupiensis* Marwick, 1927 [p. 604] (Veneridae: Venerinae).

Moderately large for family (52-60 mm long), length 1.2 x height, i.e. markedly more elongate than *M. murchisoni*; umbones low, strongly curved forwards; dorsal and ventral margins weakly convex, posterior margin slightly quadrate, anterior margin narrowly rounded. Lunule wide, very long, strongly pouting, bounded by deep groove. Sculpture of prominent, high, moderately thick, widely spaced, commarginal lamellae, 1.5-2 mm apart over central area of disc of large shells, but eroded off much of surface of many specimens. Hinge not seen (all specimens closed, articulated shells) but presumably as in *M. murchisoni*.

Tongaporutuan; Hurupi Stream (type) and nearby localities in Palliser Bay, southern Wairarapa, common in shallow-water "Hurupi facies" with diverse Mollusca; also in North Taranaki, Gisborne district, Marlborough, and North Canterbury.

Marama hurupiensis differs from *M. murchisoni* (Kapitean-Nukumaruan; Pl. 41c, d) in its longer, much less inflated shape, its longer, narrower lunule, and its much coarser sculpture, but appears likely to have been immediately (if abruptly) ancestral to *M. murchisoni*. Earlier species of *Marama (Marama)* are all smaller, more inflated, and more finely sculptured, and the origin of *M. hurupiensis* is obscure, but shells resembling the Altonian *M. ovata* are common at some Lillburnian-Waiauan localities in sparsely fossiliferous sandstone and siltstone in Southland, and seem likely to be part of a lineage that led to *M. hurupiensis*.

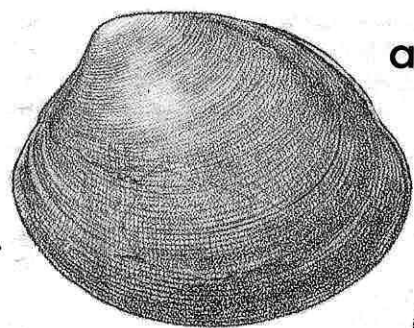
Figured specimen (Pl. 29b, c): holotype, GS1037, S28/f6446, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (TM4517, NZGS) x 1.

Pl. 29 a. *Dosinia (Kereia) cottoni* Marwick, 1927 [p. 590] (Veneridae: Dosiniinae).

Size moderate for genus (42-50 mm high), subcircular, moderately inflated, with narrow, strongly protruding umbones, weakly winged

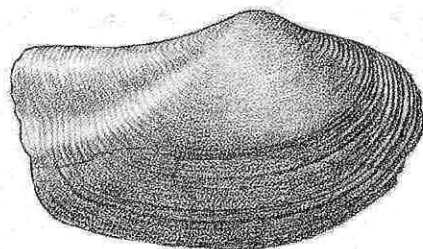
Plate 28 Late Middle Miocene-Late Miocene (Waiauan-Kapitean) Mollusca (1).

- a. "*Ennucula*" *otamaringaensis* (Marwick), x 2.
- b. *Neilo sublaevis* Marwick, x 1.5.
- c. *Sectipecten grangei* Boreham, x 0.67.
- d. *Xenostrobus altijugatus* (Marwick), x 1.
- e. *Eumarcia (Atamarcia) thomsoni* Marwick, x 1.
- f. *Sectipecten wollastoni* (Finlay), x 0.67.
- g,h. *Glycymerita (Glycymerita) rangatira* (King), x 0.67.

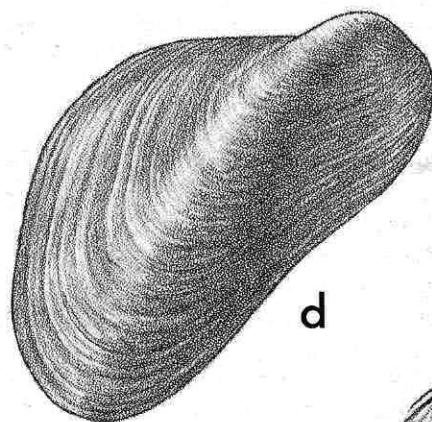
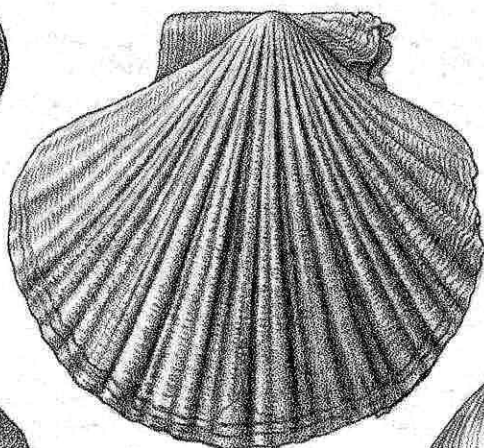


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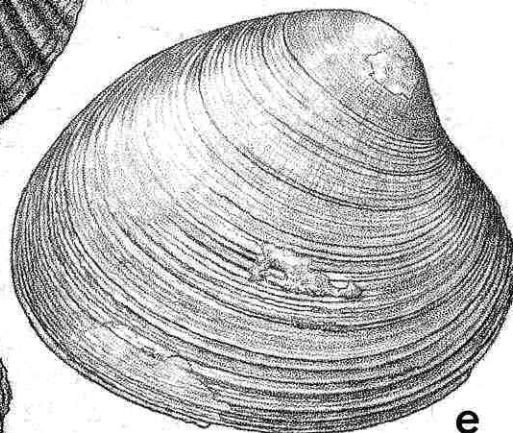
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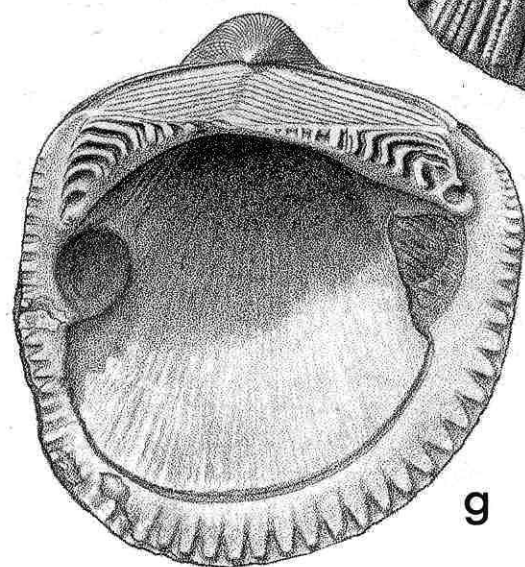
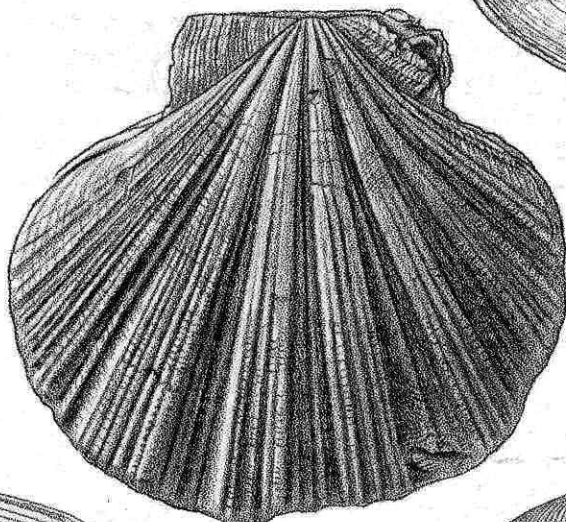


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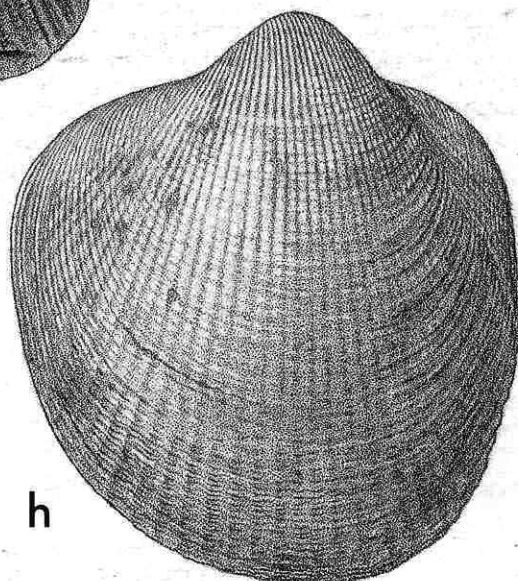
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g

h



posteriorly by weakly convex dorsal margin and weakly angling ridge from umbo to postero-ventral margin. Lunule large, narrow, deeply impressed, particularly in front. Escutcheon well marked, bounding ridge slightly more sharply keeled in left valve than in right. Sculpture of regular, very narrow, widely spaced, commarginal lamellae, normal to disc surface over central and anterior areas but more inclined outward over postero-dorsal area. Hinge visible on very few specimens (almost all are articulated shells); considerably wider and with thicker, more upright teeth than in *D. greyi* Zittel; teeth strongly divergent; right hinge with very short, high, lamellar anterior cardinal tooth close to valve margin, short, widely triangular median cardinal tooth close to anterior cardinal, very broad, grooved, weakly curved posterior cardinal, and short, wide, shallow, anterior lateral socket; left hinge with long triangular anterior cardinal tooth, broadly triangular, grooved median cardinal tooth, long, high, lamellar, weakly curved posterior cardinal tooth, and short, thick, low anterior lateral tubercle, rugose on its lower face; ligamental nymph long, smooth, with wide, bevelled, finely striated resilial surface above. Pallial sinus narrow, deep, with pointed apex, directed at top of anterior adductor muscle scar.

Tongaporutuan (and Waiauian?); Hurupi Stream and nearby localities in Palliser Bay, southern Wairarapa (type), early Tongaporutuan, very common in shallow-water assemblages with diverse Mollusca; widespread in North Taranaki, Gisborne district, throughout Wairarapa, in Marlborough, North Canterbury, and Westland; ? Fox River, Westland (Waiauian); similar shells occur in other Waiauian localities (Paparua Rapids, Wanganui River; southern Wairarapa).

Dosinia cottoni is closely similar to *D. greyi* (Kapitean-Recent), type species of *D. (Kereia)* Marwick, 1927, but differs in its larger size, its more posteriorly winged shape, its less prominent lunule, its lesser inflation, its wider hinge with thicker teeth, and in having a clearly defined escutcheon.

Figured specimen (Pl. 29a): paratype, GS1037, S28/f6446, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS) x 1.

Pl. 28 e. *Eumarcia (Atamarcia) thomsoni* Marwick, 1927 [p. 630] (Veneridae: Tapetinae).

Size moderate for subgenus (62-70 mm long), nearly as high as long, weakly inflated, umbo at anterior quarter of length; shape roundly triangular, umbones strongly protruding, posterior and particularly anterior margins sloping steeply, ventral margin weakly convex. Lunule a shallowly concave, narrowly heart-shaped depression below umbo, bounded by very low, narrow ridge in right valve and very faint groove in left valve. Sculpture of shallow, narrow, widely spaced, fairly regular commarginal grooves, on some specimens bounded by a very low, thin lamella at top of each groove; grooves are more obvious near anterior and posterior ends, central area polished. Variable in sculpture; a few specimens have regular, obvious commarginal grooves all over. Almost all specimens are closed, articulated shells with ligament preserved as prominent ridge behind umbones. Escutcheon a deep, short, triangular, steeply inclined face on right valve, but a much wider, longer, and more gently sloping area on left valve. Hinge narrow except for the short, wider, thicker cardinal area; right valve with similar, lamellar, short, high anterior and median cardinal teeth, and narrowly triangular, weakly curved, deeply grooved posterior cardinal; left valve with high, rather thick, lamellar anterior cardinal tooth, narrowly triangular, deeply grooved median cardinal, and long, curved, narrow, posterior cardinal lamella separated from nymph by shallow groove; no anterior lateral teeth. Adductor muscle scars deeply impressed; clearly separated, deeply impressed, small, socket-like pedal retractor muscle scar beneath anterior end of hinge plate, above anterior adductor muscle scar. Pallial sinus with pointed apex and convex dorsal and ventral margins, extending one third valve length, directed at base of anterior adductor scar (i.e., horizontal). Interior of ventral margin smooth.

Lillburnian?-Tongaporutuan; Whatarangi cliffs, east of Hurupi Stream, eastern Palliser Bay, southern Wairarapa, early Tongaporutuan (type), common in a

“Hurupi facies” shallow-water diverse molluscan assemblage; also other Wairarapa Tongaporutuan localities, several localities in “Tokomaru sandstone” facies inland from Tolaga Bay, north of Gisborne (Tongaporutuan), and Fox River, Westland (Waiauian).

Very similar forms to *Eumarcia thomsoni* (possibly several distinct species, but as the Palliser Bay population is variable in shape, inflation, and sculpture it is unclear at present how many species should be recognised) occur in near-shore to mid-shelf facies at Clifden, Southland (road cutting in Park Bluff Formation, Waiauian, several large specimens of a relatively low, consistently sculptured form; Lill Sand, Lillburnian, several specimens of a small form very close to typical *E. thomsoni*) and in the Oparara River area, Karamea district, southwest Nelson, Lillburnian and possibly Clifdenian (several excellent articulated shells of a short, highly inflated form, probably distinct from *E. thomsoni*). The description (above) of internal characters is based on the Clifden specimens.

No further material has come to light (to our knowledge) of *E. summersae*, which was based on a single complete, articulated Nukumaruan specimen from Gladstone, southern Wairarapa, so it is still conceivable that the holotype is a remanié Tongaporutuan specimen. However, it differs from all *E. thomsoni* we have seen in its taller outline, lesser inflation, weaker sculpture, and less well developed escutcheon, and seems likely to be a distinct Nukumaruan species. The older (and possibly ancestral) *E. curta* (Altonian, North Otago and South Canterbury) differs from *E. thomsoni* in its lower, more oval form and its more prominent commarginal grooves.

Figured specimen (Pl. 28e): GS3619, S28/f8499, Whatarangi cliffs, eastern Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS) x 1.

Pl. 29 f. *Kuia macdowellii* Marwick, 1927 [p. 601] (Veneridae: Venerinae).

Moderate-sized for family (47-56 mm long), length about 1.2-1.3 x height, with umbo at anterior quarter to third of length; umbo moderately to strongly protruding and inflated, descending rapidly in front to moderately large, heart-shaped lunule, bounded by narrow groove; posterior margin slightly quadrate, ventral margin deeply convex. Sculpture of unique broad, flat-topped, low commarginal ridges separated by very narrow, shallow grooves; lower edge of each ridge bears a low, very thin lamella in well preserved shells, but lamellae are abraded off most specimens. Almost all specimens are closed, articulated shells; interior ventral margin finely crenulate. Right valve hinge with long, low ligamental nymph, 3 narrow cardinal teeth (posterior pair partly fused but widely spaced), and 2 narrow, short, anterior lateral teeth margining large socket; left hinge not seen. Adductor scars of similar size, anterior one narrower and nearer valve margin than posterior; pallial sinus narrow, with rounded apex, directed at base of anterior adductor scar.

Waiauian-Kapitean; Park Bluff Formation, Clifden, Southland (probably from Nissen Shellbeds), Waiauian (type); moderately common at Clifden (Waiauian), Bluecliff, Te Waewae Bay (Kapitean), “Hurupi facies” diverse assemblages in Wairarapa, Hawke’s Bay, Gisborne District, and North Canterbury (Tongaporutuan), and in a debris flow with mostly Kapitean and Tongaporutuan fossils in ? Opoitian mudstone, Little Wanganui River, Karamea, southwest Nelson; specimens of undoubted Opoitian age are not known to us.

Kuia madowelli is readily distinguished from the much smaller *K. vellicata* (Kaiatan ?; Waitakian-Altonian; Pl. 11d, f) by its much lower lunule, its more quadrate shape, its markedly wider commarginal flat ridges and its much less obvious commarginal lamellae. Specimens from the Third Bay Sandstone (Lillburnian) at Clifden are similar to *K. vellicata* in most characters, but have sculpture intermediate between that of *K. vellicata* and that of *K. madowelli*.

Marwick (1927, p. 601) did not state the derivation of the species name, but it is almost certainly named after Dr F.H. McDowall, a collecting companion of H.J. Finlay's at Clifden (see Fleming in Wood 1969, p. 72) and is probably spelled incorrectly.

Figured specimen (Pl. 29f): GS2423, U23/f8341, Ongaha Stream near Dannevirke-Mangatoro Road, 10 km east of Dannevirke, southern Hawke's Bay, Tongaporutuan (NZGS) x 1.

Pl. 14 b,e; Pl. 29 j. *Crepidula radiata* (Hutton, 1873) [*Crepidula incurva* Zittel 1864, p. 44 (not of Broderip, 1834); *Crypta striata* Hutton 1873b, p. 14; *Pilaeopsis radiatus* Hutton 1873b, p. 14; *Crepidula gregaria* "Sowerby" of Suter 1914, p. 20 (not of Sowerby); *Crepidula wilckensi* Finlay 1924a, p. 101 (new name for *C. incurva* Zittel, preoccupied); possibly also = *Crepidula haliotoidea* Marwick 1926c, p. 318; *Crypta opuraensis* Bartrum and Powell 1928, p. 145; *Crypta turnialis* Bartrum and Powell 1928, p. 144; and *Maoricrypta salebrosa* Marwick 1929, p. 918; *Maoricrypta striata*; *Maoricrypta radiata*] (Calyptraeidae).

Large for family (40-100 mm long), elongate limpet-shaped but with large horizontal internal septum (so, when inverted, shaped like a boat or slipper), long and moderately wide, with apex, or beak (at posterior end) straight or, in many specimens, weakly coiled to left (in dorsal view). Sculpture of longitudinal (strictly speaking, spiral) cords, exceedingly variable in prominence, from about 6 high, widely spaced, irregularly nodulous or serrate ribs of triangular section, to very many exceedingly fine, low, close threads, or no sculpture at all; at most localities smooth or weakly sculptured shells much more common than coarsely sculptured ones. Internal septum (widely extended columellar shelf) smooth, deeply set within shell, occupying posterior 0.3-0.5 of interior; its anterior margin simple, arcuate.

Dannevirke Series(?); at least Duntroonian – Nukumaruan. Awatere Valley, Marlborough, horizon and age unknown (holotype of *Crepidula incurva* Zittel, 1864, not of Broderip, 1834, = *Crepidula wilckensi*; and presumed holotype of *Crypta striata*, the specimen figured by Zittel 1864, pl. 15, fig. 10); Awatere Valley, Marlborough, probably (as noted by Marwick 1948, p. 30) from concretions of "the Upton beds of Upton Brook" (Kapitean), a tributary of Awatere River (holotype of *Pilaeopsis radiatus*, with a fragment of *Struthiolaria cincta* in the matrix); Tirangi Stream, North Taranaki, in shallow facies with *Struthiolaria callosa*, etc., Tongaporutuan (holotype of *Crepidula haliotoidea*); Kaawa Creek, southwest Auckland, Opoitian, in shallow-water shellbeds (holotypes of both *Crypta opuraensis* and *C. turnialis*); Chatton, Southland, Duntroonian, in shallow-water shellbeds (holotype of *Crepidula salebrosa*).

Like all Calyptraeidae, *Crepidula radiata* was a sedentary filter feeder; it lived attached to stones or other shells in the manner of a limpet, copying the substrate topography in its shape and waving of the margin, and so is highly variable in form. It occupied a large variety of hard

substrates in shallow water (inner-mid shelf) environments.

This is one of the commonest and most ubiquitous and yet (taxonomically) one of the least well understood of New Zealand molluscan groups. The synonymy (above) and list of type localities follows the conventional concept of *Crepidula* in New Zealand Cenozoic rocks—of relatively few (perhaps only one) very variable species with a long time range. However, specimens aggregated in spiral stacks have been seen only from Tongaporutuan and Kapitean rocks (Tongaporutuan, Hurupi Stream area, Palliser Bay, common, and Raurimu, central North Island (illustrated); Kapitean, East Cape and Awatere Valley). In the modern American species *Crepidula fornicata* (Linné) such aggregations are protandric sexual development series, with large females at the base, small males at the summit, and individuals in between undergoing a change of gender. Although in the modern New Zealand species small male specimens are found on the shells of most large females, the formation of large stacks by Taranaki Series populations, only, suggests strongly that these specimens (typical *Crepidula radiata*) are a distinct species from all the other forms that are included under this umbrella at present.

The lectotype (here designated) of *Crypta profunda* Hutton (1873b, p. 14), Hutton's first-listed specimen from Shakespeare Cliff, Wanganui (in NZGS; the whereabouts of Hutton's six other listed lots of syntypes is unknown) may be the species previously known in the Recent fauna as *Maoricrypta youngi* Powell. The protoconch size and shape and ontogenetic sculptural changes on the early teleoconch whorls distinguish the three living species *C. costata* (Castlecliffian-Recent), *C. monoxyla* (Otaian?-Recent) and *C. profunda* (Castlecliffian?-Recent), and show that a fourth, unnamed, weakly trigonal, smooth, inflated species lives on other molluscan shells on the outer shelf around New Zealand (pers. comm. B.A. Marshall, National Museum of N.Z.). Studies of the protoconch and ontogenetic sculptural changes are needed for fossils, also, but are difficult to carry out as few fossils have well preserved apical areas. In the mean time, all that can be stated is that several species appear to be confused under the name *C. radiata*. The large, thick-shelled, deeply convex, smooth form in Opoitian to Nukumaman rocks (*C. turnialis* ?) does not form protandric sexual piles, and seems likely to be distinct from typical Tongaporutuan-Kapitean *C. radiata* (illustrated, Pl. 29j); its extinction at the end of Nukumaran time is a valuable biostratigraphic index. The Duntroonian-Waitakian *C. salebrosa* Marwick (illustrated, Pl. 14 b,e) has coarser and wider costae than later forms and also seems likely to be distinct.

We agree with Hoagland (1977) that there are no characters distinguishing *Maoricrypta* Finlay and *Zeacrypta* Finlay from *Crepidula* Lamarck, 1799.

Figured specimens (Pl. 14b, e): GS9517, I40/f9805, Campbell Park School, Otekaieke, Waitaki Valley, Otekaieke Limestone, Waitakian (NZGS; the *salebrosa* form) x 1; (Pl. 29j): Raurimu, Tongariro National Park, central North Island, Tongaporutuan, from a private collection (NZGS; part of a spiral aggregation), x 1.

Pl. 29 i. *Struthiolaria (Struthiolaria) praenuntia* Marwick, 1926c [p. 318] (Struthiolariidae).

Closely similar to *S. calcar* Hutton (Otaian-Waiauian) (Pl. 20g, h), differing in larger size and significantly taller, narrower shape of most specimens, in lacking, or having only weak, nodules around shoulder angle and, in particular, by developing median spiral cord on spire whorls. On a few specimens, median cord descends to last whorl, but on most specimens it fades out over penultimate whorl.

Tongaporutuan; Tirangi Stream, near Tongaporutu, North Taranaki (type) and common in shallow-water shellbeds in Taranaki, Gisborne district, Wairarapa, and Canterbury. Found only in inner-mid shelf, soft-bottom facies.

The median cord is very variable in prominence in all populations of *Struthiolaria praenuntia*, although it appears to be more prominent in mid-Tongaporutuan than in early Tongaporutuan populations. It represents the strongest development of this median cord in mid-late Neogene species of *Struthiolaria* and, despite its subtlety, has proved reliable in biostratigraphy; all specimens we have seen with a prominent median cord are from Tongaporutuan rocks. It is succeeded again rapidly by forms such as *S. nexa* (Kapitean, Gisborne area) and *S. cincta* (Kapitean, Awatere Valley) that have again lost the median cord. (The relationship to *Pellicaria nana* is discussed under that species).

Figured specimen (Pl. 29i): GS5740, S27/f8622, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS) x 1.

Pl. 29 d,e. *Struthiolaria (Callusaria) callosa* Marwick, 1924 [*Struthiolaria callosa* Marwick 1924b, p. 182; *Struthiolaria armata* Marwick 1924b, p. 183; *Struthiolaria fortis* Marwick 1924b, p. 183]. Type species of *Callusaria* Finlay, 1926 (Struthiolariidae).

Large for subgenus (40-70 mm high), short and wide, with moderately short spire (about equal to height of aperture) and enormously developed

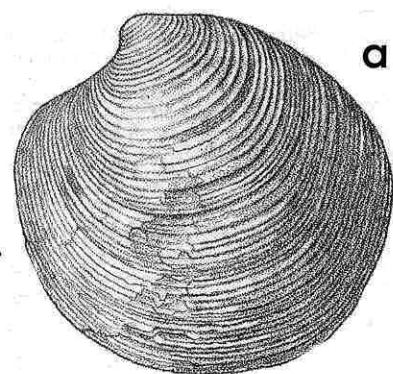
parietal callus pad; except for narrowly pointed nodules at peripheral angulation and smaller ones on weaker peribasal angulation on last whorl, the only sculpture is very faint, low spiral threads on early spire whorls. Aperture large, oval; outer lip thickly callused to form wide varix, strongly bisinuate. Inner lip expanded into most extreme callus of any mid-late Cenozoic struthiolariid, a huge pad of semicircular cross-section riding over peripheral nodules to lap onto lower part of previous whorl (forming polished, irregular band of callus around penultimate whorl below periphery), curving around parietal lip to ride over peribasal angulation as well to form large, knob-like protrusion to left of aperture, then rapidly contracting to low but still wide sheet on previous whorl, meeting outer lip at shallow anterior notch of aperture. Protoconch not seen, presumably as in *S. calcar* and *S. spinosa*, above.

Clifdenian ?; Lillburnian - Tongaporutuan; Hurupi Stream, Palliser Bay, southern Wairarapa, Tongaporutuan (type of *S. callosa*); Tutamoe Formation, Tutamoe Survey District, Gisborne, Lillburnian (type of *S. fortis*); "Tutamoe conglomerate", Pangopango Stream, inland from Tolaga Bay, Gisborne, Lillburnian (type of *S. armata*); and abundant at many localities throughout Taranaki, Gisborne district, southern Hawke's Bay, Wairarapa, Marlborough, and North Canterbury. Found in the same diverse molluscan assemblages in shallow-water, soft-bottom facies as is *S. praenuntia*.

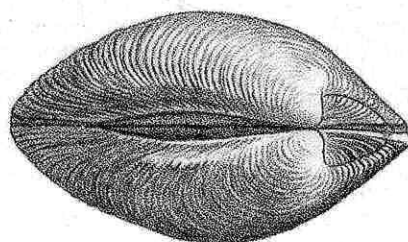
Struthiolaria callosa was apparently a direct descendant of the Altonian to Clifdenian *S. spinosa* (Pl. 20b), differing in its hugely developed parietal callus, its shorter form (in most specimens) and its absence of spiral sculpture on the last whorl. By this definition, *S. armata* and *S. fortis* are variants of *S. callosa*, although this needs confirmation from detailed population studies. At Clifden, Southland, *S. spinosa* reappears in the Waiauian Nissen Shellbeds, after *S. callosa* had evolved in the North Island. *S. callosa* was succeeded abruptly in Kapitean-Opoitian rocks by *S. obesa* (Pl. 36i) which is smaller, still shorter, more weakly callused, and less nodulose than *S. callosa*, and bears spiral threads all over. As first revisers, we select the name *Struthiolaria collosa* for the species named *S. callosa*, *S. armata* and *S. fortis* by Marwick (1924b).

Plate 29 Late Middle Miocene-Late Miocene (Waiauian-Kapitean) Mollusca (2).

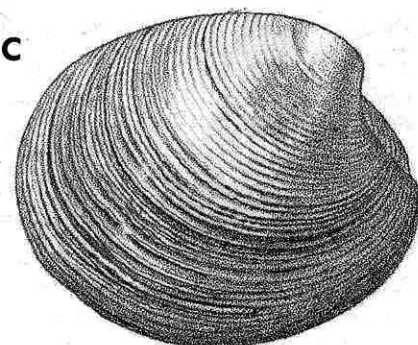
- a. *Dosinia (Kereia) cottoni* Marwick, x 1.
- b,c. *Marama (Marama) hurupiensis* Marwick, x 1.
- d,e. *Struthiolaria (Callusaria) callosa* Marwick, x 1.
- f. *Kuia macedowelli* Marwick, x 1.
- g. *Pellicaria nana* (Marwick), x 1.5.
- h. *Zeacolpus (Zeacolpus) taranakiensis* Marwick, x 2.
- i. *Struthiolaria (Struthiolaria) praenuntia* Marwick, x 1.
- j. *Crepidula radiata* (Hutton), x 1.
- k. *Polinices (Polinella) scalptus* (Marwick), x 2.
- l. *Polinices (Polinices) propeovatus* (Marwick), x 2.



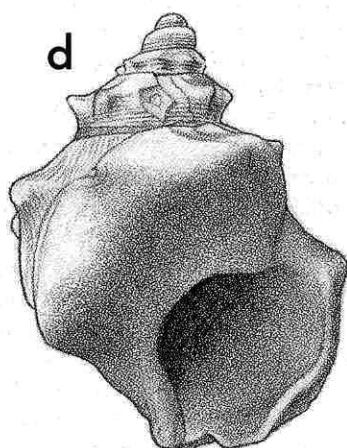
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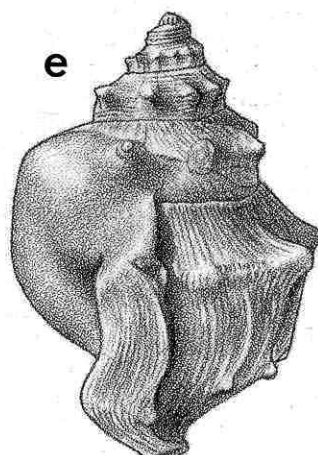
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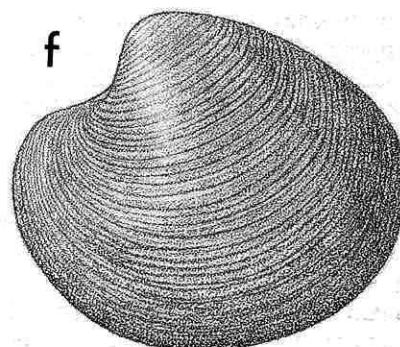
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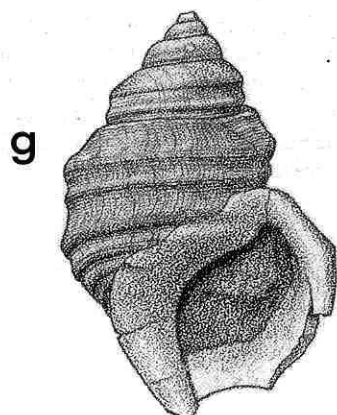
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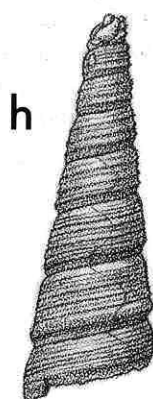
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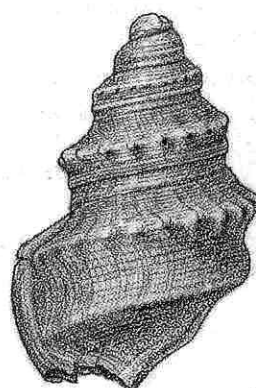
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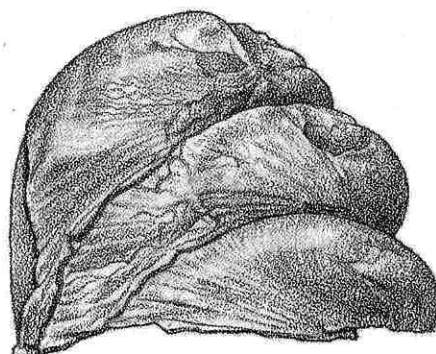
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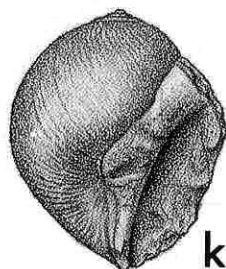
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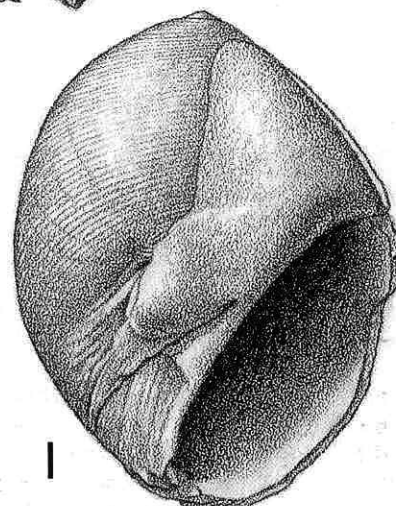
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Figured specimen (Pl. 29d, e): GS5740, S27/f8622, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS) x 1.

Pl. 29 g. *Pellicaria nana* (Marwick, 1926) [*Struthiolaria nana* Marwick 1926c, p. 318] (Struthiolariidae).

Small for family (28-38 mm high), moderately short and wide, with spire slightly shorter than aperture; whorls convex at first, then angled at upper third on spire; narrow, shallowly excavated sutural channel commences on second or third spire whorl and strengthens down shell, resembling that of many forms of *P. vermis* by last whorl. Sculpture of prominent, weakly nodulous spiral cord around shoulder angle, separated from sutural channel by wide, weakly concave sutural ramp; equally prominent, smooth spiral cord around peribasal angulation, separated from upper angle by wide, gently concave area; slightly less prominent cord in centre of mid-whorl concave area; and series of cords of decreasing prominence over base (3 and weak fourth on most specimens); whole surface crossed by many very fine, close spiral threads. Aperture large, oval; outer lip with relatively narrow varix, weakly sinuous; inner lip with usual narrow *Pellicaria* callus, meeting outer lip at shallow anterior notch. Protoconch broken, but apex clearly small, as in *S. (Struthiolaria)*.

Tongaporutuan, Tirangi Stream, North Taranaki (type), and Hurupi Stream, Palliser Bay, southern Wairarapa; very rare, in diverse, shallow-water, soft-bottom assemblages with *S. praenuntia* and *S. callosa*.

At its two known localities, *Pellicaria nana* occurs with *Struthiolaria praenuntia* (Pl. 29i), and it closely resembles early whorls of *S. praenuntia* in shape, proportions, and all sculptural details, except the sutural channel that develops progressively on *P. nana*. Also, the basal cords of *P. nana* are absent from *S. praenuntia*. It seems likely that (as suggested by Marwick 1926c, p. 318) *P. nana* was the earliest species of *Pellicaria*, and that it evolved very rapidly (at least in geological terms) from the closely similar *S. praenuntia* by acquiring the ability to mature at an earlier age (paedomorphosis), as shown by its acquisition of a mature outer lip (all modern Strombacea develop a thickened outer lip only when they stop growing, and reach sexual maturity). It is therefore interesting that *P. nana* clearly has a *Pellicaria*-type aperture, and yet appears to have had a conical, multispiral protoconch as in *Struthiolaria*. Protoconchs of fossil *Pellicaria* are poorly known, but one line of evidence about their nature is the rapidly speciating, multi-lineage plexus that developed in *Pellicaria*, presumably the genetic consequence of direct development, which is reflected in the living *P. vermis* (Morton 1950, p. 456) by its low, paucispiral, cap-shaped "blob" apex. It seems that this kind of multi-lineage development did not commence in *Pellicaria* until Waipipian time, and so it is perhaps not surprising that *P. nana*, the earliest species that appears to belong in *Pellicaria*, has a protoconch like that of the ancestral genus. The evolution of *Pellicaria* is apparently an example of the geologically instantaneous evolution of a genus (some workers rank it as a subgenus) by paedomorphosis, presumably as the result of a mutation in the gene(s) controlling development.

Figured specimen (Pl. 29g): GS5740, S27/f8622, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS; ex P. Wellman collection) x 1.5.

Pl. 29 h. *Zeacolpus (Zeacolpus) taranakiensis* Marwick, 1965 [p. 48] (Turritellidae).

Moderately large for genus (25-65 mm high), tall and slender, with

almost straight sides but outline weakly notched at deeply indented sutures; sculpture of very even, uniform, narrow spiral cords; most specimens are short lengths of shell only. Sutural ramp narrow, sloping very steeply, succeeded by wide, flat or gently concave mid-whorl area, occupying central 0.7 of whorl; another angulation near base formed by primary cord C, then contracting sharply to suture. Primary cords A, B and C are not distinguishable from evenly sculptured background in adults. Outer lip with wide, fairly shallow, V-shaped sinus, with rounded apex; base flat. Protoconch paucispiral, of 1 bulbous whorl, with a small initiation.

Waiauian?; Tongaporutuan; coast at Omaha Trig., Mimi, North Taranaki (type), and abundant at most shallow-water Tongaporutuan localities in New Zealand, in Taranaki, Gisborne district, southern Hawke's Bay, Wairarapa, Marlborough, North Canterbury, and Westland. Potentially a very useful biostratigraphic index of Tongaporutuan age, but difficult to use in practice.

Most specimens of *Z. taranakiensis* have less numerous and less regular, more widely spaced spiral cords than *Z. pukeuriensis* (Pl. 20a) and *Z. fyfei* (Lillburnian-Waiauian, Gisborne district) and lack the medially smooth zone of most *Z. fyfei*. *Z. taranakiensis* seems to have descended from *Z. nissenii* (Waiauian, Clifden, and Paparoa Rapids, Wanganui River), which differs in having two well differentiated, prominent cords around the basal angle, and finer spiral cords above. *Z. taranakiensis* is possibly on a line leading to *Z. kanieriensis* (Pl. 36n) and *Z. vittatus* (Pl. 47f). A few specimens have been collected in which the last whorl contains many juvenile shells, consisting of the one-whorl protoconch plus the first teleoconch whorl, indicating that the species was ovoviviparous (Marwick 1971b).

Figured specimen (Pl. 29h): paratype, GS2830, N33/f9106, Gower River, North Canterbury, Tongaporutuan (TM3775, NZGS) x 2.

Pl. 29 i. *Polinices (Polinices) propeovatus* (Marwick, 1924) [*Uber propeovatus* Marwick 1924d, p. 564] (Naticidae: Poliniceinae).

Moderate-sized to very large for genus (35-70 mm high), evenly oval, with very heavily callused inner lip, filled umbilicus, and regular, fine, closely spaced, shallow spiral grooves all over exterior surface. Spire short; anterior outline evenly convex. Top of inner lip swings forward markedly from suture, then descends almost straight or in a shallow arc to top of umbilical callus; umbilical callus lobe long, with weakly convex sides ("tongue-shaped"), leaving a small umbilical chink in some specimens (e.g., holotype) but completely filling umbilicus and separated from funicle by only a shallow groove in most specimens. Protoconch not preserved on available material.

Waiauian-Opoitian; Tirangi Stream, North Taranaki, Tongaporutuan (type), and many localities in North Taranaki, Gisborne district, southern Hawke's Bay, and North Canterbury (particularly near the former Ethelton School, Kaiwara River, Tongaporutuan; and Double Corner Shellbeds, lower Waipara Gorge, Waiauian); Opoitian localities include Kaawa Creek, southwest Auckland, several in Dannevirke district, and several in Awatere Valley, Marlborough. As with other *Polinices* species, *P. propeovatus* occurs in shallow-water, soft-bottom assemblages of diverse Mollusca, and at most localities occurs in large numbers.

The one very readily recognised character of *Polinices propeovatus* is its fine, even spiral grooves, which are much more strongly developed than in any other New Zealand *Polinices* species; Marwick's type material is rather worn, but still shows traces of the grooves,

although they were not mentioned by Marwick (1924d, p. 564). *P. propeovatus* does not occur in southern Wairarapa Tongaporutuan "Hurupi faunas", where it is replaced by an unsculptured member of the complex of *P. huttoni*. The taxonomy of the abundant smooth or weakly sculptured forms of *Polinices* in New Zealand Miocene rocks is poorly known (see discussion under *P. huttoni*, Pl. 20 k).

Figured specimen (Pl. 29l): GS3348, N33/f9114, near site of former Ethelton School, Kaiwara River, North Canterbury, Tongaporutuan (NZGS) x 2.

Pl. 29 k. *Polinices (Polinella) scalptus* (Marwick, 1924) [*Uber scalptus* Marwick 1924d, p. 568] (Naticidae: Poliniceinae).

Small for genus (17-20 mm high), short and oval, with low spire and large, wide, enveloping last whorl, and no anterior canal; smooth and lightly polished, except for weak growth lines and zone of short, very shallow and narrow, axial grooves below suture (curved backward to suture in conformity with strongly retracted outer lip). Aperture simple, D-shaped; inner lip with prominent wide callus, completely filling umbilicus apart from very shallow basal groove; callus of adult specimens crossed by 2 widely diverging, wide, shallow, but clearly defined grooves, one at junction of parietal and funicular calluses, the other rather low on funicle; much of callus surface irregularly grooved and granulous on many specimens; callus of juvenile specimens crossed by deep, curved central groove, shorter and wider groove above, and 2 short, weak grooves below. Left edge of callus regularly and weakly convex, or bearing one or 2 small protrusions opposite callus grooves. Aperture inclined at angle of about 25°-30° (angle varies with spire height, which is highly variable). Protoconch very low, wide, of about 2-2.5 apparently smooth whorls, not clearly distinguished from teleoconch.

Waiau-Tongaporutuan,? Kapitean; Mangare Road, upper Waitara Valley, North Taranaki, Tongaporutuan (type); Tongaporutuan, several localities in North Taranaki, and tributaries of Mangaopari Stream, southern Wairarapa; Waiau, near Karoro, Greymouth, Stillwater Mudstone (Maxwell 1988a, p. 49); ? Kapitean, Te Araroa, East Cape, and Kapitea Creek and nearby localities, Westland (ontogeny not checked but adult shells appear to be conspecific).

Maxwell (1988a, p. 49) pointed out that juvenile specimens of *Polinices scalptus* have much more prominent callus grooves than adults, and only the two most prominent grooves are retained on adults. This ontogenetic development of callus grooves distinguishes Waiau to Tongaporutuan (and perhaps Kapitean) specimens from the older ones included in the species by earlier authors. Clifden specimens (Altonian-Clifdenian) included here by Fleming (1966b) are not conspecific, and several Miocene species appear to be unnamed. Maxwell (1988a, p. 49) pointed out that juvenile specimens of *P. esdailei* (Kaiatan-Runangan) and *P. modestus* (Duntroonian-Altonian) have far less prominent callus grooves than those of *P. scalptus*. Ontogenetic development of callus grooves needs checking in other species accorded long time ranges, such as *P. obstructus* (Pl. 37i). *P. scalptus* occurs sympatrically with *P. obstructus* at some localities, but is always easily distinguished by its smaller size, lower spire, more strongly inclined aperture, wider callus, consistently closed umbilicus, more prominent and more strongly diverging callus grooves, and its axial grooves below the suture that are absent from *P. obstructus*.

Figured specimen (Pl. 29k): holotype, GS1148,

R19/f8009, Mangare Road, upper Waitara Valley, North Taranaki, Tongaporutuan (TM6526, NZGS) x 2.

Pl. 30 b. *Sassia (Haurokoa) woodi* (Fleming, 1955) [*Argobuccinum (Haurokoa) woodi* Fleming 1955a, p. 1056]. Type species of *Haurokoa* Fleming, 1955 (Ranellidae: Cymatiinae).

Moderately large for genus (40-65 mm high), wide and evenly inflated, with low, conic spire (0.5-0.7 height of aperture and canal) with only weakly convex whorls, large varices of thick, rounded cross-section every 0.67 whorl down whole teleoconch, and short, straight, moderately open anterior canal without fasciole. Protoconch large (4.0 mm wide, 3.7 mm high), turbiniform, of 3.7 superficially smooth, weakly convex whorls, with minute apex. Sculpture of low, wide, strap-like spiral cords with convex surfaces, with interspaces slightly narrower than to equal to width of 1 cord, and with 1 narrow, lower cord in each interspace in many specimens; primary cords raised at frequent (but irregular) intervals into low, narrow, laterally compressed nodules, weakly aligned into axial costae over some areas of some specimens, but merely forming an evenly, coarsely gemmate surface on most specimens. Aperture moderately large, oval; outer lip a thin flange reflected over inner third to half width of terminal varix, with prominent short ridges along its inner edge; inner lip wide, thick, forming a narrow, raised collar over neck and canal, bearing a single large parietal ridge, narrow, thin, basal columellar flange bearing numerous low ridges, and general surface sculpture of irregularly anastomosing ridges and wrinkles.

Waiau-early Opoitian; Port Craig, Te Waewae Bay, Southland, Kapitean (type); Nissen Shellbeds at Clifden, Southland (Waiau), scattered localities in Gisborne district (Tongaporutuan), Maruhou Point, between Te Araroa and East Cape (Kapitean), and Birch's Mill shell lens, Te Waewae Bay (early Opoitian). Widespread but uncommon in shallow-water, soft bottom assemblages.

Fleming (1955a) noted a resemblance of *Sassia (Haurokoa) woodi* to *Argobuccinum* Hermannsen, 1846 (Ranellidae: Ranellinae) in general shape and the shape of the varices. However, *S. woodi* has varices at each two-thirds of a whorl, rather than every half-whorl as in Ranellinae. It appears to have descended (through an intermediate, unnamed form) from *Sassia (Haurokoa) marwicki* (Kaiatan-Runangan; Pl. 7u), a small, narrow, but similarly gemmate species differing from *Sassia (Sassia)* only in its relatively large protoconch, its evenly nodulose sculpture, and in having the outer lip reflected widely but thinly over the terminal varix. The lineage appears to have descended from *Sassia* (Cymatiinae) rather than from *Argobuccinum*.

Figured specimen (Pl. 30b): GS10343, D45/f8668, Nissen "no. 1" Shellbed, Park Bluff, Clifden, Southland, Waiau (NZGS) x 1.

Pl. 30 a. *Pterynotus (sensu lato) laetificus* Finlay, 1930b [p. 76-77; *Pteropurpura laetifica*] (Muricidae: Muricinae).

Moderately large for genus (height 65-80 mm), broadly fusiform, spire 0.3-0.4 total height. Protoconch narrowly dome-shaped, of about 1 smooth whorl. Teleoconch of 7 whorls, weakly subangled near middle on most shells, but more distinctly shouldered on others, including figured specimen. Thin, elevated varices spaced a third of a whorl apart, each fused to the one above to produce 3 continuous wing-like keels down the teleoconch. Varices almost flat-faced with rounded outline in some shells, but with prominent peripheral gutter and consequently triangular outline in others. Other axial sculpture of single low peripheral nodule between each pair of varices. Spiral sculpture on most specimens of weak, well-spaced cords which extend onto backs of varices (and are expressed on the front faces as shallow grooves), apparently obsolete on most of neck. Well preserved shells with very fine striae over much, if not all surface. Aperture elongate-ovate, constricted anteriorly; siphonal canal long, straight, apparently completely or almost completely closed in adults. Inner lip callus moderately thick, smooth, outer margin

slightly raised anteriorly. Outer lip flared and fused to face of terminal varix, denticulate within, some shells with a distinct gutter corresponding to variceal spine.

Kaiatan?, Waitakian-Kapitean; "Clifden, band 7C, close to band 8" (type—probably from one of the Nissen Shellbeds i.e., Waiauan). Recorded from numerous localities throughout New Zealand, but nowhere common. A small shell from McCulloch's Bridge (Kaiatan) closely resembles younger specimens assigned here.

Pterynotus laetificus is interpreted in a very broad sense, following Beu (1970b, p. 135-138), although the available specimens vary considerably in the shape of the varices, the disposition of the peripheral spine (if present), and the strength of the spiral sculpture. In some shells (including the poorly preserved holotype) the outer lip is rounded, without any obvious trace of a gutter or channel on the shoulder, although the varix has a distinctly triangular outline; in others (including the near-topotype illustrated here) there is a distinct gutter in the outer lip and a well developed peripheral spine; in yet others (e.g. from Awamoa Creek) the varices are rounded, but there seems to have been a narrow, curved canal fused to the edge of the varix on the preceding whorl. Most specimens have weak spiral sculpture, but in a shell from Trig Z, Otiake (Waitakian) (Beu 1970b, pl. 1, fig. 1, 3) the spiral cords are exceptionally strong and frill the edges of the varices. Considerably more material will be required before it can be decided if these specimens are merely variants of a highly variable species, or if more than one species is involved. Beu (1970b, p. 135-141) referred *Pterynotus laetificus* to the ocenebrine genus *Pteropurpurea* Jousseaume, 1880 because of its resemblance to the Australian Recent species *P. bednalli* (Brazier), and recognised two additional subspecies (here regarded as species), *P. laetifica flemingi* (Mangapanian, Palliser Bay and Recent, northern New Zealand) and *P. laetifica waiareka* (Kaiatan, Lorne, Oamaru). Ponder (1972b, p. 217), however, has shown that *P. bednalli* has

radular and opercular characters like those of typical species of *Pterynotus*, suggesting that *P. laetificus* and its relatives should be retained in *Pterynotus*, even though they are not particularly like the type species *P. pinnatus* (Swainson, 1822) (Recent, Indo-Pacific). Vokes (1971a) also catalogued the New Zealand species in *Pterynotus* (sensu stricto). *P. flemingi* is very similar to *P. laetificus*, but seems to reach a smaller size and to have a more prominent intervariceal tubercle and a lower spire. *P. waiareka* was based on a single, poorly preserved specimen differing from typical *P. laetificus* in its more slender shape and much stronger spiral sculpture. *P. kauparaensis* (Otaian, Pakaurangi) is rather more distinctive, differing from *P. laetificus* in its much smaller size (height about 30 mm) and in having three elongate nodules in each intervariceal space.

Pterynotus is one of the most ancient genera in the Muricinae, with a record extending back to the Paleocene (Vokes 1970a, p. 2). Although it was widely distributed during the Cenozoic, modern species are restricted to subtropical and tropical regions, usually in moderately deep waters. *P. laetificus* seems to have ranged across the shelf and into the upper bathyal zone, but *P. flemingi* is restricted to the deeper part of this range.

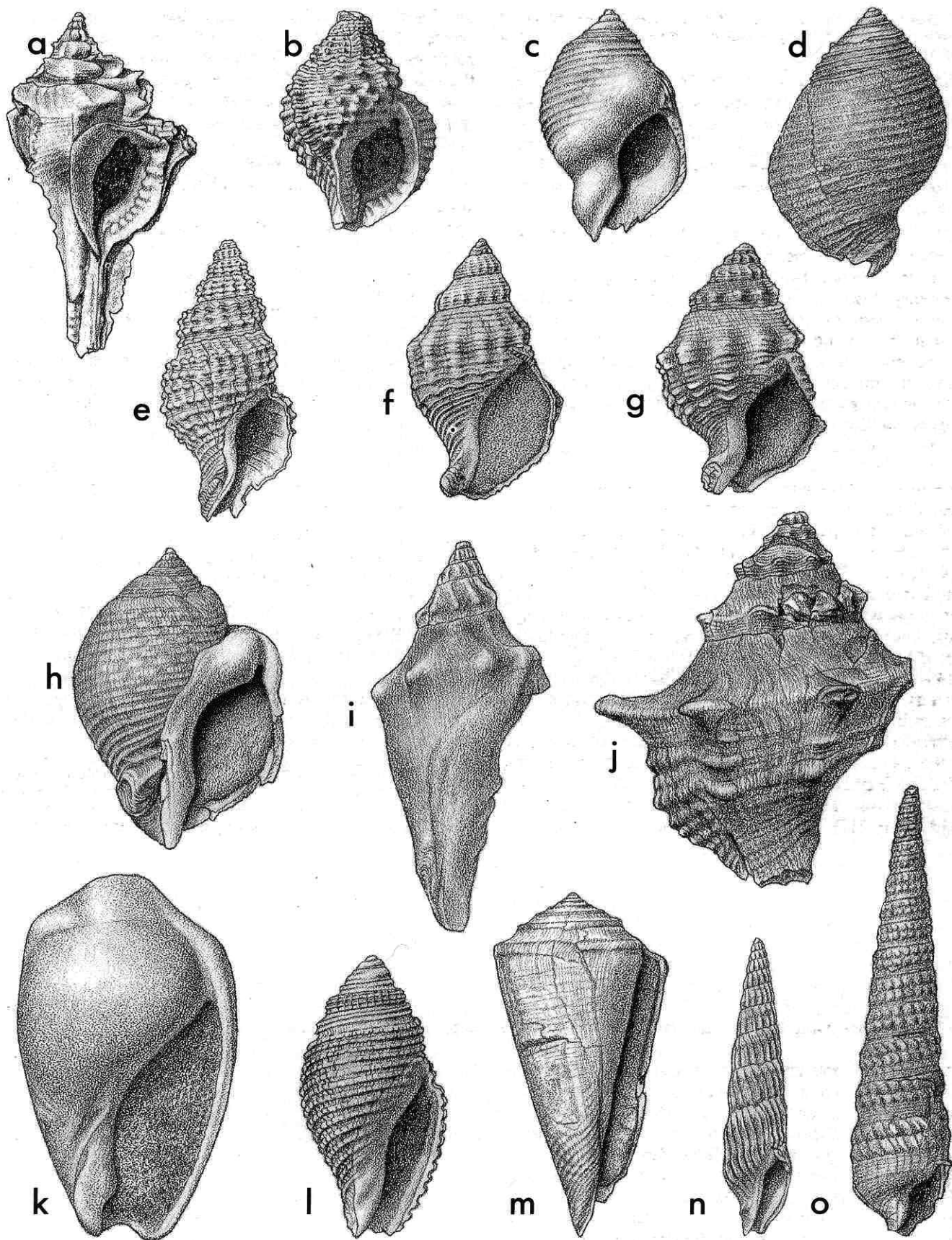
Figured specimen (Pl. 30a): GS12142, D45/f05, Waiau River, upstream from Park Bluff, Clifden Section, Southland, Waiauan (NZGS) x 1.

Pl. 30 j. *Penion crawfordi* (Hutton, 1873) [*Fusus crawfordi* Hutton 1873b, p. 3; *Austrosipho* (*Verconella*) *latispinifer* Marwick 1932, p. 501; *Austrosipho masoni* Fleming 1943, p. 201; *Austrosipho takapauensis* Fleming 1943, p. 202; *Murex crawfordi*; *Verconella crawfordi*; *Austrosipho* (*Verconella*) *crawfordi*; *Verconella latispinifer*] (Buccinidae).

Large for family (100-120 mm high, 70-100 mm wide including nodules), with relatively short, conic spire (consistently only third to half height of aperture and canal), prominent angulation at half to lower third of whorl height on spire (or even lower on some specimens) that bears

Plate 30 Late Middle Miocene-Late Miocene (Waiauan-Kapitean) Mollusca (3).

- a. *Pterynotus* (sensu lato) *laetificus* Finlay, x 1.
- b. *Sassia* (*Haurokoa*) *woodi* (Fleming), x 1.
- c,d. *Zelandiella fatua* Finlay, x 1.5.
- e. *Austrofusus* (*Austrofusus*) *coerulescens* (Finlay), x 1.5.
- f. *Austrofusus* (*Austrofusus*) *valedictus* King, x 1.
- g. *Austrofusus* (*Neocola*) *demissus* Marwick, x 1.5.
- h. *Cominella* (*Cominella*) *hendersoni* Marwick, x 2.
- i. *Alcithoe* (*Alcithoe*) *hurupiensis* Marwick, x 1.
- j. *Penion crawfordi* (Hutton), x 0.67.
- k. *Amalda* (*Baryspira*) *tirangiensis* (Marwick), x 1.5.
- l. *Austrotoma obsoleta* Finlay, x 1.5.
- m. *Conus* (sensu lato) *hendersoni* Marwick, x 1.
- n. *Zeacuminia orycta* (Suter), x 1.5.
- o. *Gemmaterebra bicorona* (Hutton), x 2.



moderately large to exceedingly long (to 30 mm long in large specimens of the form *latispinifer*), dorso-ventrally compressed, round-tipped nodules, forming strongly concave sutural ramp. Sculpture of faint, irregular spiral threads on sutural ramp and between spiral cords around periphery, and several low, rounded, somewhat irregular spiral cords around periphery and on base; on most specimens, 1 major cord around peripheral nodules, 3 or 4 other prominent ones below (the lowest forming weak peribasal angulation with low nodules), and another 8-10 closer ones on neck and canal; below periphery, cords are irregularly nodulous and scaly because of relatively coarse, close, irregular growth ridges. Aperture oval, with thick, smooth lips and low parietal callus pad. Anterior canal relatively short and wide (very incomplete on figured specimen), curved weakly to left and then right, with wide, shallow pseudumbilical groove in many specimens. Protoconch not seen, presumably as in other *Penion* species, large and subcylindrical, of about 3 whorls, with a blunt apex.

Clifdenian?; Lillburnian-Tongaporutuan; "Te Awaite, East Coast, Wellington", type of *Fusus crawfordi* (from a "Hurupi facies" faunule, early Tongaporutuan, in southern Wairarapa, and probably from Hurupi Stream area, Palliser Bay); Burnt Hill, near Oxford, North Canterbury, Waiauian (type of *Austrosipho latispinifer*); "Tutamoe formation", Takapau Survey District, southern Hawke's Bay, Lillburnian to Tongaporutuan? (type of *Austrosipho masoni*); Takapau Survey District, southern Hawke's Bay, Tongaporutuan (type of *Austrosipho takapauensis*). Dell (1952, p. 78, fig. 9) illustrated Hutton's holotype of *Fusus crawfordi*. Widespread and common in near-shore sandstone with diverse Mollusca, in Gisborne district, southern Hawke's Bay, Wairarapa, Marlborough, North Canterbury, and at Fox River, Westland; common at some localities, such as Hurupi Stream.

Penion crawfordi is extremely variable in spire height, the portion of the previous whorl hidden by the sutural ramp, the prominence of the spiral cords (particularly on the base) and, in particular, the length of the peripheral spine-like nodules. The nodules are very low and rounded in a few specimens, moderately large in most specimens, but enormously developed in the form *latispinifer*. Large collections, such as those from Hurupi Stream, show that *A. latispinifer*, *A. masoni* and *A. takapauensis* are part of the variation of *P. crawfordi*. *P. crawfordi* was apparently the culmination of a lineage of progressively more short-spined, coarsely sculptured species that are common in shallow, soft-bottom facies throughout the New Zealand mid-Cenozoic; its presumed immediate ancestor is *P. marwicki* (Altonian; Pl. 20m), which is a little taller and narrower, has more even spiral sculpture, and has fairly consistent, small to medium-sized peripheral nodules. A possible relative is *P. huttoni* (Kapitean?-Opoitian, Awatere Valley), which has lower peripheral nodules, more even spiral sculpture, and no marked lower angulation on the last whorl, and so is perhaps an early member of the species group containing the living *P. sulcatus* (Pl. 49a).

Figured specimen (Pl. 30j): Tanglewood, Bideford, east of Masterton, Wairarapa, early Tongaporutuan (NZGS; from a private collection) x 0.67.

Pl. 30 c,d. *Zelandiella fatua* Finlay, 1926b [p. 237] (Buccinidae).

Small for genus (30-33 mm high), evenly oval and weakly sculptured, with low spire (a third height of aperture and canal), tall, steep, flat sutural ramp becoming weakly concave over last whorl, evenly convex periphery, and very short, widely open, strongly twisted, deeply notched

anterior canal with prominent, long fasciole margined by high, thin ridge and bearing prominent, foliose costellae. Sculpture of simple, smooth, prominent, widely spaced spiral cords only, on most specimens; a few juvenile shells and very few adults have small, rounded nodules around top of peripheral swelling. Aperture large, relatively narrow, drawn out above into shallow posterior canal; interior of outer lip lightly thickened, bearing many low spiral ridges in some specimens; inner lip wide and moderately thick, swollen over neck into typical but relatively low *Zelandiella* callus, largely limited to narrow tongue curling back around neck. Protoconch abraded in all material seen but clearly multispiral, presumably as in *Z. subnodosa*, above.

Waiauian (- Tongaporutuan?); Double Corner Shellbeds, Lower Waipara Gorge, North Canterbury, Waiauian (type); common at a few North Canterbury Waiauian localities of very shallow-water, near-shore, sandy facies, and uncommon at a few Waiauian (and possibly Tongaporutuan) localities in southern Hawke's Bay, southern Wairarapa, and Westland. Not known in the common southern Wairarapa early Tongaporutuan "Hurupi faunas".

Zelandiella fatua is distinguished from the partly sympatric *Z. subnodosa* (Pl. 21i) (or a similar, unnamed species) by its lack of nodules, its more prominent spiral cords, its slightly narrower shape and smaller size, and its more subdued inner-lip callus. Specimens of *Z. fatua* from East Grey River, North Canterbury, show the remnants of an original colour pattern preserved as paler cords on a pale brown ground.

Figured specimen (Pl. 30c, d): GS3209, N34/f6272, Double Corner Shellbeds, Lower Waipara Gorge, North Canterbury, Waiauian (NZGS, ex P.A. Maxwell collection) x 1.5.

Pl. 30 e. *Austrofusus (Austrofusus) coerulescens* (Finlay, 1930) [*Falsiculus coerulescens* Finlay 1930e, p. 266; *Austrofusus tuberculatus* Marwick 1931, p. 113] (Buccinidae).

Small for genus (20-50 mm high), with moderately tall spire (equal to or slightly higher than aperture and canal), narrow, strongly concave sutural ramp but whorls otherwise strongly and evenly convex, and short, open, only weakly twisted anterior canal with low fasciole bounded by narrow ridge. Sculpture of high, narrowly crested spiral cords with interspaces a little wider than 1 cord, 3 or 4 on spire whorls and 10 (plus several finer ones on canal) on last whorl, with 1-3 fine spiral threads in each interspace; crossing many narrow, low, closely spaced axial costae, about 17-20 per whorl, forming small, sharply rounded nodules at all sculptural intersections around periphery and upper part of base; an overall impression of small, evenly spaced nodules all over an evenly convex shell. Protoconch conical, presumably as in other *A. (Austrofusus)* species, but abraded on specimens seen.

Kapitean (early Kapitean *Globorotalia conomiozea* zone only); Bluecliff, Te Waewae Bay, Southland (type of *Falsiculus coerulescens*); coast east of mouth of Awatere River, Te Araroa, near East Cape (type of *Austrofusus tuberculatus*); common throughout New Zealand in early Kapitean rocks wherever shelf facies occur.

Austrofusus coerulescens is an extremely distinctive species of uncertain origin, short time range, and abrupt extinction, and as it is easily recognised because of its evenly nodulose sculpture, and is abundant throughout New Zealand in early Kapitean rocks, it has long been regarded as one of the most important Kapitean index species (the other is *Sectipecten wollastoni*, Pl. 28f). However, recent studies in conjunction with micropaleontological biostratigraphy have shown that *A. coerulescens* disappears abruptly at the end of the

Globorotalia conomiozea zone, i.e., it does not occur (and nor do any other distinctly Miocene Mollusca) in the late Kapitean *Globorotalia sphericomiozea* zone.

Figured specimen (Pl. 30e): GS4588, R13/f6583, Goldsborough-Kumara Road, Hokitika district, Westland, Kapitean (NZGS) x 1.5.

Pl. 30 f. *Austrofusus (Austrofusus) valedictus* King, 1935 [*Austrofusus speighti* King 1934, p. 24 (not of Marwick, 1932); *Austrofusus valedictus* King 1935, p. 312 (new name for *A. speighti* King, 1934, preoccupied)] (Buccinidae).

Moderate-sized for genus (40–50 mm high), with conic, weakly stepped spire 0.6 height of aperture and canal; whorls with rounded angulation, median on spire whorls, forming weakly concave sutural ramp; sculpture subdued. Anterior canal short, unusually wide for genus, twisted to left, with prominent fasciole bordered by narrow ridge. Sculpture of low, narrow, widely spaced spiral cords, fairly even in spacing and size over most of shell, but slightly more closely spaced over shoulder nodules than elsewhere, and becoming slightly more prominent over base than higher up; crossing low, evenly rounded, widely spaced axial costae over peripheral area only, forming low, rounded nodules around shoulder angle and even lower ones on 2 prominent spiral cords on peribasal angulation. Protoconch not seen, presumably conical, of about 3 whorls, as in other *A. (Austrofusus)* species.

Waiauian-Kapitean; most records are Tongaporutuan. Upper Medway River, Awatere Valley, Tongaporutuan (type); uncommon in southern Wairarapa, Marlborough, North Canterbury, and Westland, in diverse shallow-water assemblages that lived on soft substrates.

The wide form, the long, only weakly concave sutural ramp, the subdued spiral cords and low, rounded nodules, the weakly contracted neck, and the relatively short canal bent to the left suggest that *Austrofusus valedictus* was ancestral to *A. conoideus* (Kapitean, Awatere Valley) and its apparent successors *A. allani* (Opoitian-Waipipian, Awatere Valley) and *A. pliocenicus* (Opoitian-Mangapanian; Pl. 37d). The origins of the group are obscure, but *A. valedictus* resembles several Pareora-Southland Series species of typical *Austrofusus*.

Figured specimen (Pl. 30f): GS3348, N33/f9114, Kaiwara River near former Ethelton School, North Canterbury, Tongaporutuan, specimen closely resembling King's incomplete holotype (NZGS) x 1.

Pl. 30 g. *Austrofusus (Neocola) demissus* Marwick, 1931 [p. 114] (Buccinidae).

Rather small for genus (height c. 35 mm), bucciniform, spire 0.45 total height. Protoconch not known, but probably like that of *A. (Neocola) alpha* (Pl. 25b). Teleoconch of about 6 whorls, broadly shouldered at or noticeably below middle on spire, sutural ramp broad, steep and concave on later whorls, whorl sides sloping inwards; last whorl with weak subangulation on base, neck short, twisted. Axial sculpture apparently commencing as narrow costae reaching from suture to suture, but soon becoming obsolete on ramp; last whorl with prominent rounded nodules on periphery and low, elongate ridges on base and little or no connection between the 2 rows; 10–12 nodules or costae per whorl. Spiral sculpture of narrow, low cords with interstitial threads and threadlets, 3 on base noticeably stronger than those above and below, and slightly thickened where they cross axial ridges. Aperture ovate, moderately large, with a short, twisted, deeply notched siphonal canal; fasciole prominent, bordered above by a narrow ridge. Outer lip with distinct "stromboid notch" near anterior end; internal characters not known.

Lillburnian-Waiauian; Island Creek, Waipaoa River (type) and other localities in Gisborne district.

Austrofusus demissus is differentiated from *A. alpha*, *beta* and *gamma* (Pl. 25 b, c, d) by its larger size, its broader

shell, its more strongly sloping whorl sides, its weaker basal subangulation, and its coarser peripheral nodules. *A. demissus* seems to be more closely allied to *A. apudalpha* (Pl. 21j) and to an undescribed species from Ardgowan Shellbed, Oamaru and from Tommy's Creek, Upper Waipara River (both Altonian), differing from them mainly in having distinctly differentiated basal spiral cords. These three species apparently belong to a different group from *A. alpha*, *beta* and *gamma*.

Figured specimen (Pl. 30g): holotype, GS1242, Y16/f7414, Tutamoe Formation, Island Creek, Gisborne district, Waiauian (TM 6804, NZGS) x 1.5.

Pl. 30 h. *Cominella (Cominella) hendersoni* Marwick, 1926c [p. 322] (Buccinidae).

Small for genus (28 to 35 mm high), short and wide, with moderately to very short spire (little elevated above top of outer lip, to quarter height of aperture), almost vertical-sided last whorl, a greatly thickened parietal callus at top of aperture, swelling in mature specimens to massive, roll-like collar around top of last whorl to form rounded shoulder that protrudes strongly above suture and, in older adults, above most of spire. Fasciole very wide, convex, with coarsely lamellose sculpture, reflecting very deep siphonal notch. Spire moderately tall in young shells, but becoming progressively reduced in older ones as shoulder becomes more elevated. Sculpture of many low, wide, weakly convex spiral cords, with moderately wide interspaces (each about equal to width of 1 cord) crossed by fine growth lamellae; the only other axial sculpture is low costae on very early spire whorls in most specimens, although *C. crassinodosa* (Marwick, 1931) is possibly a form of *C. hendersoni* retaining nodules onto last whorl. Protoconch not preserved on available material; presumably as in *C. adpersa*, of 2 smooth, strongly inflated whorls, with a blunt apex.

(Altonian?, Clifdenian?) Lillburnian-Tongaporutuan; Tirangi Stream, North Taranaki, Tongaporutuan (type of *Cominella hendersoni*); "band 6c" (Slip Point Siltstone?), Clifden, Southland, Clifdenian? (type of *Acominia ridicula*);? "Tutamoe conglomerate", Pangopango Stream, inland from Tolaga Bay, Gisborne district, Lillburnian (type of *Cominella crassinodosa*); uncommon in the Southland Series, in the more shallow-water facies at Clifden, Southland, and in the Gisborne district; and abundant in near-shore, soft-bottom facies of Tongaporutuan age in Wairarapa (notably at Palliser Bay, but also further north), North Taranaki, and in the Gisborne district. Some specimens from Palliser Bay show the remnants of a speckled colour pattern preserved as brick-wall-like markings on the spiral cords.

The taxonomy of the Miocene short, square-sided, roll-shouldered fossils possibly ancestral to the living *Cominella adpersa* is poorly understood; the great variation of *C. adpersa* suggests there are fewer true fossil taxa than nominal species. It seems likely that the small forms, developing a shoulder roll by about 26–28 mm high, are one species (*C. hendersoni*; ? = *C. crassinodosa* ? = *C. ridicula* (Altonian-Tongaporutuan)). The Altonian *C. errata* (= *Buccinum carinatum* Hutton, 1873, not of Turton, 1819) is distinct; typical specimens (basal shellbed of Enys Formation, junction of Porter and Thomas Rivers, Castle Hill Basin, Canterbury) reach a much larger size (height 50 mm) and are still more square-sided and roll-shouldered than *C. hendersoni*. *C. scirriifer* (Altonian, Sutherlands, Tengawai River, Canterbury) belongs in a different group with a taller, conic spire, large shoulder nodules, and only a weakly developed shoulder roll, although specimens similar to *C. errata* occur with it at Sutherlands. Pliocene species (*C. facinerosa*,

Opoitian, Kaawa Creek, southwest Auckland; *C. dingleyi*, Waipipian, Otahuhu Brewery well, Auckland) appear to belong in a lineage that increased progressively in size, culminating in the "giant" *C. kereruensis* (Mangapanian-Nukumaruan, Wanganui and Hawke's Bay), which is larger (75-80 mm high) and has stronger spiral cords than the Castlecliffian to living *C. adspersa* (a few specimens of *C. adspersa* reach 68-70 mm high, but most specimens over 45-50 mm high are starting to develop a shoulder roll, although it is always less prominent in this species than in the Miocene fossils). Figured specimen (Pl. 30h): GS1037, S28/f6446, Whatarangi Cliffs, east of Putangirua Stream, eastern Palliser Bay, southern Wairarapa, early Tongaporutuan (NZGS) x 2 (a young specimen with a relatively weakly developed shoulder roll).

Pl. 30 k. *Amalda (Baryspira) tirangiensis* (Marwick, 1926) [*Ancilla (Baryspira) tirangiensis* Marwick 1926c, p. 324] (Olividae: Ancillinae).

Large for subfamily (47-65 mm high), with spire low (third to quarter height of aperture), conic or dome-shaped, with flat apex on some specimens; prominent, rounded shoulder angulation above top of aperture; parietal callus enormously developed. Spire callus descends to upper third of last whorl, well below top of aperture, and is deeply grooved above posterior canal of aperture. Parietal callus descends to below half height of inner lip, obliterating upper part of basal groove and all fasciolar bands; only moderately convex on its ventral face, but greatly swollen into a lobe anteriorly, to left of upper columellar area; its left margin is strongly convex but swings back again at shoulder angle to thicken only apertural side of spire. Lower columella smooth; most fasciolar bands weakly defined; depressed band wide, strongly depressed, pale reddish brown on some well preserved Palliser Bay shells; wide band occupies central third of last whorl. Inner lip strongly excavated near centre, i.e., parietal area at strong angle to lower columella; outer lip weakly thickened, only weakly convex, smooth except for slight protrusion of depressed band.

Tongaporutuan; Tirangi Stream, North Taranaki (type) and widespread in shallow-water, diverse assemblages in North Taranaki, southern Hawke's Bay, Wairarapa, and North Canterbury. Uncommon at most localities, but reasonably common in the Hurupi Stream area, eastern Palliser Bay.

Amalda tirangiensis is the youngest, largest, and most heavily callused of the wide-spined group of species so common in the New Zealand middle Cenozoic. The possibly ancestral *A. robusta* (Dunroonian-Altonian; Pl. 22h) and *A. platycephala* (Otaian-Altonian) are similar but their parietal callus is not so long, hiding little of the fasciolar bands and groove, and *A. platycephala* does not reach such a large size. A broken specimen of *A. tirangiensis* from Palliser Bay is 35 mm wide and is estimated to have been 65 mm high; its depressed band and wide band are brown, whereas lower fasciolar bands are white.

Figured specimen (Pl. 30k): Hurupi Stream, Palliser Bay, southern Wairarapa, from basal coarse grit bed, pres. L. C. King, Tongaporutuan (NZGS) x 1.5.

Pl. 30 i. *Alcithoe (Alcithoe) hurupiensis* Marwick, 1926a [p. 292] (Volutidae: Zidoninae).

Moderately large for genus (70-85 mm high), elongate, with moderately short, conic spire (between third and half height of aperture) and long, gently contracted last whorl; low, wide fasciole margined by narrow ridge. Sculpture commences as low, evenly spaced, narrowly crested axial ridges on earliest spire whorls seen (apex damaged in all specimens),

gradually down the spire each axial ridge developing nodule at lower 0.4 of whorl height, and ridge gradually becoming weaker above and below nodule, so the only sculpture on last whorl is 7 large, smooth, narrowly pointed nodules around shoulder, producing strongly concave sutural ramp. Outer lip ascending to apex of shoulder nodules over last quarter-whorl, thickened and apparently flared (broken in all material). Inner lip with low parietal callus and 4 narrow, prominent columellar plaits. Protoconch not seen but presumably as in *A. arabica* (Gmelin), large, cylindrical, of about 2 smooth whorls, with wide, blunt apex.

Early Tongaporutuan, "Hurupi faunas" in southern Wairarapa only. Although this is reasonably common at Hurupi Stream and nearby localities in eastern Palliser Bay, complete shells have not been collected, and it seems not to occur in any other areas. All localities are in near-shore, inner-shelf sandstone with diverse Mollusca, much as is inhabited now by the common Nukumaruan to living *A. arabica*.

Marwick (1926a, p. 292) discussed the confused locality of his largest syntype of *Alcithoe hurupiensis*; later collections leave no doubts that the specimen came from the Hurupi Stream area of eastern Palliser Bay. *A. hurupiensis* was apparently an intermediate member of the "typical" *Alcithoe* lineage, between *A. turrita* (Altonian; Pl. 21s) and *A. arabica* (Pl. 49d), and is easily recognised by its almost smooth surface, apart from particularly large, sharp nodules around the shoulder angle.

Figured specimen (Pl. 30i): Marwick's largest (figured) syntype, GS1037, S28/f6446, Hurupi Stream, Palliser Bay, southern Wairarapa, early Tongaporutuan (TM6810, NZGS) x 1.

Pl. 30 l. *Austrotoma obsoleta* Finlay, 1926b [p. 253] (Turridae: Pseudotominae).

Very small for genus (to 28 mm high), with very short spire and long last whorl, tapered relatively little to short, widely open siphonal canal. Axial sculpture of very weak costae below the shoulder, fading out before last whorl of almost all specimens. Spiral sculpture of 2 narrow, closely spaced cords on very prominent, wide subsutural fold, followed below by smooth, deeply concave sutural ramp; whorl sides bear 4 (on spire) or about 12-14 (on last whorl) very prominent, wide, flat-topped cords, with each interspace slightly wider than 1 cord, and with weak secondary cords in a few interspaces of some specimens. Columella unusually well excavated in central area, followed below by straight section deflected to left. Siphonal canal with moderately deep notch, forming coarsely arcuate-sculptured fasciole, margined by prominent, narrow, smooth cord. Protoconch not seen; presumably as in other *Austrotoma* species, conical, of 4-5 whorls, first 2-3 whorls smooth, then developing flat-topped spiral cords, and finally developing narrow axial costellae over last half-whorl.

Waiauian; Double Corner Shellbeds, Lower Waipara Gorge, North Canterbury (type), and common in other North Canterbury localities with diverse soft-bottom, shallow-water Mollusca; also rare in Waiauian sandstone in southern Wairarapa.

Austrotoma obsoleta is easily recognised by its small size, its strongly concave sutural ramp, its low spire, its prominent, wide spiral cords, and its lack of axial sculpture on the last whorl. A very similar species with narrower spiral cords and with axial costae continuing onto the last whorl occurs in Tongaporutuan shallow-water sands of North Canterbury (common in Kaiwara River near the former Ethelton School), where it occurs with *A. hurupiensis*. *A. hurupiensis* is the only species common in early Tongaporutuan shallow facies ("Hurupi fauna") in South Wairarapa; it is a much larger species

with a taller spire than *A. obsoleta*, and with a wide, elevated, smooth band below the shoulder angle.

Figured specimen (Pl. 30l): GS3209, N34/f6272, Double Corner Shellbeds, Lower Waipara Gorge, North Canterbury, Waiauian (NZGS) x 1.5.

Pl. 30 o. *Gemmaterebra bicorona* (Hutton, 1885) [*Cerithium bicorona* Hutton 1885b, p. 328; *Terebra catenifera* "Tate" of Suter 1915, p. 43 (not of Tate, 1889); *Terebra bicorona*; *Acuminia bicorona*; *Perirhoe* (*Dimidacus*) *bicorona*] (Terebridae).

Moderately large for genus (42-55 mm high), very tall and slender, with spire angle of only 10°-15°, teleoconch with more than 15 whorls (apex missing from all specimens); whorls relatively short and wide (whorl height ranges from 0.5 to 0.7 whorl diameter). Sculpture of 2 wide, low, nodulose spiral cords below suture, occupying upper half of spire whorls; 4 or 5 low, narrow, rather indistinct spiral cords fill weakly concave space below the 2 subsutural cords; slightly more prominent cord forms weak peribasal angulation, emerging from suture of penultimate whorl; and several weak, obscure spiral threads on rapidly contracted base. Aperture incomplete in known specimens, small. Anterior canal short, twisted, with low, ridge-bordered fasciole. Protoconch not seen.

Clifdenian?; Lillburnian-Waipipian; Mangapanian?

Hutton's (1885b, p. 329) holotype of *Cerithium bicorona* (figured by Marwick 1924e, pl. 6, fig. 13) was said to be from "Tutaekuri River, Hawke's Bay. Collected by Mr Winkleman", but we are not aware of a soft-bottom, shelf-facies molluscan locality of suitable age within the northern lowlands of central Hawke's Bay that could be the type locality. The Tutaekuri River flows through mostly Nukumaruan mudstone and limestone, and rocks as old as Waipipian in its headwaters around the Napier-Taihapa Road and Puketitiri are mostly Te Aute limestone facies. A locality in the shelf-facies Pliocene of Takapau-Dannevirke district of southern Hawke's Bay seems feasible, but the real locality and age of the type are likely to remain a mystery.

Gemmaterebra bicorona or a close relative is an uncommon species in shallow, near-shore, sandy environments, known from Oparara River, Karamea district, southwest Nelson (Lillburnian, or possibly Clifdenian), several records from the shore platform between Te Araroa and East Cape (Kapitean), the Wanganui-South Taranaki coast (Waipipian), and Timmins Creek, Mangahao, Eketahuna district, northern Wairarapa (Waipipian or perhaps Mangapanian). It is easily recognised by being the single New Zealand terebrid with two nodulose cords below the suture. There is some evidence of two forms in the available material: specimens from Oparara River have relatively tall whorls (height 0.7 diameter) and a spire angle of only 10°, whereas Hutton's holotype (Marwick 1924e, p. 327, pl. 6, fig. 13) and specimens from Te Araroa, East Cape (Kapitean) have shorter whorls (height 0.5 diameter) and a spire angle of 15°. However, Powell's illustrations (1931a, p. 108, pl. 10, fig. 3, 4) show that South Taranaki Waipipian shells are like the markedly older Oparara River ones, with spire angles of 10°; the taxonomy needs further study.

Modern lists have followed Powell (1931a) in including *G. bicorona* in *Perirhoe* (*Dimidacus*), but such a position seems inappropriate. The type species of *Perirhoe* Dall, 1908 is *Terebra circumcincta* Deshayes, 1857 (living, Queensland and northern New Zealand; Powell 1979, p.

246, pl. 47, fig. 18), a species with no subsutural collar, but evenly spaced, clearly punctate spiral grooves over the whole shell (5-6 on spire whorls and 12 on last whorl). The type species of *Dimidacus* (Iredale 1929, p. 341), *Perirhoe* (*Dimidacus*) *melamans* Iredale, 1929 (Quaternary?, Sydney Harbour dredgings) is much more like New Zealand fossils, but has coarse spiral cords below the subsutural fold, and the subsutural fold is smooth, not nodulose. *T. melamans* appears to belong in a group close to the living *T. cingulifera* Lamarck (Cernohorsky and Jennings 1966, pl. 5, fig. 18, 18a). We propose to include the New Zealand fossil in *Gemmaterebra* Cotton (1952, p. 239) (type species: *Terebra catenifera* Tate, 1898; Pliocene, south-eastern Australia). The type species (many specimens examined in NZGS) is a bicoronate species resembling *G. bicorona* (Hutton) but with smaller subsutural nodules, and this appears to be a suitable genus to include such bicoronate living species as *Terebra anilis* (Röding) and *T. amanda* Hinds (Cernohorsky and Jennings 1966, pl. 5, fig. 15-17), which do not have the evenly spaced, punctate spiral grooves of *T. circumcincta*. Unfortunately, *Gemmaterebra* is a very obscure name that has not appeared in Neave's "Nomenclator Zoologicus" or in "the Zoological Record", and so has not been adopted by most taxonomists. Its type species is similar enough to *G. bicorona* (Hutton) that the two were confused by Suter (1915, p. 43).

Figured specimen (Pl. 30o): GS10342, Z14/f9504, Maruhou Point, east of Te Araroa, East Cape, Kapitean (NZGS) x 2.

Pl. 30 n. *Zeacuminia orycta* (Suter, 1913) [*Terebra orycta* Suter 1913b, p. 295; *Acuminia orycta*] (Terebridae).

Moderate-sized for genus (38-50 mm high), very tall and slender, relatively weakly sculptured, with large, elongate last whorl, almost straight columella and short, weakly twisted, widely open, deeply notched anterior canal bearing low fasciole bounded by very prominent, narrow spiral ridge. Protoconch small, narrowly conical. Teleoconch whorls slightly swollen below suture to produce weak subsutural fold occupying about upper 0.4 of spire whorls; in some specimens, lower boundary of fold is marked by a faint spiral groove. Lower 0.6 of spire whorls and central third of last whorl weakly concave, weakly sculptured; a low, in many specimens weakly defined, spiral cord at base of concave zone unites apices of low, narrow, axially elongate nodules, forming a further weakly convex zone around basal angulation of last whorl; nodules fade out rapidly to leave neck smooth. Similar low, narrow, widely spaced, axially elongate nodules around subsutural fold are linked, in some specimens, to basal nodules by very low, narrow axial costae over concave zone, but large specimens from the type locality are smooth medially.

Altonian-Tongaporutuan; Double Corner Shellbeds, Lower Waipara Gorge, North Canterbury, Waiauian (type); common at a few localities only: Target Gully Shellbed, Oamaru (Altonian), White Rock River, South Canterbury (Altonian), Double Corner Shellbeds and a few nearby localities in North Canterbury (Waiauian), and a few Tongaporutuan localities in North Canterbury and southern Wairarapa (mainly Hurupi Stream area, Palliser Bay).

Specimens from Target Gully Shellbed and White Rock River appear not to reach the same size as Waiauian-Tongaporutuan ones, and at least some are slightly narrower and slightly more prominently sculptured than the younger specimens, but the differences do not seem to be significant. The low axial sculpture, the medially

concave zone between two weakly convex zones, and the moderately stout form distinguish *Zeacuminia orycta* from the several other mid-Tertiary species. All localities are in near-shore sandstone and shellbeds, and *Zeacuminia* evidently lived in the same situation at modern *Terebra*, crawling only just covered in sand in lagoons and in the wave zone of sand beaches.

Figured specimen (Pl. 30n): GS4799, J39/f6468, White Rock River, South Canterbury, Altonian (NZGS) x 1.5.

Pl. 30 m. *Conus (sensu lato) hendersoni* Marwick, 1931 [*Conus (Lithoconus) hendersoni* Marwick 1931, p. 131] (Conidae).

Large for New Zealand *Conus* species (to about 70 mm high), with very low, stepped, conic spire and very long, tapered, straight-sided last whorl, long, narrow, parallel-sided aperture with shallow U-shaped sinus on the sutural ramp, and prominent but low, smooth, rounded carina around shoulder of all whorls (i.e., descending spire and forming steps in outline). Apart from growth lines, and few weak, variable, indistinct spiral grooves high on whorls, sculpture is of about 10 low, wide spiral cords on base of last whorl, increasing in prominence down shell. Protoconch not seen.

Tongaporutuan-Kapitean; Mangaotuwahito Stream, one km west of main highway, northwest of Tikitiki, near East Cape, Kapitean (type); common and well preserved in the shore platform at Maruhou Point, east of Te Araroa, East Cape (figured), and poor specimens have been collected from many localities in the Gisborne-East Cape district, mostly near East Cape. Most records are from the shallow-water Tokomaru Sandstone facies, as far south as Mangatuna Quarry, inland from Tolaga Bay,

and almost all records are Kapitean, but a few are of Tongaporutuan age.

Conus hendersoni is the youngest large *Conus* (sensu lato) in New Zealand Cenozoic rocks. It may be related to such cool-water modern species as *C. teramachii* (Kuroda, 1956), recorded by Marshall (1981b, p. 499) to be living at present just to the north of northernmost New Zealand, in 357-677 m; *C. teramachii* has a similar stepped, carinate spire and basal spiral cords to those of *C. hendersoni*, but the spire is taller and the carina nodulous in *C. teramachii*. The presence of a single common species of *Conus* in Late Miocene rocks near East Cape need only indicate sea temperatures a little warmer than those in the region at present, and only the rather more diverse (but largely undescribed) *Conus* faunas of Clifden, Southland (Altonian-Clifdenian) and Kaipara Harbour, Northland (Otaian-Altonian) indicate markedly warmer temperatures. *Conus* is an epifaunal toxoglossan carnivore, feeding on polychaete worms, molluscs or (in a few species) fish, "stinging" its prey with individual, unattached radular teeth and a toxin from a well developed poison gland, and the very poisonous fish-eating species of the modern tropics are well known. Most species occur on hard substrates in shallow water (on rocky shores and coral reefs), but *C. hendersoni* has been collected only from soft-substrate environments in mid-outer shelf depths.

Figured specimen (Pl. 30m): Maruhou Point, east of Te Araroa, East Cape, Kapitean (M43165, National Museum) x 1.

CHAPTER 14. PLIOCENE FAUNAS (OPOITIAN, WAIPIPIAN AND MANGAPANIAN STAGES): PLATES 31-37

INTRODUCTION

Pre-Nukumaruan Pliocene rocks (Fig. 21) are extremely extensive in South Auckland (the faunas of Otahuhu well and Kaawa Creek have been described, but other shellbeds occur widely below the surface south of Manukau Harbour between these two localities); in the inland areas of Wanganui Basin; along the South Taranaki-Wanganui coast, from Manaia eastward to the mouth of Waitotara River, and in Waitotara Valley; over most of eastern North Island from East Cape (East Island itself is composed of Opoitian mudstone) to Palliser Bay,

southern Wairarapa; in Marlborough and North Canterbury; on the west coast of South Island in many small basins, from Little Wanganui River (Karamea) to Halfway Bluff, between Cascade Point and Barn Bay, northern Fiordland (Nathan 1978); in the centre of the Waiau Syncline, around the head of Te Waewae Bay, western Southland (Fleming in Wood 1969, p. 64); and in the Chatham Islands (Marwick 1928). Small areas of Opoitian rocks occur outside the main depositional areas, near Makara, Wellington; on Makihihi River, South Canterbury; and offshore from Awamoa Beach, North

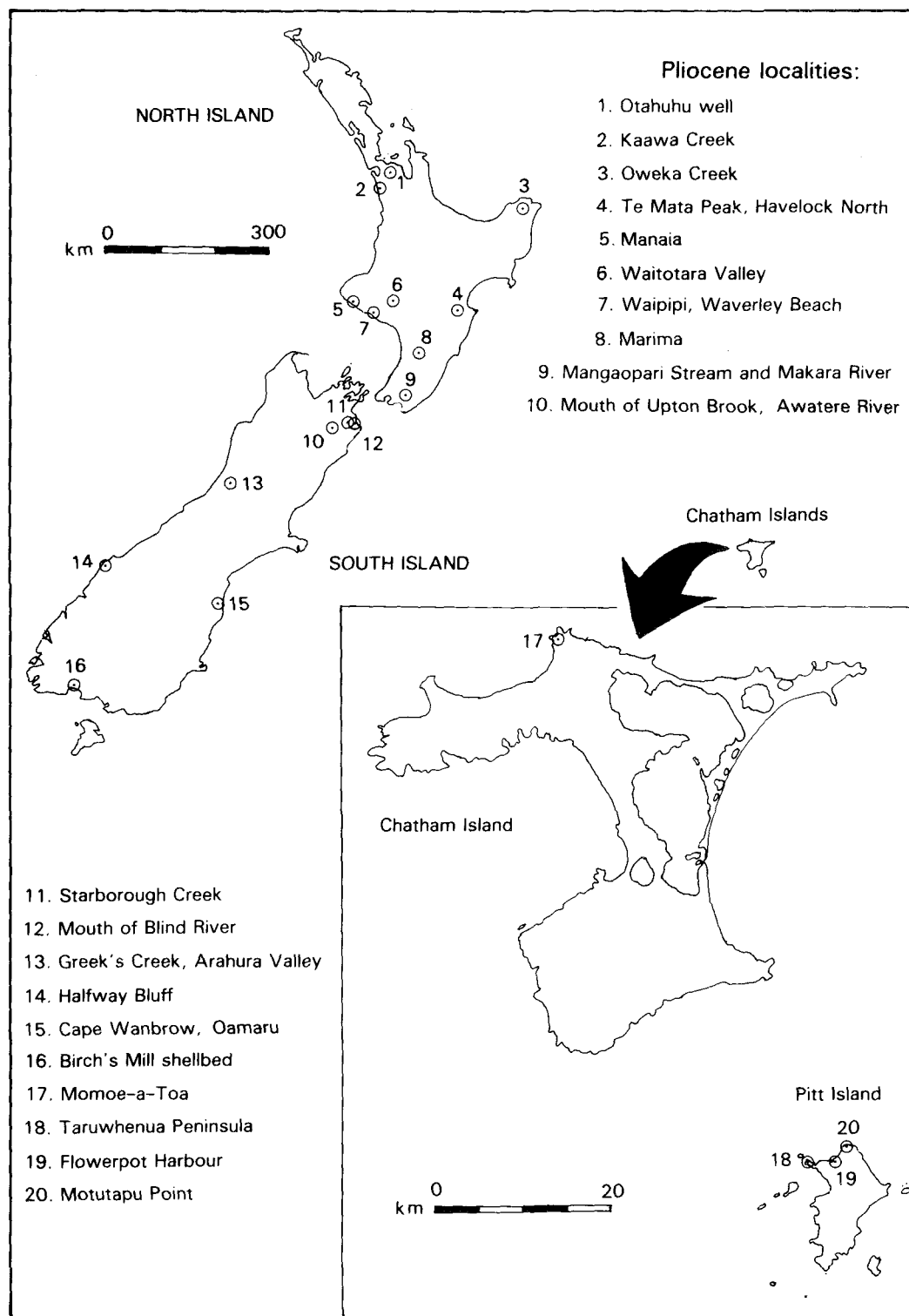


Figure 21 The main molluscan fossil localities of Opoitian to Mangapanian (Pliocene) age.

Otago, from where Opoitian fossils have been collected by trawlers and wash ashore on beaches (pers. comm. the late J. Graham, Oamaru). Pliocene rocks are therefore the most extensive fossiliferous rocks in New Zealand, reflecting their deposition in and uplift by the Indian-Australian/Pacific plate boundary system.

The best-known localities or areas, from which diverse, well preserved fossils are easily collected, are: (1) Kaawa Creek, on the west coast of South Auckland (Opoitian; Laws 1936a, b, 1940a); (2) sandstone at Oweka Creek,

between Cape Runaway and Hicks Bay, East Cape, with a very similar faunule to Kaawa Creek (Marwick 1965, p. 9) and other localities in Opoitian rocks in the Tauwhareparae area inland from Tolaga Bay; (3) the very thick and extensive, Opoitian to Mangapanian, Te Aute facies limestone beds of Hawke's Bay (Beu et al. 1980) in which *Phialopecten* species and (in Waipipian beds) *Mesopeplum crawfordi* are common at many localities (e.g., Te Mata Peak, Havelock North); (4) most notably, the Waipipian and Mangapanian rocks of South

Taranaki-Wanganui (the eastern part described in detail by Fleming 1953); and (5) Chatham Islands—Momoe-a-Toa on the north coast of Chatham Island and four localities in the Whenuataru Tuff of northern Pitt Island. The shellbeds of densely packed large pectinids at Momoe-a-Toa and of densely packed large bivalves at Waipipi, Waverley Beach, on the South Taranaki coast (Fleming 1953, p. 111) are some of the most spectacular fossil localities known in New Zealand, and the faunas of Kaawa Creek and the Whenuataru Tuff are very diverse, with about 300 species each. Finally, the largest single accumulation of fossil shells known in New Zealand is the *Crassostrea ingens* bed near the base of Wilkies Shellbed (Mangapanian) in Wanganui Basin; this densely packed oyster bed varies in thickness from about four to eight metres and crops out almost continuously from the mouth of Waitotara River over a distance of more than 45 km to the Wanganui River road, and slightly further to the east. Almost all the oysters are articulated, so this bed evidently formed as an oyster reef in quiet inshore conditions.

In the widespread Te Aute limestone facies, a shallow-water, high-energy deposit of Hawke's Bay and Wairarapa, the most useful Mollusca for identifying stages are Pectinidae (Pl. 33). The small *Phialopecten ongleyi* (Pl. 33e), restricted to Opoitian rocks, has about 28-30 radial costae and, in many specimens, a slightly oblique disc; most are about 60-70 mm high, but latest Opoitian specimens reach a maximum height of 112 mm. It is succeeded in Waipipian rocks by the equally finely costate but equidimensional *P. marwicki* (Pl. 33a), reaching 175 mm in height; at most localities, *P. marwicki* is accompanied by the restricted Waipipian species *Mesopeplum (Borehamia) crawfordi* (Pl. 33f, g), with five large radial folds in the shell. Mangapanian rocks contain *P. triphooki*, which also reaches 175 mm in height but has only 18-20 radial costae, two-thirds the number of *P. marwicki*. The base of the Nukumaruan Stage is defined (as described more fully under Nukumaruan faunas, below) by the appearance of *Chlamys patagonica delicatula*, and Nukumaruan rocks include a very brief basal zone in which *Phialopecten triphooki* and *Crassostrea ingens* survived from Mangapanian time.

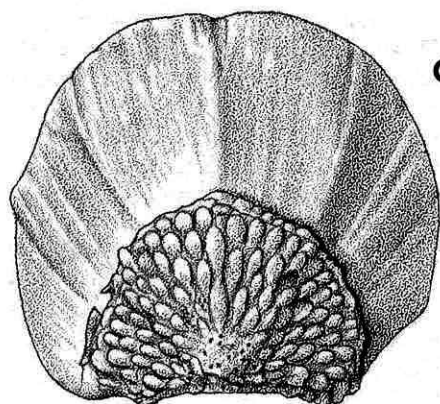
In Pliocene near-shore to outer shelf mudstone and sandstone (soft-bottom facies), Mollusca are particularly useful for identifying stages, as the common, rapidly evolving species of Struthiolariidae provide a narrowly subdivided zonation. The youngest species of the *Struthiolaria (Callusaria)* lineage, *S. obesa* (Pl. 36i), is not

known younger than Opoitian. Latest Miocene and Pliocene species of *Struthiolaria* (sensu stricto) are poorly understood, and seem to have been limited to small geographic areas; e.g., the distinctive, strongly sculptured *S. dolorosa* (Pl. 36k) is recorded only from Opoitian rocks in Awatere Valley. A similar lineage to that of *S. dolorosa* evolved independently from the *S. papulosa* lineage in Hawke's Bay during Mangapanian time, providing a useful local biostratigraphy: *S. n. sp. aff. frazeri* (Mangapanian), smaller and with narrower cords than the large, coarsely sculptured *S. frazeri* (Nukumaruan; Pl. 42f). The most useful of all biostratigraphic indices are the *Pellicaria* species. *P. parva* (very small, with three nodulous spiral cords on the last whorl) is restricted to Opoitian rocks, and was succeeded in Waipipian rocks by *P. incrassata* (Pl. 36o) with only two spiral cords. Opoitian forms related to *P. zelandiae* and *P. canaliculata* have been collected rarely in North Canterbury and Awatere Valley, respectively, whereas typical *P. zelandiae* (with almost vertical whorl sides and a deeply channelled suture) is rare away from the South Taranaki-Wanganui coast (Waipipian) and typical *P. canaliculata* occurs in Awatere Valley, in the Eketahuna area of northern Wairarapa, and uncommonly along the South Taranaki-Wanganui Coast (Waipipian). *P. zelandiae* was succeeded in Mangapanian and early Nukumaruan rocks of Wanganui and Hawke's Bay by an unnamed species with a shoulder angle below the sutural channel, and *P. canaliculata* was succeeded in Mangapanian rocks of Eketahuna by a rapidly evolving lineage (described below under *P. acuminata*) that led to the late Mangapanian-early Nukumaruan *P. acuminata* (Pl. 42e). Species of several other generic groups such as *Zethalia*, *Glycymeris*, *Nemocardium (Pratulium)*, *Maorimactra*, *Stiracolpus*, *Austrofusus*, and particularly *Hartungia* are illustrated below, and have all proved useful in Pliocene biostratigraphy.

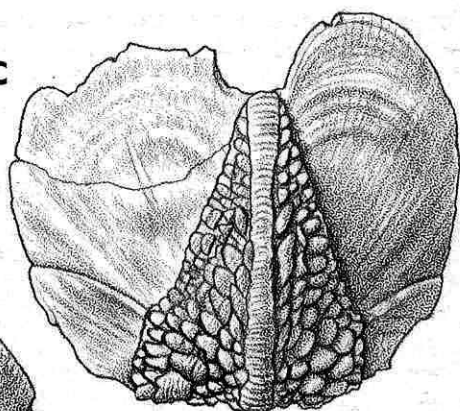
The general character of shallow-water Pliocene faunas is warm-temperate, commencing with a clearly warm Opoitian fauna, when several taxa such as *Proterato* and *Zemacies* reappeared after an apparent Late Miocene absence from the New Zealand area. The faunal succession continued with the gradual extinction (at least in New Zealand) of several warm-water genera at the end of each Pliocene stage. The end of Mangapanian time saw the disappearance of several of the last Miocene lingerers (notably *Polinices* and the large, spectacular *Maoricardium spatiosum*; Pl. 34i, j) at the same time as cold-water taxa of Pleistocene aspect appeared abruptly

Plate 31 Pliocene (Opoitian-Mangapanian) Mollusca (1).

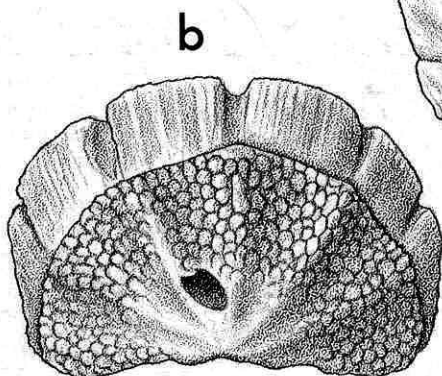
- a,d,g. *Acanthochitona (Notoplax) n.sp.A aff. latalamina* (Dell), x 10.5.
- b,e,h. *Acanthochitona (Notoplax) n.sp.C aff. mariae* (Webster), x 10.5.
- c. *Acanthochitona (Notoplax) n.sp.B aff. latalamina* (Dell), x 10.5.
- f,i,j. *Acanthochitona (Acanthochitona) flebilis* Laws, x 10.5.
- k,l *Chiton n.sp.*, x 6.3(k) and x 10.5(1).



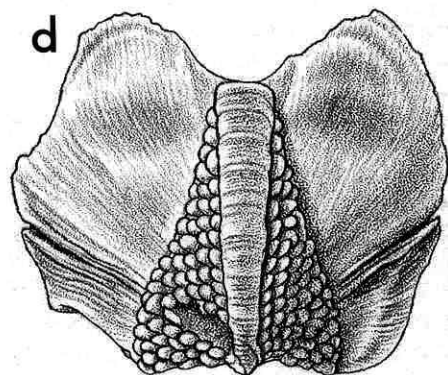
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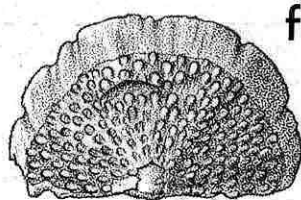
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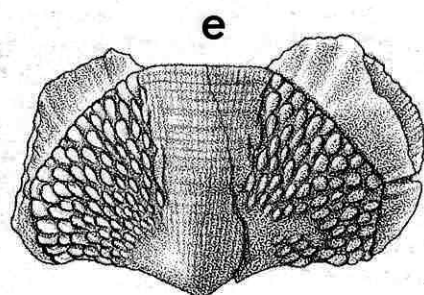
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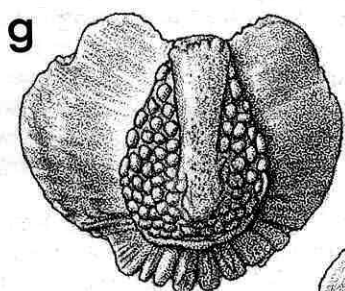
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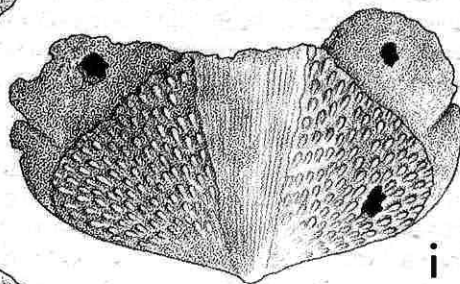
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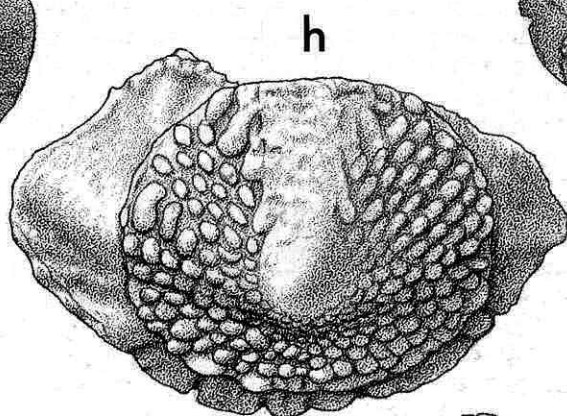
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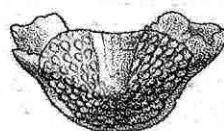
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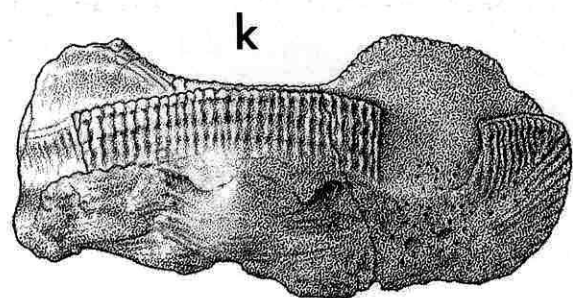
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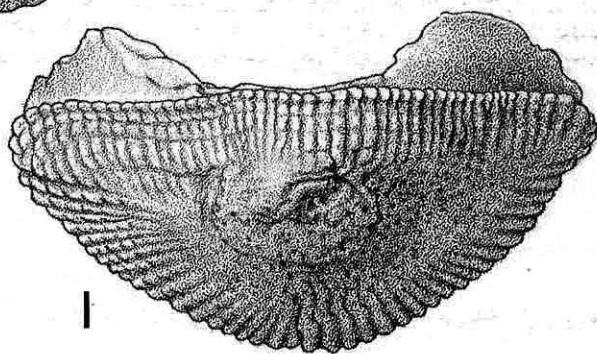
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(notably *Chlamys patagonica delicatula*; see introduction to Nukumaruan), and followed only a short time later by the disappearance of *Phialopecten* and *Crassostrea*.

REPRESENTATIVE PLIOCENE MOLLUSCA

Pl. 31 f,i,j. *Acanthochitona (Acanthochitona) flebilis* Laws, 1950 [*Acanthochiton flebilis* Laws 1950, p. 28] (Acanthochitonidae).

Shell small (each valve to 6.0 mm wide, 3.6 mm long), valves relatively short and wide; most characters as in *A. (Notoplax) mariae* (Pl. 44a, d, h). Anterior valve (holotype) semicircular, with five very weak radial angulations representing radial costae. Median valves with rather small sutural laminae, clearly triangular jugum bearing faint longitudinal grooves and ridges, no radial ridge between pleural and lateral areas, and very fine tegmental granules. Posterior valve very small, with mucro slightly nearer posterior than in *A. zelandica*, with fine tegmental granules, and with a prominent radial fold on each side.

Waipipian, Otahuhu Brewery well, Auckland (type), very common; not definitely known from any other locality. The richly diverse shellbed encountered in Otahuhu Brewery well (Marwick 1948; Laws 1950) contains only shallow-water, near-shore taxa, including a number of estuarine and rocky-shore molluscs. *Acanthochitona flebilis* almost certainly lived attached to rocks.

The longitudinally striate juga of valves 2-8, the wide tegmental area, and the relatively small posterior valve suggest that *Acanthochitona flebilis* is related to the rare modern species *A. thileniussi* Thiele, 1909 (known only from a few specimens collected living intertidally on hard substrates at Mount Maunganui, Tauranga). *A. flebilis* differs from *A. thileniussi* in having more triangular median valve tegmenta, less like the very wide ones of *A. rubiginosa* than are those of *A. thileniussi*, and in having a much narrower, more subcircular posterior valve; the posterior valve of *A. thileniussi* is very wide. *A. flebilis* was certainly correctly referred to *Acanthochitona*, and is very distinct from *A. zelandica*. Figured specimens (Pl. 31f, i, j): holotype (TM1411, NZGS; anterior valve, Pl. 31f) and two paratypes, Otahuhu Brewery well, Auckland, Waipipian (TM1412-1413, NZGS) all x 10.5.

Pl. 31 a,c,d,g. *Acanthochitona (Notoplax) n. spp. A,B* (Acanthochitonidae).

The characters of the subgenus are discussed under *A. (Notoplax) mariae* (Pl. 44 a,d,h). The Recent *A. latalamina* (Dell) (1956a, p. 57) is a large, slug-like chiton to about 70 mm long, with huge sutural laminae and small, finely sculptured tegmental areas, and its extremely wide girdle is densely felted with siliceous spicules; it has been dredged uncommonly in deep water (200-300 m) in the Cook Strait area, usually on sponges. It is closely related to the "typical" Australian *Notoplax* species, which have wide, spiculous girdles and reduced tegmenta. We have seen two lots of valves of *A. (Notoplax)* species that appear to represent unnamed species with wide girdles and very restricted tegmenta, similar to the living *A. latalamina*.

One lot of numerous valves (*A. (Notoplax) n.sp. A*, Pl. 31a, d, g) includes all three valve types; they differ from valves of large adult *A. latalamina* in being only half as large, in having slightly larger tegmenta and smaller sutural laminae, in having markedly larger tegmental

granules but very much weaker radial ridges between lateral and pleural areas of median valves, and in having unusually weak radial ridges on the anterior valve for a species of *A. (Notoplax)*. They are from a shallow-water facies with abundant, diverse Mollusca.

The other is a single median valve (*A. (Notoplax) n.sp. B*, Pl. 31c) of similar size and similar tegmentum-sutural laminae proportions to the Mangahao River specimens, but differs in its much narrower jugum and still coarser tegmental granules. The specimen is from bathyal siltstone and appears to have lived in an environment much more like that of *A. latalamina* than that of the Mangahao River specimens (above).

Figured specimens (Pl. 31a, d, g): Mangahao River, west of Pahiatua, northern Wairarapa, Mangapanian (National Museum of N.Z.) x 10.5; (Pl. 31c): cliffs east of Lake Ferry, Palliser Bay, southern Wairarapa, Mangapanian or Nukumaruan (NZGS, ex D. Cowe collection) x 10.5.

Pl. 31 b,e,h. *Acanthochitona (Notoplax) n. sp. C* (Acanthochitonidae).

Similar to *A. mariae* (Nukumaruan-Recent; Pl. 44a, d, h) but reaching a larger size (median valve to 14 mm wide, 9 mm long), having markedly thicker and heavier valves, all valves are a little shorter and wider, the tegmental granules are more nearly oval or subcircular, and the tegmentum of the very large anterior valve (10.0 mm wide, 6.5 mm long) is more weakly lobate and bears lower radial ridges than that of *A. mariae*. The large size, thick shell, and very shallow-water environment suggest that this species may be more closely related to the living intertidal species *A. violacea* (Quoy and Gaimard) than to *A. mariae*.

Waipipian or perhaps Mangapanian, Middle Waipara River at end of ridge opposite "The Deans", North Canterbury, fairly common in shallow-water sandstone with diverse Mollusca (see also *Chiton n. sp. aff. glaucus*, below); we have not seen similar specimens from any other locality.

Figured specimens (Pl. 31b, e, h): GS7176, M34/f7302, Middle Waipara River opposite "The Deans", North Canterbury, Waipipian or Mangapanian (NZGS) x 10.5.

Pl. 31 k,l. *Chiton n. sp. [Ischnochiton maorianus]* Thomson 1920, p. 365 (not of Iredale, 1914); *Chiton quoyi* Suter 1921, p. 46 (not of Deshayes, 1836); *Amaurochiton n. sp. aff. glaucus* Fleming in Wilson 1963, p. 60] (Chitonidae).

Shell short and wide, large for fossil chitons (posterior valve 10.7 mm wide, 6.7 mm long; large incomplete median valve 17.8 mm wide, 7.4 mm long), highly arched. Sutural laminae small, thick at base, tapering rapidly to thin edge; insertion plates thick, short, with many narrow, shallow slits between the major slits ("pectinate"). Anterior valve slightly incomplete; bearing 9 slits in anterior edge; tegmental sculpture of about 60 high, wide, closely spaced, weakly nodulous radial costae. Median valve with 1 short slit on each side; tegmental sculpture of high, wide, widely spaced, weakly nodulous costae, up to 13 radial ones on lateral areas and 65 longitudinal ones on pleural areas of large specimen. Posterior valve semicircular, steeply arched, with central mucro, 13-15 slits around posterior margin, and 55 coarse tegmental costae spaced as on other valves.

Waipipian (or perhaps Mangapanian), Middle Waipara River at end of ridge opposite "The Deans", North Canterbury, fairly common, with *Acanthochitona (Notoplax) n. sp. C* (above).

The new species is similar (and was perhaps ancestral) to the living *Chiton glaucus* Gray, 1828, but differs in its more highly arched dorsum, its narrower overall shape,

and its much coarser sculpture; the unnamed species has 55 radial costae around the posterior end of the posterior valve, whereas large *C. glaucus* collected on the intertidal rocky shore at Island Bay, Wellington have 80-105 low, narrow, smooth, widely spaced, radial costae around the posterior end of posterior valves. Thomson's (1920, p. 365) identification as *Ischnochiton maorianus* is understandable, as the sculpture resembles that of *I. maorianus*, but the dorsum is more highly arched and the insertion plates are much thicker and pectinate, not thin and smooth as in *Ischnochiton*. *Chiton glaucus* is an abundant living chiton (known fossil from a few "raised beach" deposits, at Mahia and Dunedin, apparently all Holocene) of rocky shores, and the near-shore molluscan fauna at the Middle Waipara site (including *Crassostrea*, *Xenostrobus huttoni*, *Bassina katherinae*, *Cominella kereruensis*) supports the interpretation that the unnamed species was intertidal as well.

Iredale and Hull (1932) recognised exceedingly narrow genera in Chitonidae (as they did in all other chiton families) and raised Thiele's infrasubgeneric sections *Amaurochiton* and *Sypharochiton* to genera, whereas all chiton specialists we have discussed them with regard these as synonyms of *Chiton* Linné, 1758. The only genera of Chitonidae occurring in New Zealand are, in our opinion, *Onithochiton* Gray, 1847, *Rhyssoplax* Thiele, 1893, and *Chiton* Linné, 1758 (= *Amaurochiton* Thiele, 1893; = *Sypharochiton* Thiele, 1893).

Figured specimens (Pl. 31k, l): GS7176, M34/f7302, Middle Waipara River opposite "The Deans", North Canterbury, Waipipian or Mangapanian (TM4902, TM5028, NZGS) x 10.5 (TM4902, posterior valve, Pl. 31l, is specimen collected by J. A. Thomson and identified by Thomson 1920 and Suter 1921).

Pl. 32 d,e. *Glycymerita (Manaia) manaiaensis* (Marwick, 1923) [*Glycymeris manaiaensis* Marwick 1923, p. 72; *Glycymeris (Manaia) manaiaensis*]. Type species of *Manaia* Finlay and Marwick, 1937 (Glycymerididae: Glycymeridinae).

Moderate-sized for genus (48-62 mm high), markedly longer than high, with low umbo, weak external sculpture, and no ligamental chevron grooves, almost evenly oval but slightly oblique postero-ventrally. Sculpture of about 35-38 extremely low, wide radial costae separated by very shallow, widely spaced, radial grooves, each costa with several very low, indistinct radial threads on its surface; costae are reasonably distinct on most specimens near umbo, but absent from anterior and posterior ends, and fade out before ventral margin of most specimens. Commarginal sculpture of weak growth ridges only. Interior ventral margin strongly and deeply crenulate. Ligamental area narrowly triangular, smooth except for weak tracks of former hinge teeth. Hinge narrow, with numerous similar, outwardly concave teeth on each side, teeth obliterated in centre by downward growth of ligamental area.

Waipipian-early Nukumaruan; Manaia Beach, South Taranaki, Waipipian (type); common in shallow-water, near-shore, shellbeds and sandstone along the South Taranaki coast, in the Mangahao area of northern Wairarapa, and in North Canterbury. Less commonly found in Pliocene rocks throughout southern Taranaki-Wanganui, southern Hawke's Bay—northern Wairarapa, the Awatere Valley of Marlborough, North Canterbury, and Westland. Previously regarded as an index of "Waitotaran" (= Waipipian and Mangapanian) age, but *G. manaiaensis* is common in early Nukumaruan rocks in North Canterbury (notably at Motunau Beach, with

common *Chlamys patagonica delicatula* and *Pellicaria rugosa*) and in northern Wairarapa.

Glycymerita manaiaensis is the last in a group of species (subgenus *G. (Manaia)*) with weak ligamental chevrons (in early species) or no ligamental grooves (in later species); the common Miocene *G. huttoni*, *G. robusta*, and *G. hurupiensis* are more inflated, much less regularly oval, and have a prominent radial fold on the postero-dorsal area that is absent from *G. manaiaensis*. *G. kaawaensis* (Opoitian, Kaawa Creek, South Auckland) is intermediate between *G. hurupiensis* and *G. manaiaensis*, and not all specimens can be distinguished from *G. manaiaensis*.

Although previously classed as a subgenus of *Glycymeris*, *Manaia* seems to be more closely related to *Glycymerita*, and we have classified it as a subgenus of the latter taxon.

Figured specimen (Pl. 32d, e): holotype (left valve), GS875, Q21/f6492, Manaia Beach, South Taranaki, Waipipian (TM4164, NZGS) x 1.

Pl. 33 b. *Phialopecten triphooki* (Zittel, 1864) [*Pecten triphooki* Zittel 1864, p. 52; *Pecten accrementa* Hutton 1873b, p. 31; *Phialopecten thomsoni* Marwick 1965, p. 22; *Pecten (Patiniopecten) accrementus*; *Phialopecten accrementus*; *Chlamys (Phialopecten) triphooki*]. Type species of *Phialopecten* Marwick, 1928 (Pectinidae).

Very large for family (100-175 mm high), most specimens slightly to markedly longer than high, left valve markedly more inflated than right; ears large, almost equal, symmetrical in the 2 valves, contracting to disc at base. Sculpture of 16-26 (about 18-20 on most specimens) very prominent radial costae with convex surfaces, complexly subdivided by grooves and costellae; costae wide and relatively closely spaced on right valve, narrow and relatively widely spaced (higher than wide, on most specimens) on left valve. Internal features visible on very few specimens.

Mangapanian and early Nukumaruan; Scinde Island Limestone, Napier, early Nukumaruan (types of *Pecten triphooki* and ? *Pecten accrementa*); Te Aute Limestone (sensu stricto), Pukeora Hill, Waipukurau, southern Hawke's Bay, Mangapanian (type of *Phialopecten thomsoni*).

Phialopecten triphooki is abundant in Te Aute limestone facies and similar limestone, and in a few near-shore shellbeds in sandstone, throughout east coast North Island and Wanganui basin, and is important (as are other members of the subgenus) for identifying Pliocene stages in shallow facies (where planktonic Foraminifera are sparse). The taxonomy and range were revised by Beu (1978a). The consistently large size, the few costae (about 18-20, rather than about 28-30) and the markedly wider radial costae on the right valve distinguish *Phialopecten triphooki* from its presumed immediate ancestor, *P. marwicki* (Pl. 33a).

Figured specimen (Pl. 33b): holotype of *Phialopecten thomsoni* Marwick, 1965 (right valve only), Te Aute Limestone, Pukeora Hill, Waipukurau, Hawke's Bay, Mangapanian (TM2682, NZGS) x 0.67.

Pl. 33 a. *Phialopecten marwicki* (Beu, 1970) [*Chlamys (Phialopecten) triphooki marwicki* Beu 1970a, p. 115] (Pectinidae).

Very large for family (97-175 mm high), most specimens equidimensional or slightly longer than high; left valve moderately to markedly more inflated than right; ears large, almost equal in the 2 valves, anterior

slightly longer and more notched at base than posterior; with very shallow byssal sinus but no ctenolium on right anterior ear. Sculpture of 25-35 (28-30 on most specimens) prominent, narrow, closely spaced radial costae, almost equal in width on 2 valves, those on left valve consistently bearing 3 or 4 low, narrow costellae on their surfaces; only 1 secondary costella in most interspaces. Internal features visible in very few specimens.

Waipipian; Waihi Beach, Hawera, South Taranaki (type); abundant in Te Aute limestone facies and near-shore sandstone and shellbeds in Wanganui basin and throughout east coast North Island.

Phialopecten marwicki is important for identifying the Waipipian Stage in shallow-water facies; it is accompanied at most localities by *Mesopeplum* (*Borehamia*) *crawfordi* (Pl. 33f, g). The taxonomy and range were revised by Beu (1978a). The consistently moderately large to very large size distinguishes *P. marwicki* from *P. ongleyi* (Pl. 33e), and the more numerous, narrower costae with only three or four surface costellae distinguish it from its apparent descendant, *P. triphooki* (Pl. 33b).

Figured specimen (Pl. 33a): holotype (right valve only), GS5240, Q21/f6501, Waihi Beach, Hawera, South Taranaki, Waipipian (TM2714, NZGS) x 0.67.

Pl. 33 e. *Phialopecten ongleyi* Marwick, 1965 [*Phialopecten ongleyi* Marwick 1965, p. 22; *Chlamys* (*Phialopecten*) *triphooki ongleyi*] (Pectinidae).

Small to moderately large for genus (64-100 mm high), most specimens equidimensional or slightly longer than high, obliquely elongate postero-ventrally; left valve moderately more inflated than right; ears moderately large, almost equal in 2 valves, anterior moderately to markedly longer than posterior, with wide, shallow, but obvious byssal sinus at base of right anterior ear, but no ctenolium in adult. Sculpture of 25-36 (about 30 on most specimens) low to prominent, narrow, closely spaced radial costae, equal in width on 2 valves, those on left valve bearing 3 low, narrow costellae on their surfaces in most advanced (late Opoitian) populations; 1 secondary costella in all interspaces on left valve, secondary costellae absent from some right valves. Internal features unknown.

Opoitian; Opoiti Limestone, tributary of Kaikoura Stream three km east of Tiniroto-Gisborne Highway, northeast of Tiniroto, northern Hawke's Bay (type); particularly abundant in Opoiti and Whakapunake Limestones in Northern Hawke's Bay; also abundant in Te Aute limestone facies and in near-shore sandstone facies in Wanganui basin, South Taranaki, the northern Ruahine Range, and throughout the eastern North Island from Gisborne (Ormond Limestone) to southern Wairarapa (limestone on the Aorangi Range).

The smaller size and the more oblique disc distinguish

Phialopecten ongleyi from its apparent successor *P. marwicki* (Pl. 33a), and the larger size, less marked obliquity, and coarser ribbing distinguish it from the apparently ancestral *P. tolagaensis* (Kapitean, Tokomaru Sandstone facies of Tolaga Bay to Anaura Bay, north of Gisborne) (height 27 to 61 mm). Statistical reassessment in long sequences is under way to more certainly distinguish *P. ongleyi* from *P. marwicki*, as these are the most useful indices of the Opoitian and Waipipian stages in the widespread Te Aute limestone facies of eastern North Island, but the lineage appears to have increased maximum shell size very gradually through Opoitian and Waipipian time.

Figured specimen (Pl. 33e): GS11886, R21/f01, Larsen shellbed, north of road end, Waitotara Valley, Wanganui basin, Opoitian (NZGS) x 0.67.

Pl. 33 c. *Sectipecten allani* Marwick, 1928 [p. 459] (Pectinidae).

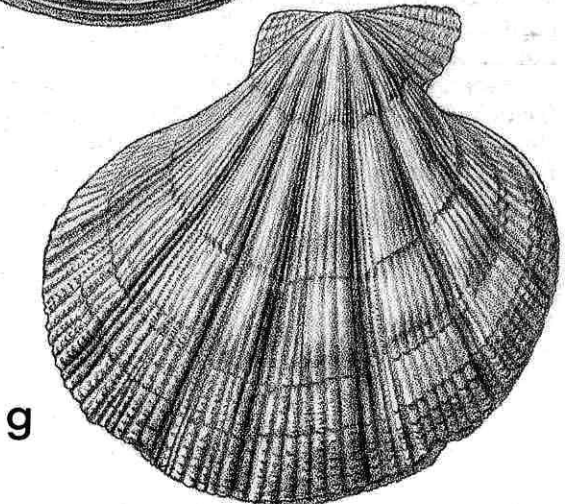
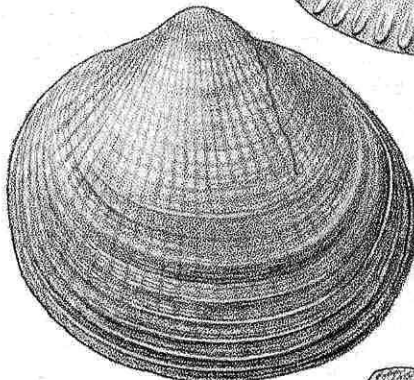
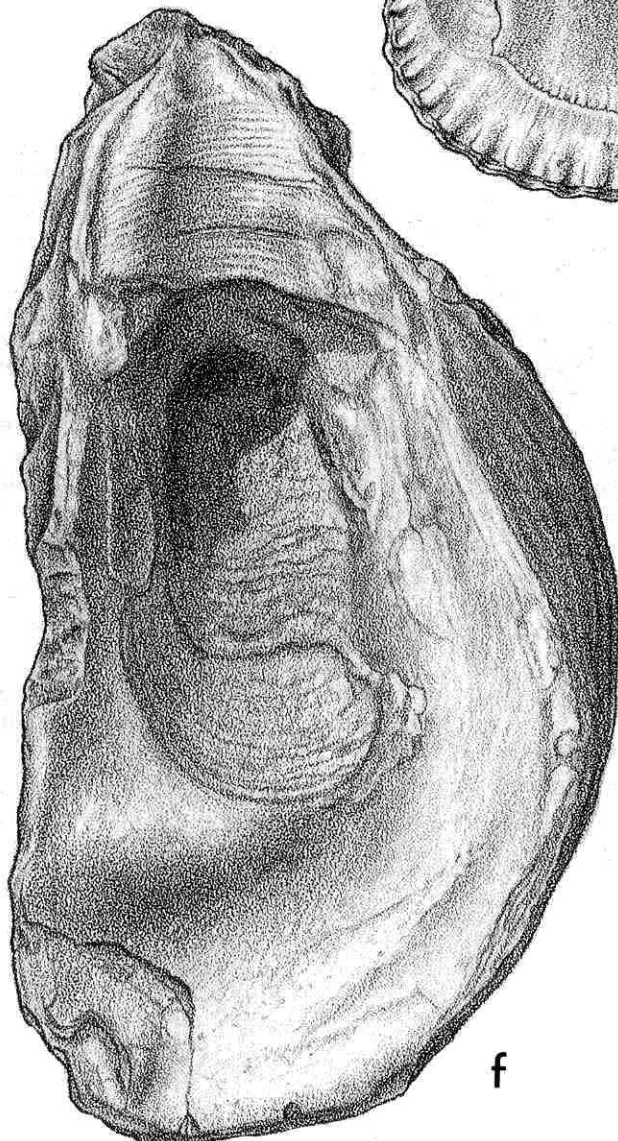
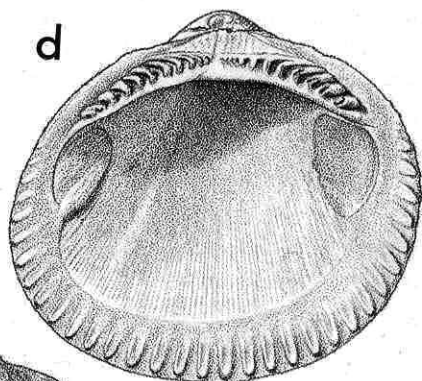
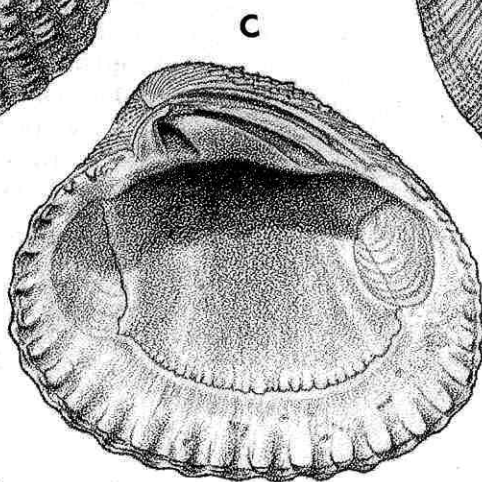
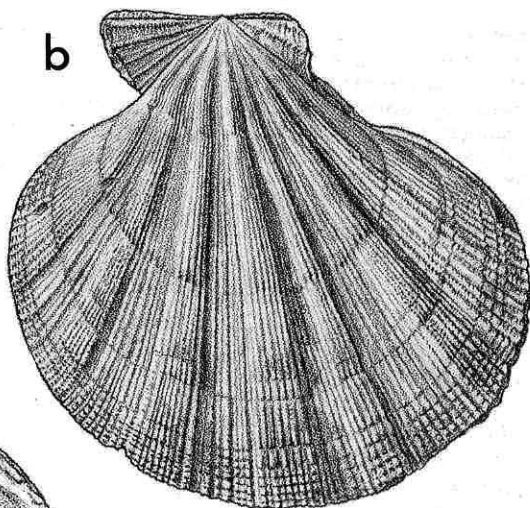
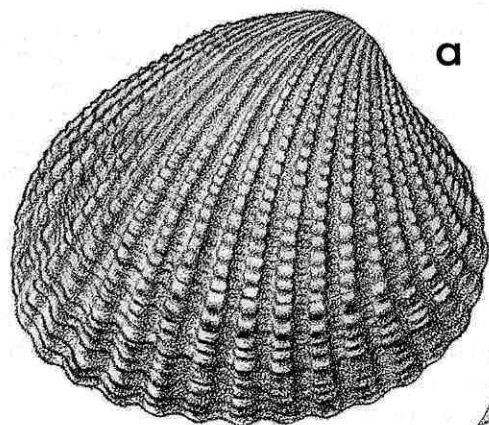
Moderately large for family (90-110 mm high), length equal to height in small specimens and in finely costate large shells, but length markedly greater than height in many coarsely costate large specimens; left valve slightly more inflated than right. Ears almost equal in 2 valves, nearly symmetrical; anterior margin of anterior ears sinuous, with broad, shallow byssal sinus but no ctenolium in right valve. Sculpture of 8 to 11 (on most specimens, 9 or 10) wide, flat-topped, square-edged radial folds on right valve and a similar number of high, narrow, widely spaced folds on left valve of coarsely sculptured end-members, with 2 or 3 low, square-edged, secondary costae in each interspace; a similar number of lower, narrower, medially subdivided folds tending to fade out towards ventral margin and with more numerous lower, flat-topped secondary costae on right valve of more finely sculptured end-members; right valve of younger (Waipipian-Mangapanian) forms develops a deep subdividing groove down the centre of major costae, and corresponding central narrow costa in wide interspaces on left valve.

Opoitian-Mangapanian; Momoe-a-Toa Shellbed, Cape Young, northern Chatham Island, early Opoitian (type); Opoitian specimens are known from a few mainland localities (Kaawa Creek, southwest Auckland; limestone, Dyerville road, northern Aorangi Range, southern Wairarapa), Waipipian specimens are known from equally few localities (Black Reef Sandstone, Cape Kidnappers; conglomeratic shellbed near head of Greek's Creek, Arahura Valley, Westland) and specimens are not uncommon at one Mangapanian locality (rubbly limestone in Blythe Valley, North Canterbury; with *Phialopecten triphooki*).

The type population of *Sectipecten allani* is very complex, and fortunately thousands of specimens can be observed on an extensive bedding plane; the fine and coarse end-members are linked by a complete range of intermediates,

Plate 32 Pliocene (Opoitian-Mangapanian) Mollusca (2).

- a,c. *Purpurocardia purpurata* (Deshayes), x 1.5.
- b,g. *Mesopeplum* (*Mesopeplum*) *dendyi* (Hutton), x 1.
- d,e. *Glycymerita* (*Manaiia*) *manaiiensis* (Marwick), x 1.
- f. *Crassostrea ingens* (Zittel), x 0.67.



and range from shells resembling *S. grangei* (Tongaporutuan; Pl. 28c) to extreme, flat-ribbed *S. allani*; as shown under *Sectipecten mariae* (Pl. 38h, i), the fine end-members apparently gave rise to *S. mariae*. The coarsely costate end-members developed into a slightly more subdivided form (Opoitian-Mangapanian of mainland New Zealand) occurring only rarely in barnacle limestone, conglomerate, and coarse, near-shore sandstone, and almost all known specimens (other than at Momoe-a-Toa) are undiagnostic left valves. Some relatively simple right valves are known from a Mangapanian limestone in the Blythe Valley, North Canterbury, and a single excellent articulated specimen from a conglomeratic shellbed in Greeks Creek, Arahura Valley, Westland (Waipipian; Otago University Geology Department, OU11904) shows that advanced right valves have the major folds subdivided by a deep groove, a new character in the lineage. The main *Sectipecten* lineage clearly became adapted to progressively more near-shore, high-energy environments after Opoitian time, and its place in limestone facies appears to have been taken by *S. mariae*.

Figured specimen (Pl. 33c): GS12184, CH/f2C, Momoe-a-Toa Shellbed, northern Chatham Island, early Opoitian (NZGS) x 0.67.

Pl. 33 f,g. *Mesopeplum (Borehamia) crawfordi* (Hutton, 1873) [*Pecten crawfordi* Hutton 1873b, p. 32; *Mesopeplum crawfordi*]. Type species of *Borehamia* Beu, 1978 (Pectinidae).

Large for genus (90-125 mm high), longer than high; right valve much more inflated than left; disc symmetrical and ears almost symmetrical, almost square, anterior ones retracted very slightly to disc, without byssal sinus or ctenolium. Dorsal margins of disc long and lightly concave, diverging at a very high angle, producing a very strongly convex ventral margin. Sculpture of 5 major radial folds in disc, evenly and regularly folded on both valves, very prominent on dorsal half of disc but becoming weaker lower down, fading out before ventral margin of large shells; superimposed on folds are many prominent, wide, closely to widely spaced radial costae, highly variable in width, spacing and numbers of secondary costellae; in most specimens, costae are relatively wide, flat-topped, and closely spaced on right valve but narrow-crested and more widely spaced on left valve; on many specimens, margins of costae are finely serrated by fine commarginal threads. Hinge lacks cardinal crura. Valves meet at thickened, flat-faced, narrowly triangular facets on each side of resilifer, at a nodule at outer base of each ear (auricular crura), and around ventral margin of commissure, leaving narrow anterior and posterior gaps. Adductor scar moderately large (0.2 height of disc), oval; pallial line broad, simple; many small muscle scars around pallial line dorsal to adductor scar, and in a curved line just above adductor scar.

Waipipian; "Maungapakeha Taipo" (actually Mangapakeha hill, north of Taueru), east of Masterton, central Wairarapa (type); abundant and widespread in conglomerate, limestone, shellbeds and near-shore sandstone in Wanganui-South Taranaki (particularly at Waihi Beach, Hawera), Hawke's Bay, Wairarapa, Marlborough, and North Canterbury (particularly in Greenwood Formation in Lower Waipara Gorge near Greenwood's Bridge). A few doubtful records from Opoitian, but all appear to be an unnamed smaller, more coarsely ribbed species; one specimen from high in the type Nukumaruan sequence (Tewkesbury Formation) at Wanganui (reworked from Waipipian?).

The complete lack of a functional byssus in even juvenile shells confirms the evidence from relative valve inflation—*Mesopeplum crawfordi* is one of the group of pectinids that lies on its more inflated right valve, and has an "aerofoil" cross-section for sustained, active swimming to escape predatory starfish, and never lives byssally attached. Members of this group (like most pectens) live on current-swept "hard-grounds", where sediment will not clog their gills, as they lack a mantle cavity cleaning mechanism. The very much larger size, the few, very prominent radial folds, the prominent, wide radial costae, and the relatively small, almost square ears readily distinguish *M. crawfordi* from the more ubiquitous *M. (Mesopeplum) convexum*; earlier species (notably Waiauan, Tongaporutuan and Opoitian unnamed ones) of *M. (Borehamia)* are smaller than *M. crawfordi*, but are still larger than *M. convexum*. The much smaller Kapitean-early Opoitian *M. (Borehamia) toaense* has more subdued radial folds but much more prominent, square-edged radial costae than those of *M. crawfordi*; specimens of *M. toaense* are very rare in the Momoe-a-Toa Shellbed, Chatham Island (type) but common in limestone and shellbeds in southern Wairarapa and at Tolaga and Anaura Bays, north of Gisborne.

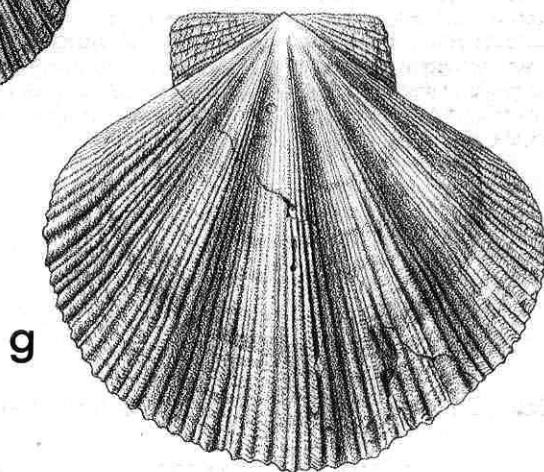
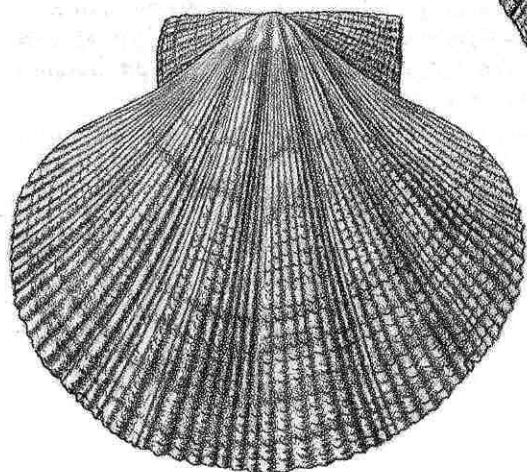
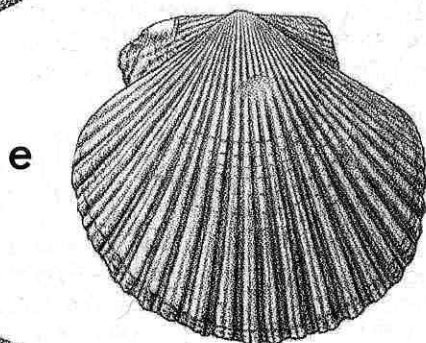
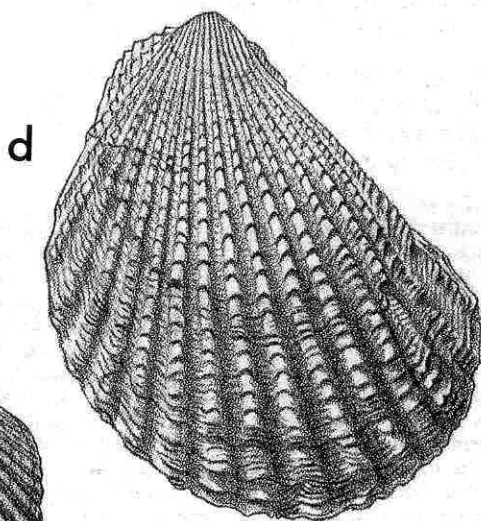
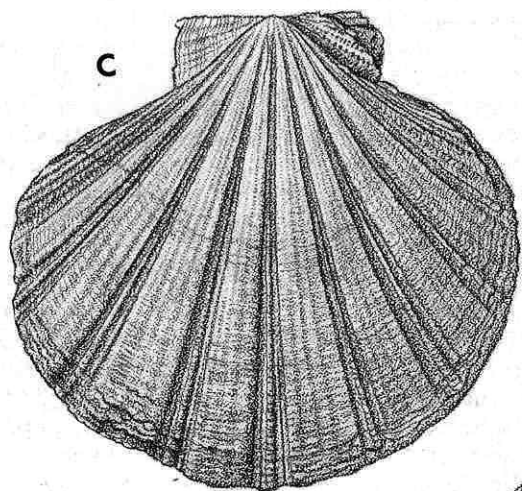
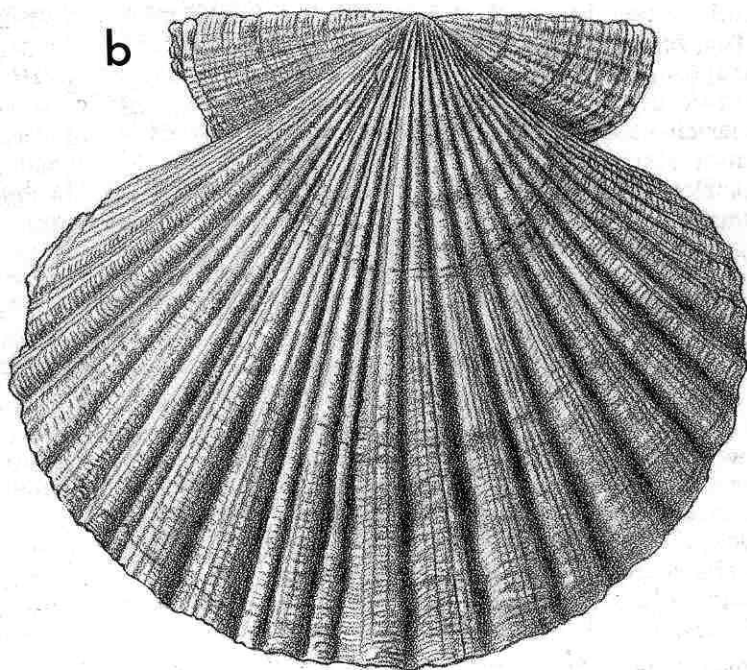
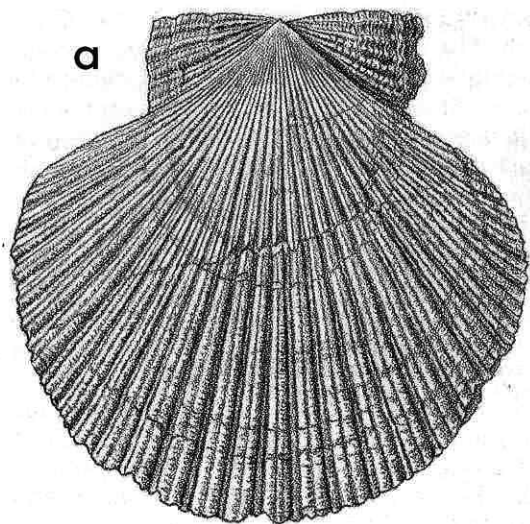
Figured specimens (Pl. 33f, g): GS5240, Q21/f6501, Waihi Beach, Hawera, South Taranaki, Waipipian (NZGS) x 0.67 (2 separate valves).

Pl. 32 b,g. *Mesopeplum (Mesopeplum) dendyi* (Hutton, 1902) [*Pecten dendyi* Hutton 1902, p. 196]. Type species of *Dendopeecten* Hertlein, 1936 (= *Mesopeplum* Iredale, 1929) (Pectinidae).

Large for subgenus (47-72 mm high), obliquely elongated postero-

Plate 33 Pliocene (Opoitian-Mangapanian) Mollusca (3).

- a. *Phialopecten marwicki* (Beu), x 0.67.
- b. *Phialopecten triphooki* (Zittel), x 0.67.
- c. *Sectipecten allani* Marwick, x 0.67.
- d. *Lima waipipiensis* Marshall and Murdoch, x 1.
- e. *Phialopecten ongleyi* Marwick, x 0.67.
- f,g. *Mesopeplum (Borehamia) crawfordi* (Hutton), x 0.67.



ventrally, umbo at or a little behind anterior third of length; 2 valves equally inflated. The most prominent sculpture is 6 or 7 radial folds, broad and closely spaced on right valve, narrow and widely spaced on left valve, folding whole shell including commissure; superimposed on and between major folds are many prominent radial costae, low, wide, and closely spaced on right valve, narrow, widely spaced, and with very narrow intermediate costellae on left valve. Ears very unequal; posterior ones small, with posterior margin inclined strongly backward, bearing 2 or 3 narrow radial costellae; anterior ears twice as long as posterior, with antero-ventral margin contracted strongly to disc, without ctenolium in adult, bearing 5 or 6 narrow radial costae. Dorsal margin of right valve ears higher than and bending slightly over dorsal margin of left valve ears. Interior not seen—all specimens articulated.

Early Opoitian, Momoe-a-Toa Shellbed, Cape Young, northern Chatham Island (type), the only known locality; abundant, with abundant *Sectipecten allani* and *Chlamys seymouri*, and rare *Mesopeplum (Borehamia) toense*. The abundant pectinids at Momoe-a-Toa occur in tuff and seem to have lived in an off-shore, hard-ground situation.

The lack of a ctenolium and the equally convex valves show that, like modern specimens of *M. convexum* (Pl. 44g), *Mesopeplum dendyi* was a free-lying species that swam actively to avoid predators. It is larger, more obliquely elongated, and with slightly more numerous radial folds than other *M. (Mesopeplum)* species.

Figured specimen (Pl. 32b, g): GS1176, CH/f2, Momoe-a-Toa Shellbed, Cape Young, northern Chatham Island, early Opoitian (TM4232, NZGS) x 1.

Pl. 33 d. *Lima waipipiensis* Marshall and Murdoch, 1919 [p. 256] (Limidae).

Moderately large for genus (70-78 mm high), narrow (length 0.6-0.7 height); small but obvious anterior and posterior ears have strongly descending dorsal margins but parallel, vertical anterior and posterior margins; disc extended very strongly obliquely anteriorly, anterior margin strongly concave. Sculpture of 14 to 17 prominent, narrow, widely spaced radial costae with narrow crests and strongly concave interspaces (so rib section is triangular in most specimens), bearing ventrally hollow, scale-like nodules at frequent intervals; anterior area and ear with 3-4 very narrow costae and with more prominent growth ridges than central area; posterior ear with 1-2 narrow, nodulous costae on a few specimens, but only growth ridges on most. "*Camptonectes* microsculpture" between main radial costae very fine. Hinge area tall, wide, flat, with wide, shallow ligamental pit in centre; hinge plate on each side, below ears, triangular and bearing 1 or 2 very small, obscure teeth on each side. Adductor scar large, subcircular, very weakly impressed.

Kapitean?; Opoitian-Waipipian; Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type); Waihi Beach, Hawera, Waipipian; moderately common. Similar specimens (but of how many species is unclear) occur uncommonly in latest Miocene and early-mid Pliocene throughout New Zealand, mostly in hard-ground, current-swept facies.

Modern *Lima* species live byssally attached in low-sedimentation environments on the shelf, and presumably *L. waipipiensis* lived in the same station. The few, widely spaced, narrow costae of triangular section and the well developed posterior ear distinguish this species group from the *L. colorata*-*L. zealandica* group (see *L. colorata*, Pl. 18 e,h), but it is difficult to distinguish *L. waipipiensis* from *L. robini* (Campbell Island, Opoitian) and *L. becki* (Te Waewae Bay, Southland, Kapitean).

L. vasis (Flowerpot Harbour, Pitt Island, Waipipian) was based on a very incomplete and poorly preserved specimen that superficially resembles *L. waipipiensis* but has 22 radial costae. A much better-preserved specimen,

presumably of this species, from another Waipipian locality on Pitt Island (Motutapu Point) indicates relationship to *L. colorata* rather than to *L. waipipiensis* (see Pl. 18 e,h).

Figured specimen (Pl. 33d): GS2589, Q21/f6491, east of mouth of Waingongoro River, South Taranaki, Waipipian (NZGS) x 1 (a specimen with unusually wide radial costae).

Pl. 32 f. *Crassostrea ingens* (Zittel, 1864) [*Ostrea ingens* Zittel 1864, p. 54] (Ostreidae: Crassostreinae).

Exceedingly large (200 mm to more than 300 mm high), exceedingly thick and heavy, calcitic; exterior irregularly foliose, without true radial or commarginal sculpture; cemented to hard substrates by umbonal area of left valve. Some specimens oval (length up to 0.7 height) but most narrowly elongate, length half height or less, and relatively deep. Left valve exceedingly thick, deep (inflation of left valve 60-80 mm or more; interior cavity 30-40 mm or more deep), most specimens curved weakly to left over ventral half; ligamental area large, in most specimens elongate (a little higher than wide), depressed medially and with a margining groove and ridge up each side; no sign of chomata in any adult specimens. Adductor scar at centre of cavity height, a little in front of centre, gently to steeply inclined (dorsal side depressed), dorsal margin straight to slightly irregular, ventral margin deeply convex, i.e., a rounded semicircular outline; retaining bright purplish red colour in most Pliocene specimens. Ventral area of internal cavity with a wide shallow groove in most specimens, extending from posterior of adductor scar to antero-ventral extremity of shell. Right valve almost flat, more weakly foliose than left, about 15 to 40 mm thick (i.e., considerably thinner than corresponding left valve); hinge a mirror image of left one; adductor scar as in left valve but less steeply inclined.

Tongaporutuan-Kapitean ?; Opoitian-early Nukumaruan. "Wanganui River", type, almost certainly from the *Crassostrea* reef in Wilkies Shellbed, Mangapanian. Widespread and abundant in shallow-water, near-shore limestone and shellbeds of Pliocene age (Opoitian to early Nukumaruan) in Wanganui basin, Gisborne district, Hawke's Bay (particularly abundant in Te Aute limestone facies), Wairarapa, and North Canterbury.

The youngest specimens of *Crassostrea ingens* (early Nukumaruan) occur in the base of Hautawa Shellbed at Hautawa Road, north of Hunterville, Rangitikei valley, and in the base of Pukenui Limestone in southern Wairarapa. The oldest specimens referred here (tentatively) are relatively small (to c. 150 mm long), narrow, laterally compressed specimens from the basal grit member of the Hurupi Formation in Putangirua Stream, eastern Palliser Bay (early Tongaporutuan); we are not aware of any Kapitean records. Rare, poorly preserved ? *Crassostrea* specimens in Castlecliffian mudstone at Ohiwa Harbour, Whakatane (in National Museum of N.Z.) appear to belong in a smaller species with a wider ligamental area than *C. ingens*. Zittel (1864) correctly pointed out the close similarity of *C. ingens* to the American "coon oyster", *C. virginica* (Gmelin), type species of *Crassostrea* Sacco, 1897. This is the sole giant oyster in New Zealand Late Miocene-Pliocene rocks, and there has never been any confusion over the identity of *C. ingens*. *C. ingens* occurs exceedingly abundantly in "reefs" (e.g., in Wilkies Shellbed, Wanganui (Mangapanian), in a bank up to eight metres thick found continuously over more than 45 km) and scattered in very near-shore, subtidal shellbeds, and apparently occupied much the same semi-estuarine, near-shore niche as *C. virginica* does now.

Figured specimen (Pl. 32f): plaster cast of holotype (original in Naturhistorisches Museum, Vienna), "Wanganui River", almost certainly from the *Crassostrea* reef in Wilkies Shellbed, Mangapanian (TM4280, NZGS) x 0.67.

Pl. 32 a,c. *Purpurocardia purpurata* (Deshayes, 1854) [*Cardita purpurata* Deshayes 1854a, p. 100; ?*C. difficilis* Deshayes 1854a, p. 103; *Venericardia australis* of Gray 1843, p. 256, and of Suter 1913c, p. 905, not of Lamarck, 1818; *Cardita tridentata* "Say" Reeve 1843, pl. 5, fig. 22 (not *Venericardia tridentata* Say, 1826)]. Type species of *Purpurocardia* Maxwell, 1969 (Carditidae: Venericardiinae).

Moderately large for family (28-60 mm long), very thick and solid, oval to subrectangular, with prominent umbones at anterior quarter of length. Lunule very short, convex, almost vertical, very deeply impressed. External sculpture of 23-26 prominent, wide, rounded radial costae, narrower on the postero-dorsal slope than elsewhere, crossed by low, narrow, rounded, closely spaced commarginal ridges on radial costal surfaces only. Inner ventral margin coarsely crenulate. Hinge wide and thick; in the right valve 1 prominent, extremely wide, bevelled cardinal tooth, with a deep socket on each side; in the left valve, 2 very prominent, relatively narrow cardinal teeth separated by a very wide, deep socket (hinges are transposed in a specimen in GS4124, Wilkies Bluff, Wanganui, Mangapanian). Anterior adductor scar significantly larger than posterior, deeply impressed; pallial line without sinus.

Opoitian?; Waipipian-Recent. Recent, New Zealand (type); abundant in shellbeds and other near-shore, soft-bottom Pliocene and Pleistocene assemblages throughout New Zealand.

Purpurocardia purpurata is highly variable and difficult to understand taxonomically; it appears likely that *P. difficilis* (Deshayes) is a distinct deep-water species in the modern fauna, and the status is unclear of the several dubiously distinct, relatively young fossils similar to *P. purpurata* (*P. beata*, Opoitian; *P. lilliei*, Waipipian; *P. southlandica*, Kapitean; *P. titirangiensis*, Nukumaruan). *P. purpurata* lives today in shallow-water, near-shore environments such as tidal channels, which explains its abundance in shallow-water shellbeds in the Wanganui Series.

Figured specimen (Pl. 32a, c): GS4124, R22/f6543, Wilkies Shellbed, Wilkies Bluff, mouth of Waitotara River, west of Wanganui, Mangapanian (NZGS) x 1.5.

Pl. 34 e,f. *Lucinoma galathea* Marwick, 1953 [*Lucinoma galathea* Marwick 1953, p. 111; *Lucinoma marwicki* Dell 1953b, p. 39] (Lucinidae).

Moderately large for family (28-50 mm high), subcircular, thin, weakly inflated, slightly longer than high; posterior outline slightly quadrate because of weak sulcus in outline caused by radial flexure marking off posterior area (or "wing"); posterior area a little less inflated than remainder of disc, relatively wide and prominent (e.g., more prominent than in *Pteromyrtea* and *Miltha*). Anterior area or "pseudolunule" very narrow, only weakly defined by a slight change in direction of sculpture. Lunule excavated for most of depth of hinge, relatively long and narrow. Sculpture of high, thin, widely spaced commarginal lamellae, the most prominent of any large New Zealand lucinid, up to 1 mm high and 2-4 mm apart over the outer area of large specimens. Hinge plate narrow, with 2 small, curved cardinal teeth in each valve, and a very small, obscure anterior lateral tooth at front edge of each valve, in front of lunule (a second one present in some left valves); ligamental nymph prominent, long and narrow, occupying lower half of hinge plate behind umbo; ligamental groove wide, moderately deep, completely below valve margin, but not enclosed above by valve margins as in *Miltha* and *Pteromyrtea*. Anterior adductor scar very tall and narrow, almost straight, largely inside and free from pallial line; posterior adductor

scar much smaller, oval; pallial line without sinus. Central area bounded by muscle scars and pallial line weakly radially wrinkled.

Opoitian to Recent; Recent, "Galathea" station 614, Milford Sound, in 268 m (type); Shakespeare Cliff Siltstone, Wanganui, Castlecliffian, and mudstone in cuttings on main highway south of Pakipaki, Hastings, Waipipian (paratypes); widespread but uncommon in deep-water siltstone facies in Wanganui basin, Wairoa district, southern Hawke's Bay, southern Wairarapa (moderately common in some localities in bathyal Mangapanian or, more probably, early Nukumaruan mudstone beneath Pukenui Limestone on the Maungaraki Range, east of Gladstone), and in North Canterbury.

Lucinoma galathea is commonly dredged buried deeply in fine sediment in moderately deep water (150-300 m) in the Southland fiords and in the upper bathyal zone around much of New Zealand, and the fossils clearly inhabited the same environment. *L. galathea* is easily recognised by its relatively large size and coarse commarginal lamellae for a New Zealand Pliocene-Pleistocene lucinid. The relationship needs to be investigated to the living Chilean to Magellanic *Lucinoma lamellata* (E. A. Smith, 1881); we can see no significant differences between New Zealand specimens and Chilean specimens of *L. lamellata* in the National Museum of N.Z.

Figured specimen (Pl. 34e, f): paratype, GS1457, V22/f6498, main highway south of Pakipaki, Hawke's Bay, Waipipian (NZGS); (f) x 1, (e) x 2.

Pl. 35 a,j. *Miltha neozelanica* Marshall and Murdoch, 1921 [*Miltha neozelanica* Marshall and Murdoch 1921, p. 78; *Miltha dosiniformis* Marshall and Murdoch 1921, p. 79; *Miltha* (*Milthoidea*) *neozelanica*; *Miltha* (*Milthoidea*) *dosiniformis*]. Type species of *Milthoidea* Marwick, 1931 (= *Miltha* H. and A. Adams, 1857) (Lucinidae).

Very large for family (47-97 mm high), discoidal and weakly inflated, almost circular, thick and solid. Sculpture of weak commarginal grooves and, on some specimens, low, very thin commarginal lamellae; a weakly defined, shallow groove and low fold define a narrow, slightly raised posterior area and a very weak groove defines a small anterior area, on both of which the commarginal lamellae are more consistently developed than elsewhere. Lunule a small, triangular, deeply excavated area, 0.5-0.7 width of hinge plate, just in front of and, in some specimens, partially obliterating anterior cardinal tooth. Hinge plate wide, with a straight lower margin, fused to disc (i.e., without umbonal hollow), with 2 narrow, curved cardinal teeth in each valve, but no lateral teeth; most of hinge plate, behind teeth, occupied by a long, smooth ligamental nymph and a wide, shallow, deeply sunken ligamental groove completely inside valve margin. Anterior adductor scar enormous, tall and relatively narrow, extending to centre of ventral margin of disc, situated immediately inside pallial line; posterior adductor scar much smaller, oval; pallial line without sinus. Central area bounded by muscle scars and pallial line consistently roughened and papillose, with a deep, almost vertical, central groove in most specimens.

Whaingaroan-Waipipian; Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type of *M. neozelanica*); Kawau Island, Auckland, Otaian (type of *M. dosiniformis*). *Miltha neozelanica* occurs rarely and sporadically throughout New Zealand Oligocene and Neogene rocks, as young as Waipipian, in shallow, near-shore facies (mostly shellbeds) in soft substrates; most specimens we have seen are from Waverley Beach (Waipipian) but it is rare even there.

New Zealand Cenozoic specimens of *Miltha* are quite variable in relative inflation of the two valves (most specimens are symmetrical, but the left or right valve may be more inflated than the other), prominence of angulations in the anterior and posterior outline, width and prominence of the anterior and posterior "wings", and prominence of commarginal sculpture; we are unable to distinguish *M. dosiniiformis* from *M. neozelanica*. A lot of five specimens from Brydone, Maitara River, Southland (Waitakian) agrees exactly with Waipipi shells in all characters. A lot of nine specimens, from Waihao River near "Pentland Hills" Station, South Canterbury (Bortonian), is consistently small (to 45 mm high), with a wide posterior wing and relatively prominent commarginal lamellae, and appears to be the one New Zealand lot that represents a species distinct from *M. neozelanica* (apart from the poorly known *M. agilis*, Wangaloan). As first revisers, we select *M. neozelanica* as the name to be used for the species named both *M. neozelanica* and *M. dosiniiformis* by Marshall and Murdoch (1921). We agree with Ludbrook (1969) that there are no characters separating *Milthoidea* Marwick, 1931 from *Miltha* (sensu stricto).

Figured specimen (Pl. 35a, j): Whakino, South Taranaki, Waipipian, a large specimen from Marshall and Murdoch Collection (NZGS) x 0.67.

Pl. 35 g. *Pteromyrtea dispar* (Hutton, 1873) [*Cyclina dispar* Hutton 1873b, p. 22; *Dosinia subrosea* Gray (in part) of Suter 1914, p. 50; *Lucinida levifoliata* Marshall and Murdoch 1919, p. 257; *Lucinida dispar*; *Callucina* (*Pteromyrtea*) *dispar*]. Type species of *Pteromyrtea* Finlay, 1926 (Lucinidae).

Small for family (18-35 mm high), almost circular, thin and fragile, weakly inflated, weakly sculptured. Some specimens almost smooth, except for weak growth ridges; others sculptured with low, very thin, irregularly placed commarginal lamellae. Lunule small, deeply impressed, deeply cut into hinge plate, narrow, bounded by a raised ridge; protrusion of a minute, shallowly impressed, anterior lateral tooth and socket causes extension of hinge plate in front of lunule, to form a second rounded, wing-like "pseudolunule", 3 times as long as true lunule, demarcated from disc by a weakly defined, angling ridge from umbo to antero-dorsal margin. Hinge very narrow; with a long, straight, narrow nymph occupying lower half of width of posterior hinge plate, margined above by a wide, rather shallow ligamental groove, completely inside valve margin; remnants of 2 very weak, obscure cardinal teeth and sockets and of very small anterior and posterior lateral teeth are present in some specimens but obliterated from most large specimens. Anterior adductor scar very tall and narrow; posterior one shorter, oval; pallial line without sinus; interior irregularly radially wrinkled.

Opoitian-Nukumaruan; Hautapu Limestone, Hautapu Falls, upper Rangitikei River (Opoitian), type of *Cyclina dispar*; "Moa beds", i.e., Tewkesbury Formation, Nukumar Beach, Wanganui (Nukumaruan), type of *Lucinida levifoliata* (the type localities, ages and synonymy were discussed by Boreham 1965, p. 56-57). Uncommon in Opoitian rocks, but a very common shell in Waipipian to Nukumaruan soft-bottom, near-shore sandstone and shellbeds throughout New Zealand, and particularly in shallow facies of Nukumaruan age in Wanganui basin and Hawke's Bay.

The abrupt extinction of *Pteromyrtea dispar* is one of many that make the end of the Nukumaruan Stage readily recognised. *P. dispar* is easily identified by its almost circular outline, its thinness and fragility, its hinge obliteration in large specimens and, in particular, its wing-like anterior "pseudolunule". Earlier species of *Pteromyrtea* are smaller and rarely have obliterated hinges.

Figured specimen (Pl. 35g): Nukumar Brown Sand, Nukumar Beach, Wanganui, Nukumaruan (NZGS, ex Marshall and Murdoch Collection) x 1.5.

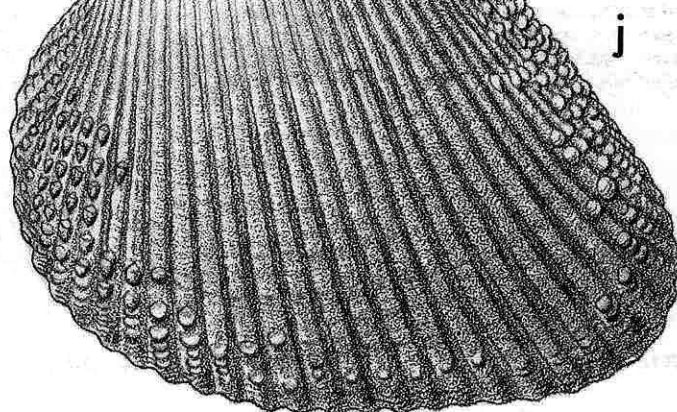
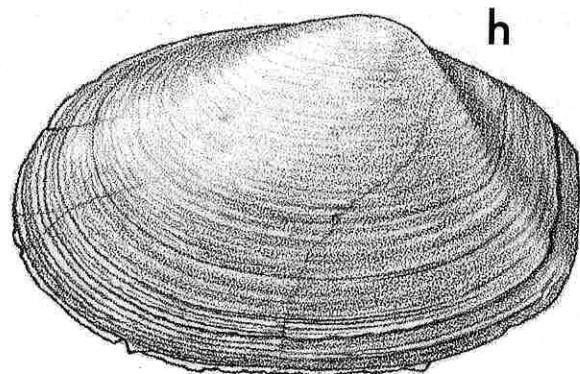
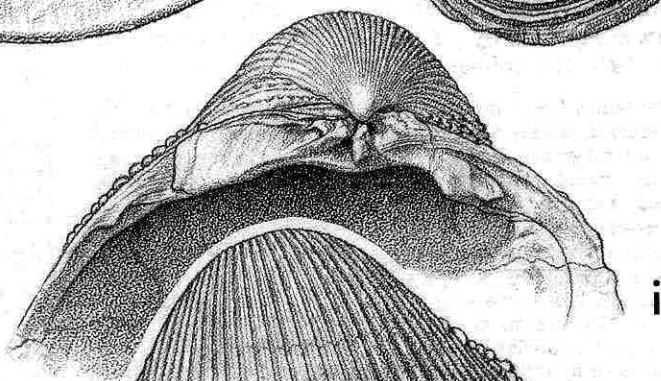
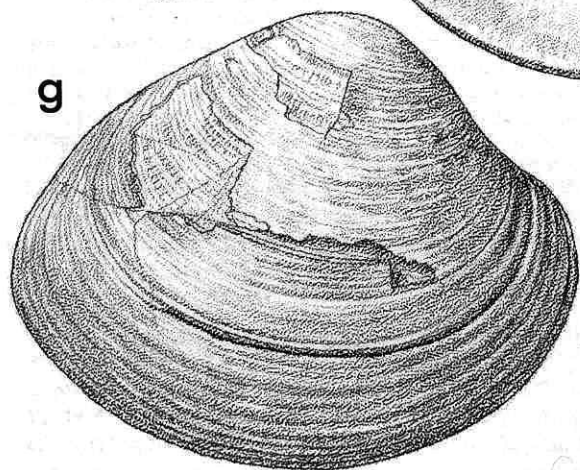
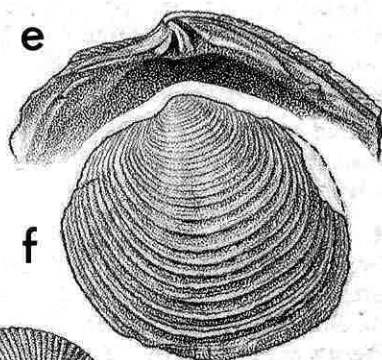
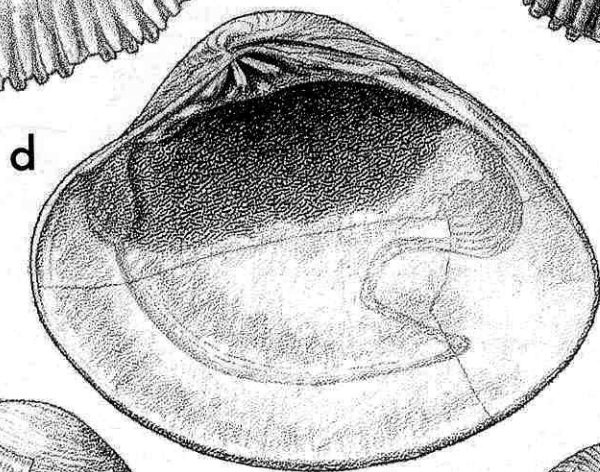
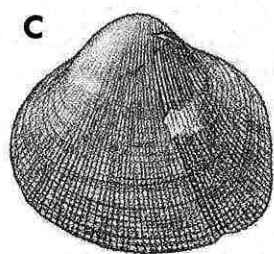
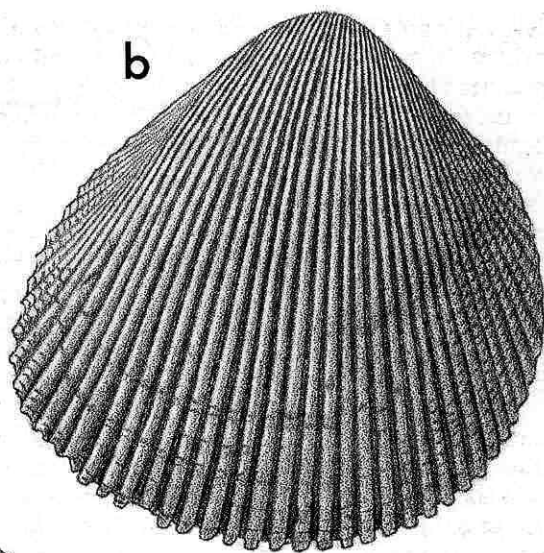
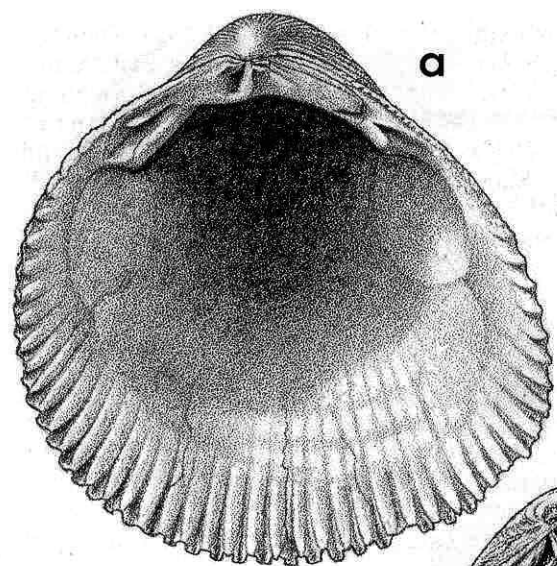
Pl. 34 c. *Nemocardium* (*Pratulium*) *quinarium* Marwick, 1944 [p. 266] (Cardiidae: Protocardiinae).

Very small (11-13 mm high; the smallest New Zealand cardiid), exceedingly thin and fragile, almost equilateral, well inflated, very finely sculptured. Posterior area clearly demarcated (as in all *Nemocardium*), in this species because of much narrower radial costae on posterior than on median and anterior areas of disc; median and anterior areas sculptured with exceedingly low, fine, yet flat-topped, relatively closely spaced, smooth radial costae, interspaces each about 0.3-0.5 width of 1 costa; 5 costae per mm at 10 mm from umbo; posterior area with high, thin, radial costae but spaced as on remainder of shell, the interspaces crossed by many low, narrow, closely spaced commarginal bars; no tubercles on costae. Ventral margin crenulate. Hinge not observed on available material, but presumably as in *N. pulchellum*, a typical (if very narrow) cardiid hinge, with very small, central cardinal teeth, and very small lateral teeth and sockets widely separated from cardinal teeth, on the hinge extremities.

Tongaporutuan ?; Kapitean-Waipipian. Mangatarehu Stream, Waikohu, Gisborne district, Opoitian (type); very common at a large number of localities throughout New Zealand in latest Miocene to mid-Pliocene soft-bottom facies, mainly from rather deep-water (outer shelf or upper bathyal) deposits, at many places occurring as "clumps" in mudstone, with no other macrofauna; probably indicative of a soft, fine substrate rather than any particular depth.

Plate 34 Pliocene (Opoitian-Mangapanian) Mollusca (4).

- a,b. *Trachycardium* (*Ovicardium*) *rossi* Marwick, x 0.75.
- c. *Nemocardium* (*Pratulium*) *quinarium* Marwick, x 3.
- d,g. *Eumarcia* (*Eumarcia*) *kaawaensis* Marwick, x 1.
- e,f. *Lucinoma galathea* Marwick, x 2(e) and x 1(f).
- h. *Thracia magna* Marshall and Murdoch, x 1.
- i,j. *Maoricardium spatiosum* (Hutton), x 0.67.



The younger *Nemocardium pulchellum* (Pl. 46k; Mangapanian-Recent) is larger (to ca. 30 mm long) than *N. quinarium* and has coarser sculpture (three radial costae per mm at a height of 10 mm), and small, sharp tubercles are common on the posterior area. *N. finlayi* (Kapitean-Waipipian) has not been found occurring sympatrically with *N. quinarium* but occurs in similar environments, perhaps in shallower water; it differs from *N. quinarium* in its larger size (to ca. 16-18 mm high) and markedly coarser, more widely spaced radial costae (two per mm at a height of 10 mm). The apparently abrupt change from *N. quinarium* to *N. pulchellum* is potentially useful for recognising the Waipipian-Mangapanian boundary but in practice is difficult to use, as these small, fragile shells are difficult to collect and prepare.

Figured specimen (Pl. 34c): holotype, GS1325, Y17/f9498, Mangatarehu Stream, 2 km south of Te Karaka, Gisborne, Opoitian (TM4501, NZGS) x 3.

Pl. 34 i,j. *Maoricardium spatiosum* (Hutton, 1873) [*Cardium spatiosum* Hutton 1873b, p. 23]. Type species of *Maoricardium* Marwick, 1944 (Cardiidae: Cardiinae).

Extremely large for family (135-155 mm long), highly inflated, exceedingly thick and massive (shell of some specimens more than 17 mm thick near anterior ventral margin), relatively short, trigonally elongate at posterior ventral corner. Umbones strongly prosogyrous. Sculpture of 40 very prominent radial costae, anterior 10 low and rounded, increasing progressively in height to high, median ones of square section, posterior 6 lower and more closely spaced than others (defined largely by their rows of tubercles); all bear large, elongate to cup-shaped (ventrally convex) periostracal tubercles (only flat scars of former tubercles remain over most of disc, except around anterior, posterior and ventral margins, on large specimens). Inner ventral margin coarsely and deeply crenulate. Hinge wide and thick, with a high, massive, square-ended nymph plate in both valves, and 2 large, conical cardinal teeth and a median socket in each valve; left valve with 1 very large, conical anterior lateral tooth, only a weak socket above it, and a very small, flange-like posterior lateral tooth; right valve with moderately large anterior lateral tooth and a very small posterior lateral tooth. Adductor scars large, subcircular; pallial line without sinus.

Lillburnian-Waiauian ?; Tongaporutuan-Mangapanian. "Waitotara", west of Wanganui, probably from Wilkies Shellbed at Wilkies Bluff, mouth of Waitotara River, Mangapanian, type (Boreham 1965, p. 58, pl. 16, fig. 1, 3; lectotype illustrated). Abundant in the Middle and Upper Waipipi Shellbeds at Waverley Beach, west of Wanganui (Waipipian), and common in many other Pliocene shellbeds near Wanganui, such as the Mangapani Shell Conglomerate and Wilkies Shellbed (both Mangapanian); widespread but uncommon in shallow, soft-bottom facies of Opoitian to Mangapanian age at Kaawa Creek and Otahuhu well near Auckland, and in Wanganui, Hawke's Bay, and North Canterbury. A few specimens are known from rocks as old as Kapitean (Mangatuna quarry, inland from Tolaga Bay) and Tongaporutuan (Tokomaru Bay; Hurupi Stream, Palliser Bay).

Maoricardium spatiosum is easily recognised by its enormous size, its very thick shell, its great inflation, and its sculpture of prominent radial costae. Specimens from high in the sequence at Clifden, Southland are intermediate between *Maoricardium spatiosum* and *M. gudexi*, being smaller and having lower, wider radial costae than typical Pliocene shells (Cucullaea Point shellbed and Lill Sand, Lillburnian; Nissen Shellbeds, Waiauian). *M. gudexi* is recorded from Altonian rocks in

Canterbury, and was presumably the ancestor of *M. spatiosum*. *M. spatiosum* is also similar in most characters to the living East African *Maoricardium pseudolima* (Lamarck), which differs only in its more quadrate, more nearly symmetrical shape. The extinction of *M. spatiosum* and of *Polinices waipipiensis* is important for recognising the end of Mangapanian time in shallow facies.

Figured specimen (Pl. 34i, j): GS4252, Q22/f7545, Middle Waipipi Shellbed, Waverley Beach, Wanganui, Waipipian (NZGS) x 0.67.

Pl. 34 a,b. *Trachycardium (Ovicardium) rossi* Marwick, 1944 [*Trachycardium (Ovicardium) rossi* Marwick 1944, p. 268; *Trachycardium (Ovicardium) parki* Marwick 1944, p. 269; *Acrosterigma (Ovicardium) rossi*]. Type species of *Ovicardium* Marwick, 1944 (Cardiidae: Trachycardiinae).

Very large for genus (90-102 mm high), inflated-oval to slightly triangular, relatively thin-shelled for its size, with low umbones; inner ventral margin coarsely and deeply crenulate. Sculpture of 40 to 50 high, narrow, flat-topped, almost smooth radial costae of square section, separated by flat-bottomed interspaces each about the same width as, or a little narrower than, 1 costa; costae are weakly noded by low commarginal lamellae near ventral margin and particularly on anterior end, and 10 costae on very poorly demarcated posterior area are of slightly more triangular section than others. Hinge with a long but low, square-ended ligamental nymph in both valves, 1 large and 1 very small cardinal tooth and a median socket in both valves, a weak, shallow, diagonal groove between posterior cardinal tooth and nymph in both valves, a large anterior lateral and 2 very small posterior lateral teeth in left valve, and 1 large and 1 small anterior lateral teeth and 1 small posterior lateral tooth in right valve. Adductor scars large, subcircular, coarsely striate; pallial line without sinus.

Kapitean-Mangapanian; early Nukumaruan ?. Sandstone in platform to west of and above Te Reinga Falls, Wairoa River, northern Hawke's Bay, Waipipian (type of *T. rossi*); Butler's Shell Conglomerate, Ototoka Beach, Wanganui, Castlecliffian (type of *T. parki*, a very abraded remanié specimen); spectacular but uncommon in shallow-water, near-shore, soft-bottom facies in east coast, North Island, particularly Tokomaru Sandstone (Kapitean) of Gisborne district, a few localities of Opoitian and Waipipian age in Hawke's Bay (common at Te Reinga Falls) and Bull Creek Limestone in Bull Creek, Ruakopkopatuna Valley, southern Wairarapa (Mangapanian or, more probably, early Nukumaruan); in Wanganui basin, a few specimens are known from the Waipipi Shellbeds and from higher Pliocene shellbeds (Mangapani, Wilkies), but specimens from Nukumarua Limestone (Nukumaruan; recorded by Fleming 1953) and Butler's Shell Conglomerate (basal Castlecliffian; type of *T. parki*) are all abraded, incomplete remanié specimens eroded from older formations.

Trachycardium rossi is very distinctive among world *Trachycardium* species because of its large size, its relatively short shape, and its prominent, smooth ribs of square section, and no New Zealand Cardiidae resemble it; the Clifdenian *T. (Regozara) delectabile* (Clifden, Southland) is small (49 mm high), fragile and much more finely sculptured.

Figured specimen (Pl. 34a, b): GS4252, Q22/f7545, Middle Waipipi Shellbed, Waverley Beach, west of Wanganui, Waipipian (NZGS) x 0.75.

Pl. 36 d,f. *Dosina* n. sp. (Veneridae: Venerinae).

Moderately large for family (53-61 mm long), relatively high and inflated-

oval, with umbones low, at anterior quarter of length; interior of ventral margin finely and closely crenulate; lunule short and moderately wide, not impressed, sculptured as remainder of disc, bordered by a deep, narrow groove. Sculpture of very prominent, high, narrow, smooth commarginal ridges, convex on ventral side and concave on dorsal side, separated by deep, smooth grooves each slightly wider than 1 ridge; ridges narrower and more closely spaced on ends, weakly anastomosing on anterior. Hinge narrow, with deep escutcheon and long, narrow ligamental nymph in each valve; right valve with a thick, slightly curved, grooved posterior cardinal tooth, a thick, strongly curved, deeply grooved median cardinal tooth, and a short, straight, thin anterior cardinal tooth; left valve with a thin, straight posterior cardinal tooth raised above nymph, a short, thick, straight, weakly grooved median cardinal tooth, and a high, thin, curved, weakly grooved anterior cardinal tooth; a short, rounded anterior lateral tooth in left valve and corresponding shallow socket in right valve. Adductor scars large, oval, subequal; pallial sinus short, narrowly triangular.

Waipipian; common in the Waipipi Shellbeds, Waverley Beach, west of Wanganui, and in sandstone in the Wairoa Syncline, northern Hawke's Bay.

The unnamed species is much more strongly sculptured than the Nukumaruan to Recent *D. zelandica*, and is apparently descended from the much larger and more strongly sculptured Miocene species *D. firmocosta* (Altonian-Lillburnian). Another, apparently related, apparently unnamed, strongly sculptured species (but more elongate and with less prominent ridges than the Waipipi shells) occurs in Maraetotara Formation (early Castlecliffian) at Cape Kidnappers.

Figured specimen (Pl. 36d, f): GS4253, Q22/f7544, Upper Waipipi Shellbed, Waverley Beach, west of Wanganui, Waipipian (NZGS) x 1.

Pl. 34 d,g. *Eumarcia (Eumarcia) kaawaensis* Marwick, 1927 [p. 627] (Veneridae: Tapetinae).

Moderately large for genus (80 mm long), evenly elongate-oval; slightly taller, more inflated, and more trigonal than *E. plana* (Pl. 40g, h); umbones higher, more inflated, and much more prominent than in *E. plana*. Exterior polished, smooth except for irregular commarginal folds that are quite prominent on some specimens. Lunule slightly depressed, otherwise poorly defined. Hinge relatively short, with 3 cardinal teeth in each valve, all narrow and protruding well, 2 of them bifid in each valve; end of nymph slightly raised in left valve to form a very small, narrow posterior lateral tooth, with corresponding weak socket beyond nymph end in right valve. Anterior adductor muscle scar deeply impressed; anterior pedal retractor muscle scar a small, deeply excavated depression just above adductor, embaying hinge margin; posterior adductor muscle scar slightly larger than and much more shallowly impressed than anterior one. Pallial sinus relatively short, margins parallel, apex rounded to obliquely truncated. Interior of ventral margin smooth, polished.

Opoitian-Waipipian; Kaawa Creek, southwest Auckland, Opoitian (type); also recorded from Otahuhu Brewery well, Auckland, Waipipian (Marwick 1948). Both localities are shallow-water, near-shore shellbeds.

Similar large, almost smooth forms similar to (and presumably ancestral to) *Eumarcia plana* (Pl. 40g, h) but having higher, more inflated umbones, are known also from Tongaporutuan rocks in North Taranaki and southern Wairarapa. *E. kaawaensis* differs from *E. plana* mainly by its much greater inflation and its larger, more nearly central umbones. The small left posterior lateral tooth is unique among New Zealand *Eumarcia* species. All these species are larger and considerably more inflated than *E. pareoraensis* (Altonian, Southburn Sand facies of South Canterbury).

Figured specimen (Pl. 34d, g): GS3528, R11/f7014, Otahuhu Brewery well, Auckland, Waipipian (TM4701, NZGS) x 1.

Pl. 36 a,b. *Eumarcia (Atamarcia) benhami* Marwick, 1927 [*Venus sulcata* Hutton 1875, p. 458 (not of Lamarck, 1835); *Cytherea (Circomphalus) sulcata*; *Eumarcia (Atamarcia) benhami* Marwick 1927, p. 631 (new name for *Venus sulcata* Hutton, preoccupied)] (Veneridae: Tapetinae).

Moderately large for genus (65-77 mm long), elongate-oval, umbo at anterior third of length; only moderately inflated; with smooth interior ventral margin; lunule deeply impressed, smooth, long and narrow, not marked off by a groove. Exterior sculptured with many prominent, smooth, relatively widely spaced, commarginal ridges, strongly convex on ventral side and weakly concave on dorsal side, the lamellar outer dorsal edge often broken and appearing frilled; separated by deep grooves equal in width to ridges. Hinge relatively narrow, with very long, narrow, ligamental nymph and deep escutcheon in each valve, a prominently grooved posterior cardinal tooth and thin, simple, median and anterior cardinal teeth in right valve, and a long straight posterior cardinal tooth, a thick, grooved median cardinal tooth and a triangular, undivided anterior cardinal tooth in left valve. Adductor scars large, almost equal; anterior pedal retractor scar separate from adductor, deeply impressed above it, a prominent facet just in front of anterior cardinal tooth. Pallial sinus deep, reaching almost half length, curved slightly upward, obliquely truncated.

Kapitean-Nukumaruan; "Napier, in limestone" (type; Hutton 1875, p. 458), presumably Scinde Island Limestone at Napier, Hawke's Bay (Nukumaruan); moderately common in shallow-water, soft-bottom facies and diverse molluscan assemblages, in Wanganui basin (Pliocene, shellbeds at Waipipi, Mangapani, and Wilkies Bluff), in the Gisborne district (Tokomaru Sandstone facies of Tolaga Bay to Anaura Bay, Kapitean), in Hawke's Bay (moderately common in soft sandy facies of Mangapanian and Nukumaruan limestone) and in southern Wairarapa (rarely in Pukenui Limestone of the Maungaraki Range).

Eumarcia benhami is easily identified by its low, oval shape and by having much the most prominent commarginal sculpture of all New Zealand *Eumarcia* species; all its older relatives have shallower commarginal grooves. At many Pliocene localities, *E. benhami* occurs with (but is much less common than) *E. plana*. The extinction of *Eumarcia* is a useful biostratigraphic index of the end of Nukumaruan time.

Figured specimen (Pl. 36a, b): mouth of Inaha Stream, South Taranaki, Waipipian (NZGS, ex F.D. Chambers Collection) x 1.

Pl. 35 c,i. *Mactra (Mactrona) mula* Marwick, 1948 [p. 22]. Type species of *Mactrula* Marwick, 1948 (not of Risso, 1826) = *Mactrona* Marwick, 1952 (Mactridae: Mactrinae).

Large for genus (74 mm high, 84 mm long), thick and solid, smooth except for weak growth ridges. Strongly trigonal, with high narrow umbo, rounded anterior extremity, and curved ventral and postero-dorsal margins meeting at posterior angle at termination of a sharply angling umbonal ridge. Hinge with a central, deep, rather narrowly triangular resilifer beneath umbo, and in front of resilifer a large, bilobed cardinal tooth and a small cardinal lamella in left valve and a pair of large cardinal teeth in right valve (similar to the large, slightly oblique cardinals of *Cyclomactra*); left valve with a single stout, relatively short, prominently pustulose or pitted lateral tooth on each side of hinge, right valve with a corresponding pair of short, stout, pustulose teeth and a deep, wide socket on each side of hinge. Hinge with a short spur above top of resilifer, but no "mactroid ridge" separating resilifer from dorsal ligament. Adductor scars oval, relatively small, near valve margins; pallial sinus small, semicircular, immediately below posterior adductor scar.

Waipipian-Nukumaruan; Otahuhu Brewery well,

Auckland, Waipipian (type, only specimen found). A huge, thick shell (101 mm high) from the Wanganui River road (Nukumaruan) and a suite of 15 specimens from Kaiwaka South Road, near Devil's Elbow, north of Napier (Nukumaruan) show a huge range of variation in shape (larger shells are taller and more angled than smaller ones) and seem to indicate that the same species occurs in the Nukumaruan. All occurrences are in very shallow-water, near-shore facies (the Kaiwaka South Road locality is estuarine, with common *Barytellina*, *Xenostrobus*, *Cyclomactra*, and *Zeacumantus*) which may explain the apparent rarity of the species.

As pointed out by Marwick (1948), *Mactrona* is a curious group combining the spiculoid ligament and large, slightly oblique cardinal teeth of *Cyclomactra* with coarsely pustulose lateral teeth and a shell similar to that of *Mactra* (sensu stricto). We can see few differences between *Mactrona* Marwick and *Pseudocardium* Gabb, 1866 (Moore 1969, p. N601, fig. E94.10; Uozumi et al. 1986, pl. 9, fig. 2, 3, 5, pl. 10, fig. 1, 5), previously recorded only from Oligocene to Recent faunas of western North America and northern Japan, and comparison of specimens is needed to be sure that *Mactrona* is distinct from *Pseudocardium*.

Figured specimen (Pl. 35c, i): holotype, GS3528, R11/f7014, Otahuhu Brewery well, Auckland, Waipipian (TM1280, NZGS) x 1.

Pl. 35 b,e,f. *Maorimactra chrydaea* (Suter, 1911) [*Corbula dubia* Hutton 1873b, p. 18 (not of Deshayes, 1837); *Mactra chrydaea* Suter 1911, p. 596] (Mactridae: Mactrinae).

Small for family (17-28 mm long), relatively high and very inflated and evenly convex for genus, thick and solid; exterior smooth except for weak growth ridges; umbo at anterior third. Hinge relatively narrow, with a very small, central, narrowly triangular resilifer in each valve; right valve with a pair of diverging, inverted-v-shaped, very small, but thick cardinal teeth immediately in front of resilifer, and a pair of heavy, short, smooth lateral teeth on each side of hinge; left valve with a very short cardinal lamella in front of resilifer, and a single heavy, short, smooth lateral tooth on each side of hinge. Both valves also have a "mactroid" ridge and spur below umbo, above-top of resilifer. Adductor scars small, subcircular, very close to anterior and posterior margins; pallial sinus small, semicircular, equal in size to and just below posterior adductor scar.

Kapitean-Waipipian; New River, south of Greymouth, Westland, Opoitian or Waipipian (type of *Corbula dubia*,

preoccupied; illustrated by Boreham 1965, pl. 20, fig. 4); "North Island main trunk [railway] line, between Mataroa and Turanga-a-rere", i.e., central North Island near Tongariro National Park, Opoitian or Waipipian (types of *Mactra chrydaea*). Common enough in shallow-water, soft bottom facies of Kapitean to Waipipian age throughout New Zealand to form a useful biostratigraphic zone indicator, particularly in the Tongariro-Waiouru area (central North Island), in the Blue Bottom Group in Westland, and in Southland; abundant and well preserved in the Birch's Mill shell lens at Te Waewae Bay, Southland.

Maorimactra chrydaea is much more rounded, inflated, and solid than other *Maorimactra* species. *M. acuminella* (? Waitakian-Altonian) (Pl. 19 c,h) is smaller, more elongate and more thin-shelled, with a prominent umbonal-posterior ridge; *M. ordinaria* (Opoitian-Recent), the type species, is smaller, much less inflated, and with its umbo nearer the anterior end; a very large, weakly inflated, unnamed species at Castlecliff, Wanganui (Castlecliffian) is larger and has a thinner shell than *M. chrydaea*.

Figured specimens (Pl. 35b, e, f): GS5626, C46/f9594, Birch's Mill shell lens, cliffs behind Te Waewae Bay, Southland, early Opoitian (NZGS) x 1.5.

Pl. 35 d,h. *Zenatia flemingi* Marwick, 1948 [p. 23] (Mactridae: Zenatiinae).

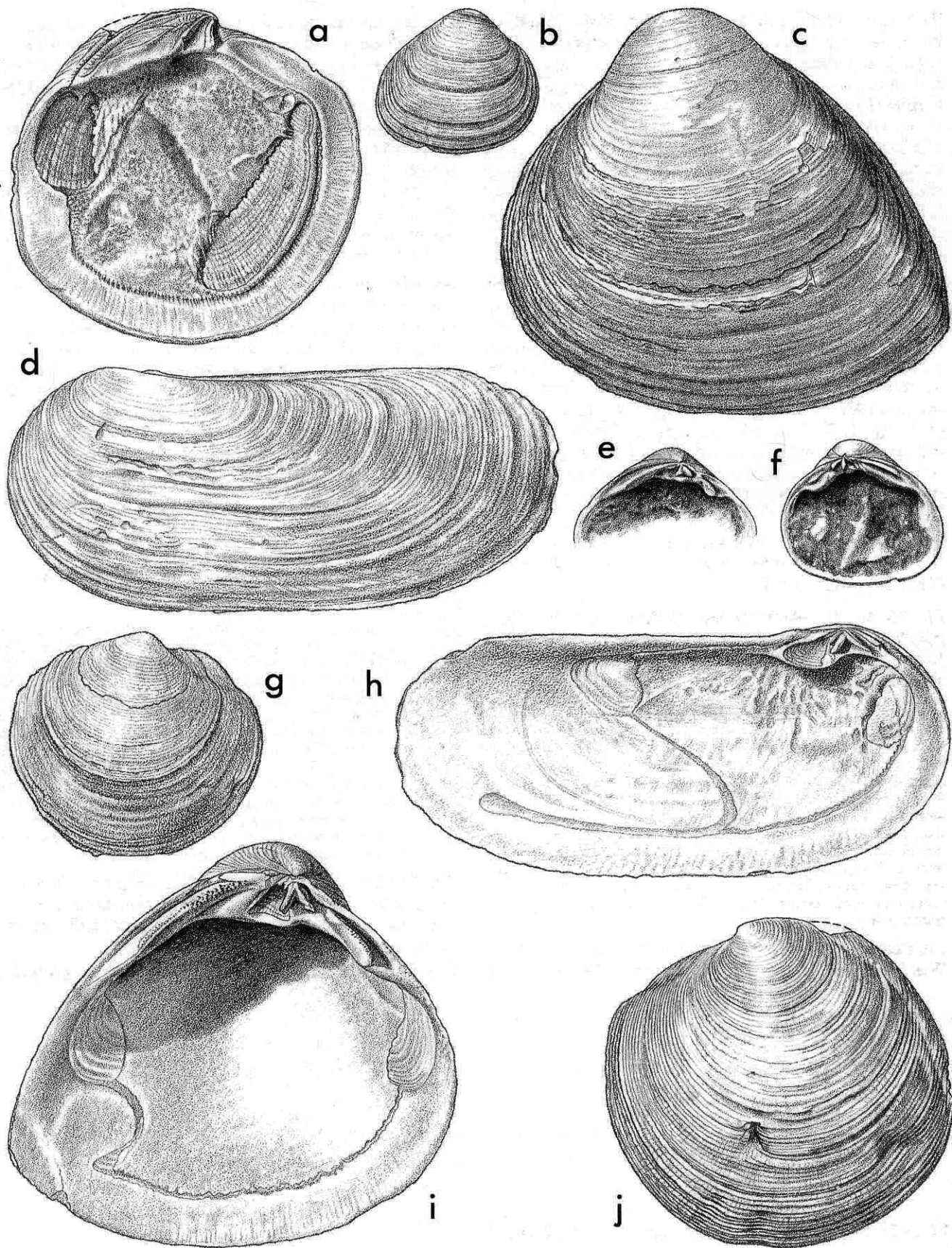
Large for genus (105 mm long), low and elongate, with very short anterior end and very long posterior end (i.e., umbo at anterior fifth), weakly inflated, with parallel, weakly down-curved, dorsal and ventral margins, regularly rounded anterior end, and rounded but slightly backward-sloping posterior end. Lunule a small, steeply sloping, striated area inside valve margin, immediately in front of hinge. Exterior sculptured only with weak growth ridges and weak periostracal wrinkles. Hinge with large bilobed cardinal tooth in left valve and pair of inverted-v-shaped cardinal teeth in right valve, margined by low anterior lateral tooth alongside lunule and very thin cardinal lamella alongside resilifer in left valve; a large, triangular resilifer below hinge plate behind teeth in both valves. Adductor scars large, subequal; pedal retractor scars small, separate, above anterior adductor; pallial sinus very deep, extending more than half length of shell.

Waipipian, Otahuhu Brewery well, Auckland, Waipipian (type); poor moulds from a few nearby surface exposures, otherwise not known elsewhere; but very similar to the Tongaporutuan-Recent *Z. acinaces*.

In living *Zenatia acinaces*, both anterior and posterior

Plate 35 Pliocene (Opoitian-Mangapanian) Mollusca (5).

- a,j. *Miltha neozelanica* Marshall and Murdoch, x 0.67.
- b,e,f. *Maorimactra chrydaea* (Suter), x 1.5.
- c,i. *Mactra* (*Mactrona*) *mula* Marwick, x 1.
- d,h. *Zenatia flemingi* Marwick, x 1.
- g. *Pteromyrtea dispar* (Hutton), x 1.5.



ends gape slightly, and dorsal and ventral margins are not parallel, allowing the animal to "rock" the valves open and closed during burrowing. Large specimens live in less than about 10 m of water, and smaller shells (to about 60 mm long) live in about 10 to 40 m. *Zenatia* is an endemic New Zealand genus of deep-burrowing mactrids of unusual long, narrow shape, still more extremely elongated than *Lutraria* (Pl. 39j, k). The Australian genus *Zenatiopsis* is still longer and narrower, with differently arranged pedal retractor muscle scars and a large internal strengthening ridge beneath the hinge; *Zenatina* is an Australian genus with a much more nearly central umbo, situated at the anterior third of the length.

A brief review of *Zenatia* species is in order, as a change is needed from the conclusions by Beu (1966).

- (1) The earliest species is *Zenatia cretacea*, based on a single small (length 44 mm) composite mould (internal mould of the hinge area and anterior end, external mould of the posterior end). Beu (1966) concluded that this specimen was from a Tertiary (Early-Middle Miocene ?) concretion, but Warren and Speden (1977, p. 45, table 2, fig. 27) regarded the holotype of *Z. cretacea* as a Piriapuan (Late Cretaceous) specimen from the base of the Okarua Sandstone at Haumuri Bluff, Marlborough. The rather poorly preserved holotype (much the oldest recorded zenatiine) has a narrower and still more nearly horizontal lunule than the oldest known Cenozoic form; this name should be restricted to the Late Cretaceous species, and the early Cenozoic species identified by Beu (1966) as *Z. cretacea* should be renamed.
- (2) *Zenatia* n. sp. (Whaingaroan-Altonian; possibly also Altonian-Waiauian): small (rarely more than 60 mm long), with the lunule a little wider and more steeply outward-sloping than in *Z. cretacea*; the cardinal angle (angle between the cardinal teeth of the right valve, or between the arms of the cardinal tooth of the left valve) averages 73° (specimens of Altonian-Waiauian age are poor, but appear to be intermediate between the earlier *Zenatia* n. sp. and the later *Z. acinaces*).
- (3) *Z. acinaces* (Tongaporutuan-Recent): large (shallow-water specimens to 100 mm long), cardinal angle averages 71°, lunule the shortest and widest of the genus, flat on the hinge plate or sloping slightly inwards.
- (4) *Z. flemingi* (Waipipian, Otahuhu well only): large, cardinal angle averages 81°, lunule slightly longer, narrower, and more outward-sloping than in *Z. acinaces*.
- (5) *Z. tepikiensis* (Haweran, Te Piki beds, Cape Runaway, only): status uncertain as known by immature specimens only (to 53 mm long); cardinal angle averages 88°, i.e., this form appears to belong in a "northern lineage" and to be descended from *Z. flemingi* rather than to be related to *Z. acinaces*; but a close relationship to *Z. acinaces* is possible.
- (6) *Z. (Zenatraria) waipipiana* (Waipipian, Wanganui-South Taranaki coast only): the subgenus *Z. (Zenatraria)* was proposed for species with a rounded (rather than obliquely angled) posterior outline, a narrow cardinal angle (averages 55° in both known species), a long, rather narrow, bevelled lunule sloping outward towards the dorsum, and differently arranged pedal retractor muscle scars from those of *Zenatia* (*Zenatia*). *Z. waipipiana* has a very short anterior end, with a steeply angled lunule, and the lower pedal retractor muscle scar is elongate, subrectangular, and just above the top of the anterior adductor muscle scar (closer to it than in *Z. acinaces*).
- (7) *Z. (Zenatraria) vellai* (Nukumarian, Wanganui coast and southern Wairarapa; not uncommon in Nukumaru Brown Sand, but rare elsewhere): more inflated than other *Zenatia* species (superficially resembling a small *Lutraria*), with a relatively long anterior end whose dorsal outline is a little straightened by the large, bevelled lunule; the lower pedal retractor muscle scar is an oval facet on the posterior edge of the anterior adductor muscle scar.

Figured specimen (Pl. 35d, h): holotype of *Z. flemingi*, GS3528, R11/f7014, Otahuhu Brewery well, Auckland, Waipipian (TM1369, NZGS) x 1.

Pl. 34 h. *Thracia magna* Marshall and Murdoch, 1921 [p. 77] (Thraciidae).

Large for genus (73-80 mm long), thin and fragile, nacreous internally, chalky externally, elongate, anterior end markedly longer than posterior (umbo at posterior third of length). Smooth except for low growth ridges, very fine, low pustules on posterior end, and faint periostracal wrinkles over much of surface. Dorsal and ventral margins roughly parallel, lightly convex; anterior end rounded; posterior end truncated, with a concave postero-dorsal margin, a ridge from umbo to postero-ventral corner, and a narrow posterior gape. Hinge plate lacking teeth, thin except for a large, thick, triangular nymph behind umbo, extending to hinge line posteriorly, supporting lithodesma (a small calcified plate supporting ligament and linking the 2 valves) in a deep, concave groove at its front end, inner ligament in a shallow socket on commissural face, and outer ligament in a shallow groove along its dorsal margin. Muscle scars very shallowly impressed; anterior adductor scar tall and very narrow, posterior one much smaller, subcircular. Pallial sinus deep, extending in front of umbo, with parallel dorsal and ventral margins and semicircular anterior end.

Waipipian-Nukumarian; "on the coast about 3 miles [4.8 km] north of the Waipipi Stream, in brown sand and blue sandy clay" (type; Marshall and Murdoch 1921, p. 78), probably from the Pepper Shell Sand (Fleming 1953, p. 108-9) cropping out near Snapper Point, west of Waverley Beach, west of Wanganui, Waipipian; sporadic and uncommon in Pliocene shellbeds along the Wanganui-South Taranaki coast, notably the Waipipi shellbeds; also Nukumaru Brown Sand (Nukumarian) and rarely in Pliocene rocks elsewhere.

Slightly smaller but otherwise similar large, elongate species apparently closely related to *Thracia magna* are uncommon in Waiauian to Opoitian rocks in North Canterbury and the Gisborne district. This is much the largest species of New Zealand Thraciidae, fossil or living but is apparently closely related to the much smaller Haweran and Recent species, *T. vitrea*.

Figured specimen (Pl. 34h): GS10843, Q22/f7674, Waverley Shellbed, Waverley Beach, west of Wanganui, Waipipian (NZGS) x 1.

Pl. 36 c,g. *Calliostoma* (sensu lato) *waiparaense* Suter, 1917 [*Calliostoma waiparaense* Suter 1917, p. 4; *Maurea waiparaensis*] (Trochidae: Calliostomatinae).

The largest New Zealand fossil *Calliostoma* (40-70 mm in diameter), with relatively low, stepped spire, strongly convex whorls, strongly rounded periphery, and weakly convex base. Sculpture of 3 prominent, wide, smooth, widely spaced spiral cords on first teleoconch whorl; number of cords increasing rapidly by intercalation of secondary and then tertiary cords, so 3rd and 4th whorls have 6 or 7 very prominent, wide, relatively coarsely beaded cords, and last whorl has 8-10 similar cords, all with wide, concave interspaces; on last whorl, a single narrow, smooth, low thread in the centre of each spiral interspace; cords become more numerous, smooth, and more closely spaced around periphery, to merge into 10 smooth, high, relatively closely spaced spiral cords on base. On some specimens, cords on base are beaded near periphery, and fine secondary threads occur between primary ones. Aperture oval, large; inner lip thick and wide, forming a pad over umbilicus. Protoconch not seen but presumably as in other *Calliostoma* species, very small, of 1 whorl with distinctive, prominent, honeycomb sculpture of narrow ridges.

Waipipian; conglomeratic shellbeds in Greenwood Formation near Greenwood's Bridge, Lower Waipara Gorge, North Canterbury (type); not certainly known at any other locality, but common in several beds at the type locality.

The similar but smaller, more finely sculptured form recorded as *Calliostoma waiparaense* from Nukumaru Brown Sand at Nukumaru Beach, Wanganui (Nukumarian) by Beu (1973b, p. 320) is an unnamed species (pers. comm. B. A. Marshall, National Museum

of N.Z.) The rounded whorls and periphery and very coarse sculpture make *C. waiparaense* one of the most distinctive of our fossil *Calliostoma* species, certainly very different from the partly coeval flat-sided *C. hawera* (below).

Figured specimen (Pl. 36c, g): GS4949, N34/f6180, Lower Waipara Gorge near Greenwood's Bridge, North Canterbury, Waipipian (NZGS) x 1 (a small but reasonably complete specimen).

Pl. 36 j. *Calliostoma* (sensu lato) *hawera* Oliver, 1926 [*Calliostoma hawera* Oliver 1926b, p. 114; *Maurea hawera*] (Trochidae: Calliostomatinae).

Large for genus (40-55 mm in diameter), conical, with tall, straight-sided to slightly concave spire outline, sharply keeled periphery (narrowly rounded on last half-whorl of some large shells), and almost flat base. Sculpture of 3 narrow, well raised, beaded spiral cords on early spire whorls, increasing to 5 on later whorls, with an intermediate, finer, weakly beaded cord in each interspace, and some very fine, tertiary spiral lirae; base with about 20 prominent, narrow spiral cords, the inner ones beaded, the outer ones smooth. Aperture rhomboidal; inner lip inclined slightly to right. Protoconch not seen, presumably as described under *C. waiparaense*.

Waipipian; Waihi Beach, Hawera, South Taranaki (type); also sporadically in shallow-water shellbeds of Waipipian age in Wanganui, Hawke's Bay, and Marlborough (Starborough Formation in Starborough Creek, Seddon, and at the mouth of Blind River).

Calliostoma hawera is distinctive because of its large size, its tall spire, its very flat sides and base, and its narrowly keeled peribasal angle. It was possibly ancestral to the Castlecliffian-Recent *C. selectum*, which has a much lower spire, a more convex base, and a more rounded peripheral angle.

Figured specimen (Pl. 36j): GS11879, P29/f285, Starborough Creek, lower Awatere Valley, Marlborough, Waipipian (NZGS) x 1 (a specimen with a slightly lower spire than Hawera shells).

Pl. 36 e,h. *Zethalia russelli* Marwick, 1965 [p. 27] (Trochidae: Umboniinae).

Very small for genus (6-7 mm in diameter, 4.5-5 mm high), depressed conical, with low spire; base slightly convex, narrowly umbilicate. Spire outline almost straight. Sculpture of 2 very narrow, closely spaced, low spiral cords forming a narrow, biangled periphery; a row of low, rounded beads below suture down whole shell; many very fine, low, closely spaced spiral threads on base; a row of low, closely spaced beads bordering narrow umbilicus (which is a third diameter of base), and a large, beaded spiral ridge within umbilicus (formed by a callused columellar lobe of inner lip), leaving a narrowly open central umbilical tube.

Opoitian; Urumatai Stream, near Te Karaka, Gisborne (type), abundant in concentrated *Zethalia* beds in shallow-water sandstone; localities are uncommon (but specimens always abundant when found) on the Napier-Taihape Road, in northern Hawke's Bay and in the Gisborne district.

The evolution of *Zethalia* was discussed by Marwick (1965, p. 27-28). *Z. russelli* is similar to an unnamed, partially coeval species of *Antisolarium* in Birch's Mill shellbed, Te Waewae Bay (early Opoitian) in size, shape, and most sculpture, but the *Antisolarium* species has a much more widely open, deeper umbilicus and a third spiral cord above the periphery. The unnamed *Antisolarium* appears to have been ancestral to *A. stoliczkai* (Opoitian-Waipipian); *A. stoliczkai* has more

spiral cords and no subsutural beads. The unnamed Opoitian *Antisolarium*, or a similar species, was also thought likely by Marwick (1965) to have been ancestral to *Z. russelli*, and if so *Zethalia* evolved independently in New Zealand and is therefore only superficially similar to *Umbonium*. The succeeding *Z. coronata* (Waipipian-Mangapanian; early Nukumaruan?) is much larger (almost as large as *Z. zelandica*; up to 15 mm in diameter), has the biangulate periphery and subsutural nodules of *Z. russelli*, but has a much more widely callused, almost filled umbilicus. It is succeeded in turn by the Nukumaruan-Recent *Z. zelandica* (Pl. 47l, p), with a smooth subsuture and an obliterated umbilicus. All these behave as typical Trochidae Umboniinae, with elaborate calluses on the base and in the umbilicus formed by lobes of the inner lip, and (judged by *Z. zelandica*) lived gregariously in huge numbers in the wave zone of sandy beaches.

Figured specimen (Pl. 36e, h): holotype (TM2728; Pl. 36h) and paratype (Pl. 36e), GS8074, Y17/f7683, Urumatai Stream, off Kanakanaia Rd, Te Karaka, Gisborne, Opoitian (NZGS) x 5.3.

Pl. 36 m. *Zefallacia lawsi* Marwick, 1948 [p. 29] (Cerithiidae).

Small for genus (40-42 mm high), tall and slender, with about 20-22 very short whorls with almost flat sides; spire outline slightly concave over upper half, slightly convex below. Early spire whorls with 3 prominent, narrow spiral cords, beaded by numerous low, closely spaced axial costae; over mid-height, whorls have 4 low, wide cords, posterior one widest and weakly beaded, others smooth; by eighteenth whorl sculpture becomes obsolete, leaving 2 or 3 very weakly defined, narrow spiral ridges and an unusual malleate appearance produced by weak oblique ridges over last 4 whorls. Protoconch of 3 smooth whorls, tall and narrow, with a protruding nucleus (similar to that of *Zeacolpus*). Aperture large, subquadrate; outer lip lightly thickened and slightly flared, with a wide shallow sinus on whorl side but swinging forward strongly over base, joining inner lip at top in a narrow, shallow, but well defined posterior canal margined by a parietal ridge; inner lip a wide, thick pad on last whorl, with base of columella protruding to form a low spiral fold; meeting base of outer lip at a short, deep, unnotched, weakly twisted anterior canal with no fasciole.

Waipipian; Otahuhu Brewery well, Auckland (type); not known from any other locality.

The Paleogene and early Neogene species of *Zefallacia* are much larger and have more strongly shouldered whorls and so more stepped spire outlines than younger species. *Z. ruamahanga* (Tongaporutuan, northern Wairarapa) is similar in most characters to *Z. lawsi*, but is shorter and smoother. The only other Late Neogene species we are aware of is an unnamed one from Ngamatapouri, upper Waitotara Valley, Wanganui (Waipipian), which is shorter and more coarsely sculptured than *Z. lawsi* and *Z. ruamahanga*, retaining four spiral cords onto the last whorl. The genus is found only in estuarine and other very near-shore environments, on soft substrates, and apparently occupied a similar niche to the modern tropical "mangrove-creepers" *Pyrazus* and *Terebralia*.

Figured specimen (Pl. 36m): paratype, GS3528, R11/f7014, lower part of shellbed, Otahuhu Brewery well, Auckland, Waipipian (TM6771, NZGS) x 1.5.

Pl. 36 n. *Zeacolpus* (*Zeacolpus*) *kanieriensis* (Harris, 1897) [*Turritella* (*Zaria*) *tricincta* var. B Hutton 1873b, p. 13 (not of Borson, 1821); *Turritella patagonica*

"Sowerby" Hutton 1887, p. 219 (not of G. B. Sowerby I, 1846); *Turritella kanieriensis* Harris 1897, p. 241 (new name for *T. tricineta* Hutton, preoccupied); *Stiracolpus kanieriensis*] (Turritellidae).

Large for genus (38-70 mm high), very tall and slender, but most specimens are short lengths of incomplete shells; sculpture greatly dominated by 3 spiral cords. Wide, straight sutural ramp slopes strongly out from suture to prominent spiral cord A, near upper quarter of whorl height; wide, strongly concave interspace (a third of whorl height) separates A from very prominent cord B; cord C is almost as prominent as B but very close below it; whorls then contract sharply to lower suture. A background of many fine spiral threads is obvious on most specimens. Outer lip with a wide, fairly shallow, V-shaped sinus, with a rounded apex; base flat. Protoconch not known.

Kapitean-Waipipian. Harris (1897) proposed the name *Turritella kanieriensis* as a replacement name for the preoccupied *T. tricineta*. The sole remaining original specimen from Hutton's material is from Shakespeare Cliff, Wanganui (Castlecliffian; a specimen of the form illustrated here as *Z. delli murchisoni*, Pl. 47g) and, as use of the name *kanieriensis* for this form would cause confusion as well as leave Lake Kanieri shells without a name, the International Commission on Zoological Nomenclature chose as lectotype of *Turritella kanieriensis* Harris the specimen from Kanieri illustrated by Suter (1914, pl. 16, fig. 5); type locality therefore Kanieri, Westland, Kapitean or Opoitian (ICZN Opinion 810, *Bulletin of Zoological Nomenclature* 24: p. 87, 1967). The species is common in but largely limited to shallow-water (mid-outer shelf ?) sandy siltstone of Kapitean to Waipipian age in the Kanieri district, Westland; some specimens of *Zeacolpus* in a drill core from Makara, Wellington (Opoitian) are nearer to *Z. kanieriensis* than to *Z. opositus*, although others are more like *Z. opositus*. *Z. kanieriensis* is a large, typical species of *Zeacolpus*, possibly ancestral to both *Z. vittatus* (Pl. 47f) and *Z. opositus*; it differs from them in its wider A-B interspace, narrower B-C interspace, and much more prominent major cords. The origins of the group are obscure, however, as earlier species referred to *Zeacolpus* by Marwick (1971a) have much weaker spiral sculpture.

Figured specimen (Pl. 36n): GS10199, J33/f7761, borehole at Humphrey's, Arahura Valley, Westland, at 41 m depth, Kapitean (NZGS) x 1.5.

Pl. 36 l. *Stiracolpus huttoni* (Cossmann, 1912) [*Turritella bicincta* Hutton 1873b, p. 13 (not of S. V. Wood, 1842, nor of J. de C. Sowerby, 1850); *Turritella ambulacrum* "Sowerby" of Hutton 1886b, p. 355 (not of G. B. Sowerby I, 1846); *Turritella huttoni* Cossmann 1912, p. 113 (new name for *Turritella bicincta* Hutton, preoccupied); *Zeacolpus* (*Stiracolpus*) *haweraensis* Powell 1931a, p. 101; *Turritella* (*Archimediella*) *huttoni*; *Zeacolpus* (*Stiracolpus*) *huttoni*] (Turritellidae).

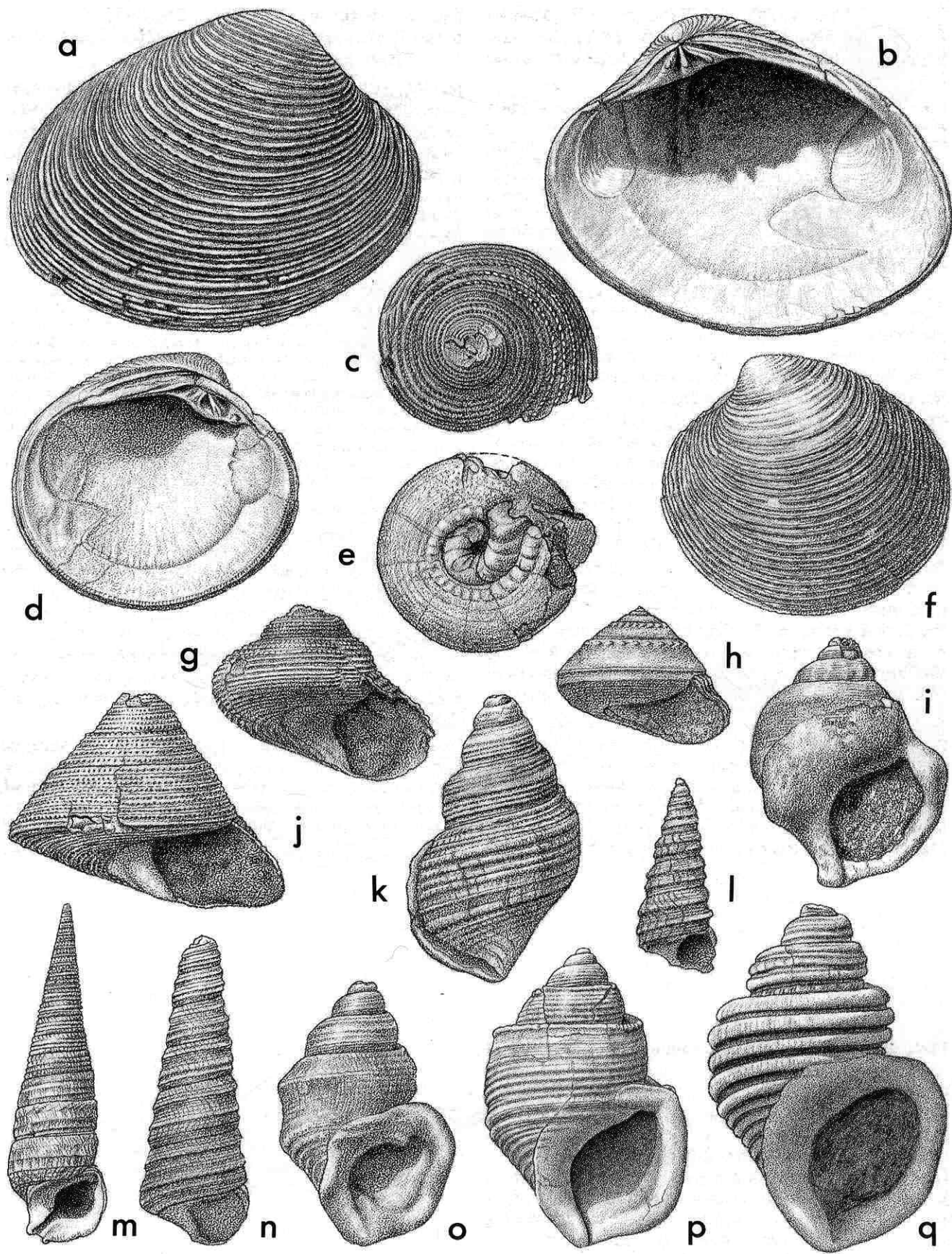
Small for family (13 to 19 mm high), tall and slender but variable in spire angle, many specimens rather broad compared with other *Stiracolpus* species (Pl. 47g); sculpture greatly dominated by 2 smooth spiral cords. Unlike almost all other Neogene turritellids of New Zealand, only spiral cords A and B are strongly developed on most adults, and their interspace is wide, so they are evenly spaced on most shells; a secondary cord is fairly prominent on the sutural ramp (above cord A) on some specimens, but most have a generalised background of fine spiral threads on strongly concave areas between and below 2 prominent cords. Aperture simple, thin-lipped, quadrate; outer lip with a wide, fairly shallow, V-shaped sinus with a rounded apex. Base flat, with many fine spiral threads, and a shallow sinus in outer lip.

Opoitian-Nukumarian; Kanieri, Westland, Opoitian or Waipipian (type of *Turritella bicincta* = *T. huttoni*); Waihi Beach, Hawera, South Taranaki, Waipipian (type of *Z. haweraensis*); widespread in shallow-water, soft-bottom facies at Kaawa Creek, southwest Auckland (Opoitian), in Wanganui basin (Waipipian, Mangapanian), northern Hawke's Bay (Opoitian-Waipipian), central Hawke's Bay Petane Limestone facies (Nukumarian), and in Westland (Lake Kanieri, Arahura Valley, and Kapitea Creek-Hokitika district, all Waipipian).

Most Opoitian-Waipipian specimens of *Stiracolpus huttoni* are wide and short, with cords A and B almost equally prominent, whereas Nukumarian shells are all tall and narrow, with cord B more prominent than the upper one. Marwick (1957, p. 36) named a "subspecies" *Z. huttoni ohopeus* (Castlecliffian, Ohope Beach,

Plate 36 Pliocene (Opoitian-Mangapanian) Mollusca (6).

- a,b. *Eumarcia* (*Atamarcia*) *benhami* Marwick, x 1.
- c,g. *Calliostoma* (sensu lato) *waiparaense* Suter, x 1.
- d,f. *Dosina* n.sp., x 1.
- e,h. *Zethalia* *russelli* Marwick, x 5.3
- i. *Struthiolaria* (*Callusaria*) *obesa* Hutton, x 1.
- j. *Calliostoma* (sensu lato) *hawera* Oliver, x 1.
- k. *Struthiolaria* (*Struthiolaria*) *dolorosa* King, x 1.
- l. *Stiracolpus* *huttoni* (Cossmann), x 2.
- m. *Zefallacia* *lawsi* Marwick, x 1.5.
- n. *Zeacolpus* (*Zeacolpus*) *kanieriensis* (Harris), x 1.5.
- o. *Pellicaria* *incrassata* (Powell), x 2.
- p. *Pellicaria* *zelandiae* (Marshall and Murdoch), x 1.5.
- q. *Pellicaria* *canaliculata* (Zittel), x 1.5.



Whakatane, Bay of Plenty), which differs in its lower-placed and still more prominent cord B, and appears to connect *S. huttoni* with the living *S. pagoda* (Reeve).

Figured specimen (Pl. 36l): GS2877, J33/f7580, Lake Kanieri Road, Westland, Waipipian (NZGS) x 2.

Pl. 37 a,b. *Hartungia typica* Bronn, 1861 [*Hartungia typica* Bronn 1861, p. 119; *Janthina hartungi* Mayer 1864, p. 242; *Heligmope dennanti* Tate 1893, p. 329; *Turbo(?) postulatus* Bartrum 1919, p. 100; *Parajanthina japonica* Tomida and Itoigawa 1982, p. 60; *Bulbus (Heligmope) dennanti*; *Hartungia postulata*]. Type species of *Hartungia* Bronn, 1861 (= *Heligmope* Tate, 1893; = *Parajanthina* Tomida and Itoigawa, 1982) (Janthinidae).

Large for family (17–40 mm high, 19–38 mm in diameter), shaped much as in the common “garden snail”, *Helix aspersa*, with low, convex spire and large, enveloping, evenly inflated last whorl; imperforate; very thin and light, with a conspicuous pale brown outer calcitic layer. Aperture very large, subcircular, with curved inner lip merging into strongly and regularly convex outer lip in apertural view; in basal view, a shallow sinus in base of outer lip slightly to right of junction with inner lip, producing a conspicuous costa parallel to inner lip on most specimens. Sculpture of low, indistinct, spiral folds in the shell wall, 9–11 on most specimens, almost as prominent on sutural ramp as lower down; whorl surface crossed by low, very thin, widely spaced, axial lamellae, about 1 mm apart on large specimens. Protoconch not seen, presumably pupiform and inclined to the teleoconch axis, as in *Janthina*.

Kapitean-Waipipian; Santa Maria Island, Azores Islands, eastern Atlantic, early-mid Pliocene (types of *H. typica* and of *Janthina hartungi*); MacDonald’s Bank, Muddy Creek, western Victoria, Australia, Kalimnan (type of *Heligmope dennanti*); Kaawa Creek, southwest Auckland, Opoitian (type of *Turbo(?) postulatus*); Higashigumi, near Mori-machi, Shizuoka Prefecture, Japan, Pliocene (type of *Parajanthina japonica*); common at a few localities in south-eastern Australia, near Perth in western Australia, at a few localities in north-eastern New Zealand, and apparently at Santa Maria Island in the Azores and in the Canary Islands, eastern Atlantic; rare in Japan; not reported from elsewhere but presumably formerly cosmopolitan in tropical and temperate seas. In New Zealand, *Hartungia typica* is rare in a few Kapitean localities near East Cape, relatively common at Kaawa Creek, southwest Auckland (Opoitian) and rare in other Opoitian localities in northern Hawke’s Bay; and uncommon but widespread in Waipipian localities along the Wanganui-South Taranaki coast, in northern Hawke’s Bay, and in Westland; presumably most are near-shore localities where on-shore winds have cast the pelagic snails onto beaches, as happens now around New Zealand with *Janthina*, the pelagic “violet snail”.

The succeeding *Hartungia chavani* (? = *H. chouberti* Chavan 1951, p. 135) (Mangapanian-Nukumaruan in New Zealand) is very variable in spire height, large specimens having a much taller spire than adult *H. typica*, and its sutural ramp is less strongly convex than that of *H. typica* and lacks spiral folds. The presumed evolutionary change occurred abruptly in two widely separated New Zealand sequences (Te Ekaou Creek, Pohangina district, eastern Wanganui basin; Mohaka River, northern Hawke’s Bay) at the Waipipian-Mangapanian boundary, suggesting this was a rapid speciation event that produced a world-wide pelagic macrofossil datum-plane. *Hartungia chavani* is common

in the Roe Calcarenite, south-eastern Western Australia (Ludbrook 1978) and rare at a few localities in New Zealand (Mangapanian: Te Ekaou Creek, Pohangina; Mohaka River, shellbeds near base of sandstone zone upstream from rail viaduct; Nukumaruan: main highway near Utiku, Rangitikei Valley; Nukumaruan Limestone, Nukumaruan, Wanganui; Darkys Spur Formation, richly diverse fossiliferous sands halfway down Darkys Spur road, west of Devil’s Elbow, central Hawke’s Bay, mid-Nukumaruan; all localities are within the Pliocene part of Nukumaruan time). The genus apparently did not survive into the Pleistocene. *H. chavani* seems little different from *H. chouberti*, from Morocco, but there appear to be no other Northern Hemisphere records of this latest Pliocene form.

Hartungia is a member of the Janthinidae, which float at the surface by means of a bubble raft, feeding on siphonophores, and casting ashore in persistent on-shore winds. The recorded localities for the fossil appear to include most of the known Pliocene localities of sufficiently oceanic, wind-swept situation to have had janthinids blown ashore. *Janthina* differs from *Hartungia* in having the sinus in the centre of the outer lip, rather than at the base; it is possible that *Hartungia* is more nearly related to the modern brown janthinid *Recluzia* than to *Janthina*.

Figured specimen (Pl. 37a, b): Kaawa Creek, southwest Auckland, Opoitian (NZGS, ex Fleming Collection) x 2 (apertural view of a slightly laterally compressed specimen, and basal view to show sinus).

Pl. 36 k. *Struthiolaria (Struthiolaria) dolorosa* King, 1934 [*Struthiolaria cingulata* Zittel 1864, p. 35; *Struthiolaria dolorosa* King 1934, p. 22] (Struthiolariidae).

Moderately large for genus (53 to at least 70 mm high), with moderately tall, stepped spire (equal to or slightly taller than height of aperture), narrow sutural channel, wide, flat, steeply sloping sutural ramp, a strong, slightly rounded angulation at upper third of spire whorls, a rounded peribasal angle, a normal oval *S. (Struthiolaria)* aperture with narrow varix and thin inner lip, and no axial sculpture other than weak growth lines. Sculpture of many wide, flat-topped, square-sided spiral cords, slightly irregular in development and width; in most specimens, relatively widely spaced and with a single narrow intermediate spiral thread over sutural ramp and whorl side, but much more closely spaced over base. Protoconch not seen, presumably as in *S. papulosa*.

Opoitian; mouth of Upton Brook, Awatere River, Marlborough (type), common, also common at a few other localities at the same horizon in Marlborough (notably shellbeds in Stace Stream, a tributary of Blind River). Not known elsewhere.

The status and evolutionary history of the three Awatere Valley Kapitean-Opoitian species *Struthiolaria cincta* (? late Tongaporutuan; Kapitean), *S. cingulata* (Kapitean ?-Opoitian ?) and *S. dolorosa* (Opoitian) are poorly known. Zittel’s (1864, pl. 15, fig. 2) illustration of *S. cingulata* and a poor cast of the holotype in NZGS show few differences from *S. dolorosa* but the name *S. cingulata* has been used in NZGS collections for a more weakly sculptured form, regarded by Dr J. Marwick (in NZGS manuscript labels) as intermediate in a short-lived lineage between *S. cincta* and *S. dolorosa*. The earliest member, *S. cincta*, has narrow, finely nodulous upper and lower angulations and an evenly concave, weakly sculptured mid-whorl, and so is possibly descended from *S. praenuntia* (Pl. 29 i), differing in lacking the median cord

of *S. praenuntia*. Specimens identified as *S. cingulata* (Kapitean-Opoitian?) are similar to *S. dolorosa*, but have lower, narrower, more widely spaced spiral cords. The comprehension of this sequence needs study of much more complete material. *S. dolorosa* is illustrated here as an example of the complex lineages of *Struthiolaria* in New Zealand Late Miocene and early Pliocene rocks. *S. dolorosa* has a close resemblance to *S. frazeri* (Nukumaruan) (Pl. 42f), but the similarity is superficial, as *S. frazeri* is much larger and appears to have evolved from an unnamed Mangapanian ancestor intermediate between it and the Nukumaruan-Recent *S. papulosa*. Figured specimen (Pl. 36k): GS10951, P29/f6582, mouth of Upton Brook, Awatere Valley, Marlborough, Opoitian (NZGS) x 1.

Pl. 36 i. *Struthiolaria (Callusaria) obesa* Hutton, 1885b [p. 329] (Struthiolariidae).

Small for subgenus (42-58 mm high), with spire equal to or shorter than height of aperture, simple suture, strongly bisinuate, varicate outer lip meeting heavily, widely callused inner lip at relatively deep anterior notch, and very large, strongly inflated last whorl. Whorls roundly angled at a shoulder that is medial on spire whorls; shoulder bears low, pointed nodules on early whorls of most specimens; below shoulder, whorls are only weakly convex above a gently rounded, obscure peribasal angulation; sutural ramp straight, base weakly concave. Spiral sculpture of many very fine, closely spaced threads, obscure on many specimens. Inner-lip callus low, wide and smooth, ascending at least to shoulder, and above suture on some specimens; anteriorly, heavily callused individuals have a nodule to left of aperture, separated from last whorl by a deep groove. Protoconch not known, presumably similar to that of *S. papulosa*.

(Upper Tongaporutuan?) Kapitean-Opoitian; "Shepherd's Hut, Waipara" (type), presumably in Middle Waipara River region, North Canterbury (probably of Opoitian age) but "the type locality of this species and of *Xymene monilifera* (Hutton), 'Shepherd's Hut, Waipara', has never been satisfactorily located" (Fleming in Wilson 1963, p. 62). Fleming thought the type specimens of *S. obesa* resemble in preservation the specimens in GS3865, Omihi Creek, a northern tributary of Waipara River west of Weka Pass, and suggested "possibly the shepherd's hut referred to was on Glenmark Station". *S. obesa* occurs widely in New Zealand in shallow-water, near-shore, soft-bottom facies of Kapitean and Opoitian age, in the northern Rangitikei River tributaries (eastern Wanganui basin) where shallow-water Neogene rocks lap onto the Ruahine-Kaimanawa ranges, in the Glenross area of the north-eastern Ruahine range (near the Napier-Taihapa Road), in the upper Wanganui River sequence near Retaruke, near Tarata in inland Taranaki, at several localities in Dannevirke district, southern Hawke's Bay, and in the Manawatu Gorge saddle sequence, very commonly in the Awatere Valley (Upton Brook and Stace Stream sections), and sporadically but widely in North Canterbury (Weka Pass—Omihi area, and in the Kowai Syncline). A particularly interesting record is the specimens found on beaches between Cape Wanbrow and Gee's Point, south of Oamaru, presumably washing ashore from submarine Opoitian exposures (the late J. Graham, Oamaru, pers. comm.), possibly the source of Finlay's "Awamoa" specimen cited by Marwick (1924b, p. 184). These and other Pliocene molluscs typically have a distinctive pale orange colour that distinguishes them from the Altonian fossils that are also cast up on these beaches.

Specimens from diverse shallow-water molluscan faunules of Opoitian age in northern New Zealand (Kaawa Creek, southwest Auckland; Oweka Creek, between Cape Runaway and Hick's Bay; and in the extensive Opoitian outcrops in the Tauwhareparae area, inland from Tolaga Bay) consistently differ from southern specimens of *Struthiolaria obesa* by bearing prominent, pointed nodules around the shoulder angle, and are the form named *S. arthritica* by Bartrum and Powell (1928). As the nodules are the sole differentiating character, and as the character seems to have a clear geographic separation, it is possible that *S. arthritica* was a geographic subspecies of *S. obesa*. The apparently ancestral *S. callosa* (Pl. 29d, e) differs from *S. obesa* in its larger size, taller spire, much heavier callus, and in consistently bearing peripheral nodules. Intermediate forms occur in middle-late Tongaporutuan rocks at a few localities (Tirangi Stream, North Taranaki; Mt Bruce, Wairarapa). The extinction of the subgenus at the end of Opoitian time is a particularly useful biostratigraphic index.

Figured specimen (Pl. 36i): GS14088, U20/f116, Taruarau River, Ngamatea plateau, northern Ruahine Range, Opoitian (NZGS) x 1.

Pl. 36 q. *Pellicaria canaliculata* (Zittel, 1864) [*Struthiolaria canaliculata* Zittel 1864, p. 34; *Pellicaria canaliculata becki* Neef 1970, p. 469] (Struthiolariidae).

Large for genus (38-55 mm high), with moderately tall spire (slightly shorter than to slightly taller than aperture), with a deep, narrow sutural channel, evenly and strongly convex to slightly quadrate whorls, and normal *Pellicaria* aperture with weakly sinuous, varicate outer lip meeting thickened, smooth, narrow inner lip at shallow anterior notch. Sculpture of exceedingly prominent, wide, high spiral cords with weakly convex tops and deeply undercut edges, 3-4 on spire whorls and 8 on last whorl, very obscurely nodulous at the shoulder in some specimens; the whole surface closely crowded with fine spiral threads. Protoconch irregular, paucispiral, normal for subgenus.

Waipipian; Awatere Valley, Marlborough (type), almost certainly from the Starborough Formation in Starborough Creek, near the present town of Seddon, where the species is common. Common also at the mouth of Blind River, Awatere, and in the Mangahao district west of Pahiatua, northern Wairarapa; also occurs rarely in the Waipipi shellbeds at Waverley Beach, west of Wanganui.

Pellicaria canaliculata is highly variable in form; very inflated specimens with relatively low cords occur in some populations, and Neef (1970) regarded these as "typical" *P. canaliculata*, and named narrow, prominently carinate specimens as *P. canaliculata becki*; however, the two are extremes of one intergrading population. Neef (1970) described a sequence at Mangahao, northern Wairarapa, where *P. canaliculata* evolved progressively into *P. acuminata* (late Mangapanian-early Nukumaruan; Pl. 42e); intermediate species are *P. clarki* (early Mangapanian; lower cords than in *P. canaliculata*, with vertical sides) and *P. marima* (mid-Mangapanian; still lower cords). An apparently ancestral species, *P. procanalis* (Opoitian, mouth of Upton Brook, Awatere Valley) has much lower, wider and closer spiral cords than *P. canaliculata*.

Figured specimen (Pl. 36q): Lower Awatere Valley, Marlborough (almost certainly from Starborough Creek), Waipipian (NZGS, ex Marshall and Murdoch Collection) x 1.5.

Pl. 36 o. *Pellicaria incrassata* (Powell, 1931) [*Struthiolaria incrassata* Powell 1931a, p. 101] (Struthiolariidae).

Very small for genus (23-27 mm high), with spire about equal in height to aperture, with shallow, narrow, but obvious, ridge-margined sutural channel, and with normal *Pellicaria* aperture with weakly sinuous, varicose outer lip meeting thickened, narrow inner lip at shallow anterior notch. Sculpture of 3 spiral cords only; the uppermost a prominent carina forming a shoulder at 0.6 whorl height on spire, the middle one a prominent carina around peribasal angle, and the third a much lower one close below the second, at top of base. A few faint spiral threads present elsewhere on some specimens, and on base of most specimens, but most have a wide, steeply inclined, weakly concave sutural ramp, and a wide, deeply concave whorl outline between the 2 major carinae. A few low nodules on shoulder carina of some specimens. Protoconch low, paucispiral, typical of genus.

Waipipian; Waihi Beach, Hawera, South Taranaki (type), common here and at a few nearby localities in inner-shelf blue-grey sandstone along the Wanganui-South Taranaki coast.

Pellicaria incrassata is extremely distinctive because of its small size and only two prominent spiral cords. The Opoitian *P. parva* is very similar (and was presumably ancestral) but has a third prominent, narrow carina midway between the two major ones of *P. incrassata*, and all specimens have a nodulous upper carina.

Figured specimen (Pl. 36o): Waihi Beach, Hawera, South Taranaki, Waipipian (NZGS, ex F.D. Chambers Collection) x 2.

Pl. 36 p. *Pellicaria zelandiae* (Marshall and Murdoch, 1920) [*Struthiolaria zelandiae* Marshall and Murdoch 1920, p. 130] (Struthiolariidae).

Moderately large for genus (36-50 mm high), with spire about equal to or slightly shorter than aperture, with a normal, wide *Pellicaria* aperture with weakly sinuous, varicose outer lip meeting thickened, smooth, narrow inner lip at shallow anterior notch; with an exceedingly deep, wide sutural channel (largest in genus). Whorls sloping inward above suture on spire to the marked subsutural carina, but vertical-sided on last whorl above a prominent protruding peribasal spiral cord (forming base of sutural channel on spire), then contracting rapidly below peribasal cord. Sculpture of narrow, prominent, vertical-sided, flat-topped spiral cords, exceedingly variable in number, prominence, and spacing; a few specimens have as few as 5 massive, wide cords above peribasal angle, but most have 6-8 narrow cords, and on many shells cords are very numerous, low, narrow and closely spaced above peribasal angle, producing a relatively smooth surface; all have 6 or 7 prominent basal cords; entire surface crowded with minute spiral threads; the only axial sculpture is faint, irregular growth lines. Protoconch irregular, paucispiral, normal for *Pellicaria*.

Opoitian?; Waipipian. Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type); common in Waipipian sandstone and shellbeds of shallow-water, soft-bottom facies along the Wanganui-South Taranaki coast; also rarely in Omihi Stream and nearby localities (Opoitian?; and in part Waipipian) in North Canterbury.

The flat whorl sides, extremely prominent sutural channel, and relatively low spiral cords (apart from the prominent cord around the peribasal angle) lacking undercut sides distinguish *Pellicaria zelandiae* readily from *P. canaliculata* (Pl. 36q), with which it is occasionally sympatric in the Waipipi Shellbeds. *P. zelandiae* is succeeded by an unnamed species with a similar peribasal angle and sutural channel but a biangled upper whorl profile, in the Mangapanian and early Nukumaruan (Wilkie's Shellbed, Hautawa Shellbed) of Wanganui basin and in the Mangapanian of northern Hawke's Bay (base of sand zone upstream from railway viaduct, Mohaka River).

Figured specimen (Pl. 36p): Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (NZGS, ex Marshall and Murdoch Collection) x 1.5 (a weakly sculptured individual).

Pl. 37 i. *Polinices (Polinella) obstructus* (Marwick, 1924) [*Natica (Mamilla) ovata* Hutton 1873b, p. 9, in part (not of Klipstein, 1843); *Polinices (Mamma) ovatus*; *Uber obstructus* Marwick 1924d, p. 567 (new name for *Natica ovata* Hutton, preoccupied)] (Naticidae: Poliniceinae).

Large for subgenus (30-40 mm high), relatively tall and narrow, with moderately tall, convex spire (0.3 height of aperture), large enveloping last whorl, and no anterior canal; smooth except for weak growth lines. Growth lines retracted to suture, without obvious axial grooves. Aperture simple, D-shaped; inner lip with prominent, relatively narrow parietal callus, merging into weakly lobed umbilical callus above a low funicle that fills most of umbilicus, leaving (in most but not all specimens) a moderately wide, deep umbilical groove; umbilical callus tapers and slightly into lower part of inner lip. Left edge of parietal callus regularly, weakly convex, except for small, triangular, protruding lobe immediately above umbilicus; callus bears 1 wide, shallow, indistinct but consistently present groove opposite triangular lobe, and another shorter and slightly shallower one, not quite parallel to upper one, opposite widest lobe of umbilical callus, above funicle. Aperture inclined at an angle of about 20° to the coiling axis. Protoconch as in *P. scalptus* (Pl. 29 k), but slightly taller.

Altonian(?) - Waipipian; GS227, Lake Kaniere, Westland, Kapitean or Opoitian? (type); widespread but uncommon in Kapitean to Waipipian blue-grey sandy mudstone along the Wanganui-South Taranaki coast (Waipipian), on the coast between Te Araroa and East Cape (Kapitean), in the Tauwhareparae area inland from Tolaga Bay (Opoitian), in the Awatere Valley, Marlborough (Kapitean-Opoitian), in Westland (Kapitean-Waipipian) and in Southland (Kapitean).

Marwick (1924d, p. 568) referred specimens from Altonian to Waiau formations at Clifden, Southland, to *Polinices obstructus*, but in view of the distinctive ontogeny described above for *P. scalptus* (Pl. 29k) the identity of these older specimens needs confirmation. *P. obstructus* is one of the larger and more distinctive species of subgenus *P. (Polinella)*, recognisable by the two shallow, in most specimens diverging grooves in the inner-lip callus near the top of the umbilicus. Much larger, narrower, with weaker and more nearly parallel grooves on the callus, and with a narrower callus than *P. scalptus* (Pl. 29l).

Marwick (1924d, p. 565, 568) named as new species both *Uber ovuloides* and *Uber obstructus*, formerly included in the species previously named *Natica (Mamilla) ovata* Hutton (1873b, p. 9; not of Klipstein, 1843). He discussed the status and types of *Natica ovata* Hutton, pointing out that no lectotype had been formally designated, and then decided that, as Hutton's name is preoccupied, "we can start again with fresh specific names". However, Marwick's action constitutes the replacement of a preoccupied name, not the proposal of a new species, and a lectotype is still needed (and to this day has not been designated) for *Natica ovata*. We therefore designate as lectotype of *Natica (Mamilla) ovata* Hutton (1873b, p. 9) the specimen illustrated here, the "holotype" of *Uber obstructus*, the specimen from Lake Kaniere figured as *Polinices ovatus* "holotype" by Suter (1914, p. 21, pl. 17, fig. 1a, b), supposedly from "Shakespeare Cliff, Wanganui" (the locality confusion was clarified by Marwick 1924d, p. 565).

Figured specimen (Pl. 37i): lectotype of *Natica ovata* Hutton, 1873 (preoccupied) = *Uber obstructus* Marwick, 1924, GS227, J33/f7010, Lake Kaniere, Westland, Kapitean-Opoitian? (TM6813, NZGS) x 1.

Pl. 37 f. *Polinices (Polinices) waipapiensis* (Marwick, 1924) [*Uber waipapiensis* Marwick 1924d, p. 564; *Uber pateensis* Marwick 1924d, p. 564; ?*Uber ovuloides* Marwick 1924d, p. 565; *Polinices stanleyi* Marwick 1948, p. 30] (Naticidae: Poliniceinae).

Large for genus (37–48 mm high), moderately to highly inflated, with low, conic spire and large, regularly convex, enveloping last whorl, large umbilicus, heavy parietal callus, and evenly rounded base, lacking a siphonal canal. Smooth, except for very faint, irregular spiral grooves and fine, irregular growth lines. Aperture D-shaped, with straight inner lip, inclined at an angle of 25° to the coiling axis; callus highly variable in thickness, penetration into umbilicus, and outline of lobe or lobes in umbilicus, but in all specimens having a strongly convex outline at top of parietal area (retracting to suture), an inward inflection followed by a small to moderately large lobe extending at right angle to left just above umbilicus, and another shallow inflection above umbilical lobe. In most specimens, umbilical callus weakly to prominently bilobed. Protoconch not well preserved on any specimens examined, presumably as in *P. huttoni*, low, of about 2.5 very weakly inflated whorls, not clearly differentiated from teleoconch.

Opoitian?; Waipipian-Mangapanian. Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type of *Uber waipapiensis*); mouth of Patea River, South Taranaki, Waipipian (types of both *Uber pateensis* and *U. ovuloides*); Otahuhu Brewery well, Auckland, Waipipian (type of *Polinices stanleyi*). Abundant and widespread throughout New Zealand in Pliocene (particularly Waipipian and Mangapanian) rocks of shallow-water, near-shore, soft-bottom facies, usually in shellbeds with diverse assemblages; particularly abundant in Waipipian and Mangapanian shellbeds along the Wanganui-South Taranaki Coast and in the Starborough Formation, Awatere Valley.

The taxonomy of the highly variable *Polinices* species is poorly understood, but it seems very likely that such forms as *P. waipapiensis* and *P. pateensis* are deeply and shallowly umbilicate variants of one species, as occurs in the living tropical *Polinices* species. *P. stanleyi* includes more heavily callused forms, but some forms are indistinguishable from *P. waipapiensis*. *P. ovuloides* may be a distinct, narrower species living with *P. waipapiensis* on the South Taranaki coast, but it seems just as likely to be the male form of *P. waipapiensis*, as living species of *Polinices* show marked sexual dimorphism. As first revisers, we select *Uber waipapiensis* Marwick (1924d, p. 564) as the name to be used by all authors who regard *U. waipapiensis* Marwick, *U. pateensis* Marwick, 1924, and/or *U. ovuloides* Marwick, 1924 as conspecific.

Although *Polinices* lives now in Northland, and seems likely to have done so throughout Plio-Pleistocene time, its extinction in central and southern New Zealand at the end of Mangapanian time is an important biostratigraphic marker.

Figured specimen (Pl. 37f): holotype of *Uber waipapiensis* Marwick, GS1101, Q22/f7303, Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (TM5762, NZGS) x 1.

Pl. 37 c. *Semicassis (Kahua) skinneri* (Marwick, 1928) [*Phalium (Kahua) skinneri* Marwick 1928, p. 482]. Type species of *Kahua* Marwick, 1928 (Cassidae: Phaliinae).

Moderate-sized for family (41–58 mm high), subspherical, with low, conic spire, very large, enveloping last whorl, and very short, deeply notched, very strongly twisted anterior canal separated from last whorl by deep, narrow groove, forming a very prominent, ridge-margined fasciole. Sculpture of many low, wide, flat-topped, closely spaced spiral cords, 4 or 5 on spire whorls and about 23 on last whorl, those on sutural ramp bearing many fine, close, prominent spiral lirae; on most specimens, 1 wide cord at base of sutural ramp is a little more prominent than others and bears a row of low nodules. On small specimens, spiral cords cross many narrow, prominent, closely spaced axial costae (about 40 on last whorl of holotype) but on large shells, costae are absent from all but sutural ramp of last whorl. Aperture large, oval, strongly thickened; outer lip a very thick, rounded varix, with about 20–26 low, narrow, short ridges down inside edge; inner lip prominently ridged with many anastomosing wrinkles on inner columellar area. Protoconch conical, of 2.5 smooth, inflated whorls.

Opoitian-Waipipian; Whenuataru Tuff, northern Pitt Island, Chatham Islands, Waipipian (type); uncommon (most specimens are fragmentary) in Whenuataru Tuff on the tip of Tarawhenua Peninsula, Pitt Island, and rare in Birch's Mill shell lens (early Opoitian), Te Waewae Bay, Southland.

The Chatham Islands *Semicassis skinneri* differs from the coeval mainland species *S. fibrata* (type species of *Mauicassis* Fleming, 1943) only in its more numerous, narrower spiral cords and smaller nodules on the shoulder angle, and in our opinion *Kahua* Marwick, 1928 is the same group as *Mauicassis* Fleming, 1943 (with which Abbott (1968, p. 117) synonymised *Liracassis* Moore, 1963; but in our opinion *Kahua* and *Liracassis* have evolved independently from *Echinophoria* in the southern and northern hemispheres, respectively). Large shells of *S. fibrata* have very similar, strongly thickened, lirate apertures to that of *S. skinneri*.

Figured specimen (Pl. 37c): holotype, GS10193, CH/f106, Whenuataru Tuff, tip of Tarawhenua Peninsula, Pitt Island, Chatham Islands, Waipipian (TM6814, NZGS) x 1.

Pl. 37 h. *Bedevea bartrumi* (Marwick, 1948) [*Otahua bartrumi* Marwick 1948, p. 32]. Type species of *Otahua* Marwick, 1948 (here synonymised with *Bedevea* Iredale, 1924) (Muricidae: Trophoninae).

Large for genus (42–48 mm high), tall and narrow, with spire a little shorter than aperture and canal. Whorls sharply carinate at about lower third on spire, sutural ramp sharply descending at first (to produce a wide, low subsutural fold) and then wide, straight; weakly convex to almost straight below shoulder, gradually contracting to neck and then swelling to long, narrow, prominent fasciole marginating narrow pseudumbilical chink. Sculpture of a single prominent, rounded, spiral cord around shoulder angle, then relatively sparse, low, indistinct spiral cords below shoulder, gradually becoming more prominent on neck and canal; sutural ramp lacks spiral sculpture; cords cross low, rounded, widely spaced, finely foliose axial costae, 8–9 per whorl, without forming nodules, except low, compressed ones around shoulder carina. Aperture long and narrow, lips weakly thickened, with a few low nodules inside outer lip, merging into the moderately long, widely open anterior canal. Protoconch of about 2 whorls, smooth, with a bulbous apex.

Waipipian; Otahuhu Brewery well, Auckland (type), uncommon; also rare in Lower Waipara Gorge near Greenwood's Bridge, North Canterbury, at both localities in very shallow-water, near-shore environments (*Bedevea* is common today in the intertidal zone of rocky shores).

We can see no differences between *Bedevea* and *Otahua*. *B. bartrumi* is similar to the living tropical western Pacific *B. blosvillei* (Deshayes, 1832) ("Philippines to Queensland"; Radwin and D'Attilio 1976, p. 27) in its large size, carinate shoulder angle, and distribution of

spiral cords, but has a much longer, more steeply inclined sutural ramp and weaker spiral cords than *B. blosvillei*. (We are indebted to Prof. Emily Vokes, Tulane University, for pointing out the resemblance to *B. blosvillei*). An interesting, apparently warm-water element in Waipipian faunas.

Figured specimen (Pl. 37h): paratype, GS3528, R11/f7014, Otahuhu Brewery well, Auckland, Waipipian (NZGS) x 1.5.

Pl. 37 e. *Siphonochelus (Laevityphis) tepungai* (Fleming, 1943) [*Typhis tepunga* (sic) Fleming 1943, p. 205; *Typhis (Neotyphis) tepungai* of Vella 1961, p. 385]. Type species of *Neotyphis* Vella, 1961 (synonymised with *Laevityphis* Jousseaume, 1880 by Gertman 1969) (Muricidae: Typhinae).

Small for family (20-22 mm high), relatively tall and narrow for subfamily, smooth apart from growth lines, and hollow tubes characteristic of subfamily; spire equal to height of aperture and canal. Varices high and rounded, sloping slightly backward, with prominent shoulder formed by a short, upward-pointing tube; weakening rapidly across sutural ramp; 4.5 per whorl (18 in 4 whorls). Upper part of varix (above weak lower angulation produced by the upper of 2 small, accessory tubular spines lower on varix) almost vertical. A large tubular spine on shoulder angle halfway between each pair of varices, directed almost vertically upward and a little backward, weakly linked to succeeding varix by low ridge from its shoulder spine, and linked to suture by prominent ridge extending from front edge of intervariceal spine. Aperture small, oval, with thick, raised, continuous peristome; anterior canal moderately long (longer than aperture), a fused tube directed slightly to left, with prominent fasciole formed of bases of

former anterior canals. Protoconch relatively large, smooth, of 1.5 whorls, with a bulbous apex.

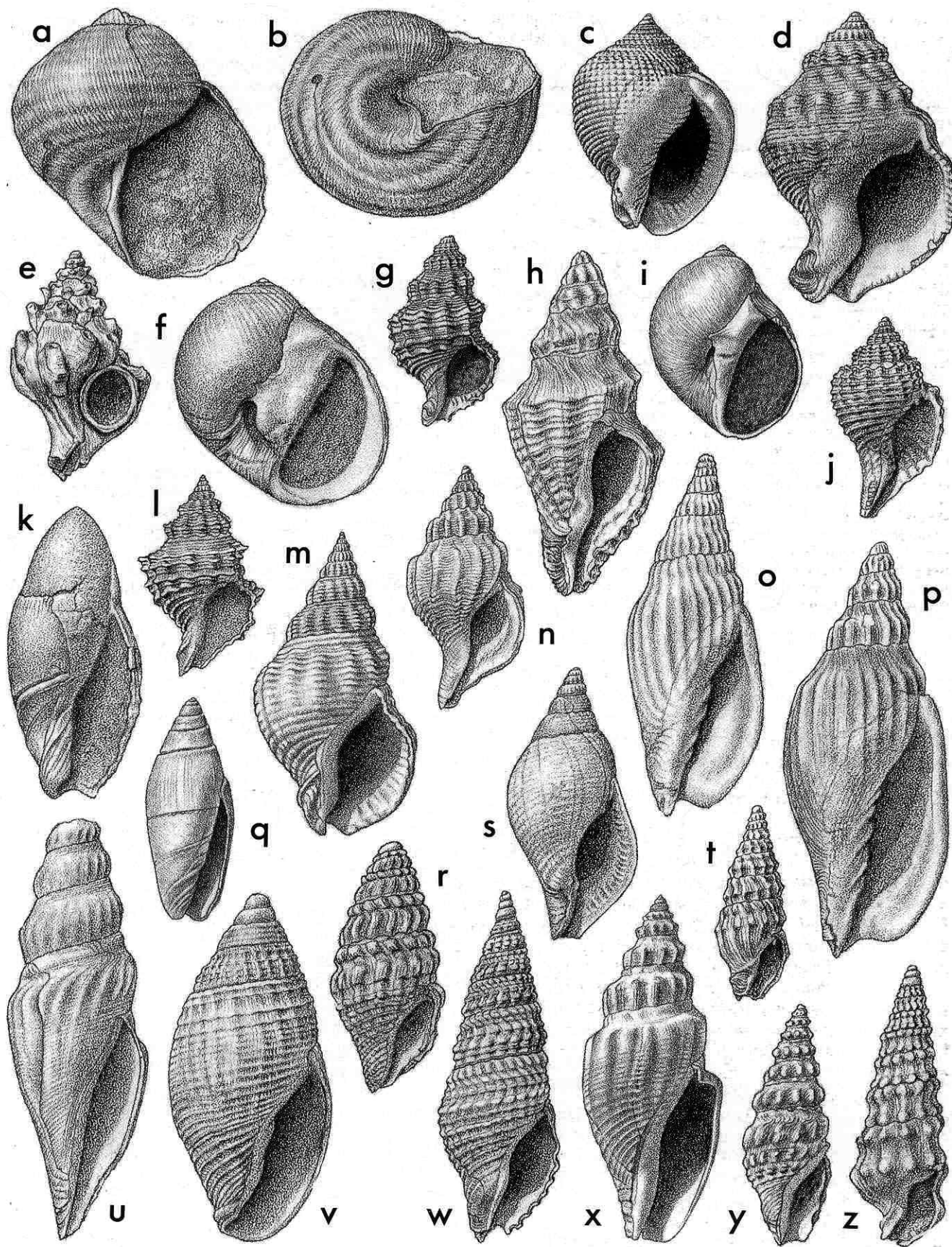
Opoitian-Waipipian; "Takapau faunule", tributary of Awapikopiko Stream near Awapikopiko Road (Druce Road on T24), c. 3 km south of Kumeroa, southern Hawke's Bay, Waipipian (type); uncommon but widely distributed in shelf facies sandstone and mudstone with diverse, scattered Mollusca in the Wairoa district, northern Hawke's Bay, and in the Dannevirke-Takapau district, southern Hawke's Bay.

The narrow shape with almost parallel whorl sides and the strongly upward-directed spines show that this (the type species of *Neotyphis* Vella, 1961) is a species of *Siphonochelus (Laevityphis)* (Gertman 1969, p. 171); in the presence of small accessory tubes on the varices it resembles such species as *S. parisiensis* (d'Orbigny) (Eocene, Paris Basin) and *S. fistulosus* (Brocchi) (Pliocene, Italy). The superficially similar living species *S. solus* Vella is very small (eight mm high) and narrowly fusiform, with smooth varices lacking all tubular spines, and perhaps belongs in *Lyrtotyphis* Jousseaume, 1880, near the living Australian species *L. syringianus* (Hedley). We know of no other closely related New Zealand species.

Figured specimen (Pl. 37e): holotype, GS2661, T24/f7399, tributary of Awapikopiko Stream, near Awapikopiko Road (Druce Road on T24), c. 3 km south of Kumeroa, southern Hawke's Bay, Waipipian (TM3140, NZGS) x 2.

Plate 37. Pliocene (Opoitian-Mangapanian) Mollusca (7).

- a,b. *Hartungia typica* Bronn, x 2.
- c. *Semicassis (Kahua) skinneri* Marwick, x 1.
- d. *Austrofuscus (Austrofuscus) pliogenicus* (Powell), x 1.5.
- e. *Siphonochelus (Laevityphis) tepungai* (Fleming), x 2.
- f. *Polinices (Polinices) waipipiensis* (Marwick), x 1.
- g. *Austrofuscus (Austrofuscus) pagoda* (Finlay), x 1.
- h. *Bedeva bartrumi* (Marwick), x 1.5.
- i. *Polinices (Polinella) obstructus* (Marwick), x 1.
- j. *Aeneator (Ellicea) validus* (Marwick), x 1.
- k. *Amalda (Baryspira) oraria* (Olson), x 1.
- l. *Austrofuscus (Neocola) ngatuturaensis* Bartrum and Powell, x 1.5.
- m. *Nassicola ultima* Beu, x 1.
- n. *Aeneator (Aeneator) elegans* (Suter), x 1.5.
- o. *Alcithoe (Leporemax) gatesi* Marwick, x 1.5.
- p. *Alcithoe (Alcithoe) haweraensis* Marwick, x 1.
- q. *Lamprodomina neozelanica* (Hutton), x 1.5.
- r. *Awateria streptophora* Suter, x 4.
- s. *Buccinulum(?) pangoides* Beu, x 1.
- t. *Kaweka fulva* Marwick, x 2.
- u. *Zemacies prendrevillei* Marwick, x 1.
- v. *Mitrolumna granum* (Marwick), x 8.
- w. *Phenatoma decessor* Marwick, x 5.
- x. "*Marshallena*" *impar* Powell, x 1.5.
- y. *Clavatoma pulchra* Powell, x 2.
- z. *Zeacuminia planitas* Laws, x 4.



Pl. 37 s. *Buccinulum(?) pangoides* Beu, 1973b [p. 323] (Buccinidae).

Large for genus (50-62 mm high), weakly sculptured, tall and moderately narrow, with spire a little shorter than aperture and canal; canal moderately long, widely open, deflected weakly to left, with very weak fasciole. Whorl profile regularly convex from suture to base, except on last 0.5-1 whorl where it becomes concave over sutural ramp, producing a long, narrow, posterior apertural canal, unusual for genus. Sculpture of a few weak, indistinct spiral cords only, more obvious on neck than elsewhere. Outer lip thickened and lightly flared, with a row of about 16-18 low, narrow ridges inside. Inner lip thin, with single small, narrow, prominent parietal ridge, and 2-3 small nodules and single, narrow, prominent ridge on base of columella; columellar ridge formed on very low true spiral ridge at base of columella. Protoconch unknown.

Waipipian; Upper Waipipi Shellbed, Waverley Beach, west of Wanganui (type), common in the basal sand member only; we have not seen specimens from any other locality. The shellbed was deposited on the inner shelf and represents a period of sediment-bypassing and shell concentration, but almost all taxa in the basal sandy member are soft-substrate, shelf species. Taxa present in the basal member include *Coluzea*, *Murexsul*, fairly common *Scalptia haweraensis*, and common *Nassicola ultima*, as well as *B. pangoides* and more common Waipipi taxa.

The taxonomic position of *Buccinulum pangoides* is uncertain, as the protoconch is unknown, and as the weak sculpture, narrow posterior apertural canal, thickened outer lip, and small but prominent, sharp parietal and columellar ridges are unusual for *Buccinulum*, but *Buccinulum* appears to be the most reasonable location. The specific epithet records the (superficial ?) similarity to *Pangoa mira* (Lillburnian, "Tutamoe conglomerate" in Pangopango Stream, inland from Tolaga Bay, north of Gisborne), a genus and species of mysterious affinities, based on a single severely abraded specimen. *Pangoa mira* has a shorter spire and very much more heavily thickened outer lip than those of *B. pangoides*.

Figured specimen (Pl. 37s): holotype, GS4253, Q22/f7544, Upper Waipipi Shellbed, Waverley Beach, west of Wanganui, Waipipian (TM5092, NZGS) x 1.

Pl. 37 j. *Aeneator (Ellicea) validus* (Marwick, 1928) [*Ellicea (Pittella) valida* Marwick 1928, p. 486]. Type species of *Pittella* Marwick, 1928 (here synonymised with *Ellicea* Finlay, 1928) (Buccinidae).

Small for genus (37 mm high), very prominently sculptured, with short spire (half height of aperture and canal) and moderately long, widely open anterior canal, straight but deflected to left. Outline stepped, with prominent round shoulder at top of whorls, with evenly convex periphery and gently contracted base and neck. Sculpture of relatively few, wide, very prominent spiral cords, 5 on spire whorls and about 18 on last whorl and canal, becoming low and indistinct on canal; crossing (without forming nodules) prominent, narrowly rounded, widely spaced axial costae, extending from outer edge of sutural ramp to lower suture on spire whorls but only to periphery on last whorl. Aperture large, oval; outer lip thick, lirate within, with very thick posterior lip inside sutural ramp; inner lip thin posteriorly, with a single narrow parietal ridge, but thick anteriorly, bearing 8-10 low nodules on base of columella. Protoconch small, dome-shaped, of 2 smooth whorls.

Waipipian; Whenuataru Tuff, northern Pitt Island, Chatham Islands (type), only known locality; rather rare. One of several bathyal indicators in the Whenuataru Tuff fauna (others are *Coluzea* aff. *mariae*, *Galeodea trigancae*, and *Volutomitra banksi*, specimen in Pl. 27k).

Aeneator validus differs from such typical mainland *A.*

(*Ellicea*) species as the Pliocene *A. orbitus* and the living *A. recens* (Dell) only in its relatively wide sutural ramp; similarly prominent costae are seen on many specimens of *A. orbitus*. There seems little point in recognising subgenus *Pittella*, but we regard *Ellicea* as a useful subgenus for the deep-water *Aeneator* species with very prominent spiral cords; all species appear to have lived in the bathyal zone as noted under *A. willetti* (Pl. 27i), and in Pliocene rocks the presence of *A. (Ellicea)* is a primary bathyal indicator.

Figured specimen (Pl. 37j): holotype, GS10192, CH/f105, Whenuataru Tuff, tip of Tarawhenua Peninsula, Pitt Island, Chatham Islands, Waipipian (TM6815, NZGS) x 1.

Pl. 37 n. *Aeneator (Aeneator) elegans* (Suter, 1917). [*Siphonalia elegans* Suter 1917, p. 29] (Buccinidae).

Small for genus (28-33 mm high), tall and narrow, with moderately long, narrow canal twisted strongly to left; axial costae commence abruptly at shoulder as narrowly rounded nodules, producing a strongly concave sutural ramp. Sculpture of prominent, narrow, weakly sinuous axial costae, 10-12 per whorl, extending well down onto base of last whorl, crossed by many very fine, closely spaced spiral threads on spire, grading down into much more prominent, narrow, closely spaced spiral cords on base of last whorl. Aperture smooth, lightly thickened in large shells. Protoconch dome-shaped, of 2 whorls, smooth except for axial costellae on last quarter-whorl, very small for genus.

Mangapanian-Recent; "Oaro Creek valley, Amuri Bluff district", type, almost certainly from the Oaro bathyal molluscan fauna (Beu 1979) on the summit of the hill east of Glenstrae Station homestead, northern Hundalee Hills, southern Marlborough, Nukumaruan; a common fossil in mudstone and "pebbly mudstone" near-shore, deep-water facies (probably indicating deposition in former deep-sea canyons) in North Canterbury (Cheviot-Parnassus area and the Conway River) and southern Marlborough; abundant at the presumed type locality in the northern Hundalee Hills.

Aeneator elegans is an unusually strongly ribbed and shouldered little species, restricted in the living fauna to the upper bathyal zone (in about 450-1200 m) in canyons and on the continental slope of north-eastern South Island, offshore from the area where it occurs as a fossil. The more widespread but less common Recent species *A. valedictus* (Watson) has axial sculpture only as nodules around the shoulder angle, and occurs with *A. elegans*, but also lives in somewhat shallower water; the two are smaller than other finely sculptured *Aeneator* species.

Figured specimen (Pl. 37n): holotype, "Oaro Creek valley, Amuri Bluff district", collected by C.A. Cotton, almost certainly from summit of hill east of Glenstrae Station, northern Hundalee Hills, southern Marlborough, Nukumaruan (TM6816, NZGS) x 1.5.

Pl. 37 g. *Austrofusus (Austrofusus) pagoda* (Finlay, 1924) [*Fusus nodosus* var. D Hutton 1873b, p. 3; *Siphonalia turrita* Suter 1914, p. 24 (not of T. Woods, 1875); *Aethocola pagoda* Finlay 1924a, p. 103 (new name for *S. turrita* Suter, preoccupied)] (Buccinidae).

Moderate-sized for subgenus (36-55 mm high), with prominent shoulder angle and strongly stepped spire, prominent spiral sculpture, and (for subgenus) relatively short, strongly twisted anterior canal with fasciole bordered by prominent, narrow ridge. Sculpture of prominent, narrow spiral cords; typical Kaniere shells and many from other localities have 1 very prominent cord at shoulder angle, 2 more on a less marked

peribasal angle, 4 similar strong cords on base and canal, a single slightly weaker cord halfway between the 2 angulations, and 4 or 5 low cords on sutural ramp, with a variable number of fine interstitial lirae in major interspaces; but details of spiral cord prominence and number vary widely. Cords cross high, narrowly rounded, moderately widely spaced axial costae, 12 to 16 per whorl, extending from suture to peribasal angulation, forming small, narrow nodules at sculptural intersections. Aperture large, oval to subrectangular, with about 12 lirae inside outer lip. Protoconch small, conical, with sharp apex, of about 3.5 smooth whorls.

Opoitian-Mangapanian; Lake Kaniere, Westland, Waipipian? (type); common and widespread in mid-outer shelf assemblages in mudstone throughout New Zealand, and particularly common in the Wairoa district, northern Hawke's Bay, and in Westland.

Austrofuscus pagoda is the common Pliocene species of "typical" *Austrofuscus*, apparently ancestral to and occupying the same niche as *A. taitae* (Nukumaruian; Pl. 42k) and *A. glans* (Castlecliffian-Recent; Pl. 49c). All closely related species have more numerous, weaker spiral cords, in particular lacking the few prominent basal cords seen in most collections of *A. pagoda*, and *A. glans* reaches a much larger size. *A. pagoda* has been thought of as a restricted Waipipian species previously, but Opoitian specimens from many localities are little different from Kaniere specimens, and the typical coarsely spiralled form ranges into Mangapanian in Wairoa district (as do such previously "Waipipian" taxa as *Austrofuscus pliogenicus*, *Coluzea spectabilis*, *Semicassis (Kahua)* aff. *fibrata*, and *Clavatoma pulchra*). Suter (1914, p. 24) named Hutton's variety D of *Fusus nodosus* (i.e., *A. glans*) as *Siphonalia turrita*, and Finlay (1924a, p. 103) provided the similar name *Aethocola pagoda* for the preoccupied *S. turrita*. Suter's material of *S. turrita*, in NZGS, consists of several relatively large, strongly sculptured specimens from GS145, Lake Kaniere; the age could be either Opoitian or Waipipian.

Figured specimen (Pl. 37g): topotype (paratype?) from Suter's material of *Siphonalia turrita*, Lake Kaniere, Westland, (Opoitian? or) Waipipian? (NZGS) x 1.

Pl. 37 d. *Austrofuscus (Austrofuscus) pliogenicus* (Powell, 1931) [*Zelandiella pliogenica* Powell 1931a, p. 102] (Buccinidae).

Small for genus (35-40 mm high), short and wide, with low spire (half height of aperture and canal) and short, widely open anterior canal inclined strongly to left, deeply notched and strongly twisted to form very prominent, ridge-margined fasciole. Spire outline weakly stepped, with low angulation formed by row of nodules above suture; shallowly concave sutural ramp ends at low, wide subsutural fold on spire whorls, becoming more prominent over last half-whorl; last whorl descends vertically below shoulder to weak peribasal angulation, then contracts sharply to narrow neck. Sculpture of 2 low, indistinct spiral cords, one around each angulation, and remainder of surface closely sculptured with many narrow, prominent, closely spaced spiral lirae; low, rounded, closely spaced axial costae are moderately prominent on some specimens but weak on others (e.g., weak on figured specimen), forming low nodules at subsutural fold and the 2 angulating spiral cords. Aperture large; outer lip lightly thickened, smooth internally; inner lip thick, with large parietal nodule and irregularly thickened columellar callus. Protoconch small, conical, pointed, of 3.5 smooth whorls, as in other *Austrofuscus*.

Opoitian-Mangapanian; South Taranaki coast 0.8 km northwest of mouth of Patea River, Waipipian (type); abundant in the Birch's Mill shell lens, Te Waewae Bay, Southland (early Opoitian; a very near-shore shell accumulation dominated by *A. pliogenicus*, *Maorimacra*

chrydaea and *Lamprodomina neozelanica*), and occurring less commonly in shallow-water shellbeds along the Wanganui-South Taranaki coast (Waipipian; as high as the Mangapani Shell Conglomerate, basal Mangapanian), in the Mohaka River section in northern Hawke's Bay (base of sands upstream from railway viaduct; Mangapanian, accompanied by *Bassina parva*), and in North Canterbury (Opoitian-Waipipian); rare younger than Waipipian. A taxonomically complex and poorly understood species, defined here in a broad sense. The taxonomic position of this species group is discussed under *Zelandiella subnodosa* (Pl. 21 i).

Figured specimen (Pl. 37d): holotype, GS1171, Q22/f6498, coastal cliffs 0.8 km northwest of mouth of Patea River, South Taranaki, Waipipian (TM6818, NZGS) x 1.5.

Pl. 37 m. *Nassicola ultima* Beu, 1973b [p. 325] (Buccinidae).

Large for genus (55-60 mm high), with tall, narrow, weakly stepped spire, and very short, widely open, strongly twisted anterior canal with deep anterior notch, producing low, rounded fasciole margined by very prominent, narrow, sharp ridge. Whorl outline with broadly rounded shoulder angle (at upper third on spire whorls) and moderately wide, shallowly concave sutural ramp; last whorl with strongly rounded periphery, contracting strongly below to marked short neck. Sculpture of low, relatively widely spaced, indistinct spiral cords, moderately prominent on sutural ramp and base but obsolescent over central area of last whorl; crossing prominent, rounded, widely spaced axial costae that do not descend below periphery of last whorl. Outer lip thickened and bearing a row of about 17-18 low, short ridges within, thin at edge; inner lip thick but smooth. Protoconch not well preserved but clearly conical, small and sharply pointed, of about 3.5-4 whorls.

Tongaporutuan-Waipipian; basal sand member of Upper Waipipi Shellbed, Waverley Beach, west of Wanganui, Waipipian (type), moderately common; sandstone in road cuttings on hill south of Te Araroa, East Cape, Tongaporutuan; uncommon in Opoitian diverse shelf assemblages in the Gisborne district.

Nassicola ultima resembles *Cominella* species in its tall spire, its very short, strongly twisted canal, and its prominent fasciole, but it has the small, multispiral, conical protoconch of *Austrofuscus* and *Nassicola*, rather than the paucispiral, dome-shaped protoconch of *Cominella*. It was the last of a long-lived group of species beginning with the Danian *N. subhurida*; the several Miocene species (e.g., *N. finlayi*, Pl. 21m) are all smaller and have longer anterior canals and shorter spires than *N. ultima*.

Figured specimen (Pl. 37m): holotype, GS4253, Q22/f7544, basal sand member of Upper Waipipi Shellbed, Waverley Beach, west of Wanganui, Waipipian (TM5098, NZGS) x 1.

Pl. 37 l. *Austrofuscus (Neocola) ngatuturaensis* Bartrum and Powell, 1928 [p. 147] (Buccinidae).

Small for genus (22-24 mm high), strongly biconic, spire slightly shorter than or equal to aperture and canal. Spire outline strongly stepped, with very prominently carinate shoulder angle, wide, shallowly concave sutural ramp, weak second angulation at top of aperture on last whorl, and last whorl contracting strongly over base to narrow neck and short, strongly twisted, narrow anterior canal with low fasciole bordered by a sharp, thin ridge. Sculpture of prominent, narrow spiral cords, 3 on spire whorls and about 8-9 on last whorl more prominent than the rest, with 1 narrow spiral thread in each of uppermost 3 interspaces and 4-5 threads on sutural ramp; crossing very prominent, narrowly rounded, moderately widely spaced axial costae that strengthen across ramp, form

prominent, sharp nodules at shoulder angle, and die out below 4th prominent spiral cord on last whorl. Aperture large, with thin lips; inner lip smooth. Protoconch small, conical, of 3.5 smooth whorls, with a sharp apex.

Opoitian; Kaawa Creek, southwest Auckland (type); uncommon in shallow-water, soft-bottom facies (near-shore shellbeds to mid-shelf mudstone) at Kaawa Creek, at Oweka Creek near Cape Runaway, in the extensive Opoitian outcrops in the Tauwhareparae area inland from Tolaga Bay, and in the Kaniere district, Westland.

Austrofusius ngatuturaensis is the culmination of the long-ranging mid-Cenozoic group of species (belonging in at least two lineages) included in *A. (Neocola)*. All taxa are very useful in biostratigraphy, and the most important are described and illustrated here (*A. alpha*, Pl. 25b; *A. beta*, Pl. 25c; *A. demissus*, Pl. 30g; *A. flexuosus*, Pl. 25g; *A. gamma*, Pl. 25d). *A. ngatuturaensis* is distinguished from its presumed ancestor, *A. gamma* (= *A. marwicki*?), by having the prickliest and most prominent nodules and most prominent spiral cords of all *A. (Neocola)* species.

Figured specimen (Pl. 37l): GS8101, Y14/f7618, Oweka Creek, between Cape Runaway and Hick's Bay, East Cape, Opoitian (NZGS) x 1.5.

Pl. 37 q. *Lamprodomina neozelanica* (Hutton, 1885) [*Oliva neozelanica* Hutton 1885b, p. 314; *Lamprodroma neozelanica*; *Olivella neozelanica*; *Olivella (Lamprodomina) neozelanica*]. Type species of *Lamprodomina* Marwick, 1931 (Olividae: Olivinae).

Moderate-sized for subfamily (25–40 mm high), with conic spire a third to a quarter height of aperture, and long, cylindrical, almost parallel-sided last whorl, tapering slightly anteriorly. Outer lip thin, smooth. Inner lip with narrow parietal callus, weakly concave in outline from fasciole to top of aperture but evenly convex around top of aperture, above aperture uniting with narrow callus band of shallow triangular section that forms upper border of the narrow, deep sutural channel, and is visible as a low white spiral ridge on the otherwise pale brown spire of well preserved shells. Fasciole with 2 prominent grooves and ridges extending around from basal columellar plaits; raised, wide, upper fasciolar band extending to halfway up inner lip, with sharply defined, raised posterior margin, its outer surface somewhat irregularly washed with arcuate callus ridges, chalky white. A further wide, chalky white band, margined by narrow but obvious posterior groove, extends only a third height of last whorl on juvenile shells (height 15–17 mm) but progresses up last whorl as shell grows, emerging from beneath inner lip at about 4 fifths height of inner lip on large shells, and ascending last whorl to reach top of outer lip on large shells; on well preserved specimens wide mid-whorl band is clearly visible because its chalky white surface contrasts with wide, polished, pale brown uppermost band, below suture. Lower columella bears 6–8 low, narrow folds. Protoconch not seen.

Lillburnian-early Nukumaruan; mouth of Patea River, South Taranaki coast, Waipipian (type); abundant in the Birch's Mill shell lens, Te Waewae Bay, Southland (Opoitian) and widespread (but, at most localities, uncommon) throughout New Zealand in shallow-water, near-shore, soft-bottom facies, in diverse molluscan assemblages. Noteworthy localities are Clifden, Southland (Lillburnian-Waiauian, the earliest record), near the former Ethelton School, Kaiwara River, North Canterbury (Tongaporutuan; common), the Tauwhareparae area inland from Tolaga Bay (Opoitian; common), the Wairoa district of northern Hawke's Bay (Opoitian-Mangapanian), and the Mangahao district, west of Pahiatua, northern Wairarapa (Mangapanian-early Nukumaruan, the youngest record).

Olsson (1956, p. 159, 216) pointed out that *Lamprodomina neozelanica* belongs in a distinctive genus of Olivinae, and its non-spiral mid-whorl groove, climbing the shell during growth, is unique; Fleming (in Watters and Fleming 1972, p. 399) showed that the Chilean Miocene (and early Pliocene ?) *L. dimidiata* (Sowerby) is congeneric, but we are not aware of any other species of *Lamprodomina*. The arrival of *Lamprodomina* in New Zealand during Lillburnian time is among the earliest of many possible dispersals of Mollusca to New Zealand from South America.

Figured specimen (Pl. 37q): GS5626, C46/f9594, Birch's Mill shell lens, Te Waewae Bay, Southland, early Opoitian (NZGS) x 1.5.

Pl. 37 k. *Amalda (Baryspira) oraria* (Olson, 1956) [*Baryspira (Baryspira) oraria* Olson 1956, p. 14] (Olividae: Ancillinae).

Large for genus (54–57 mm high), tall and narrow, with spire half height of aperture; smooth except for basal spiral bands, growth lines on broad band, and very indistinct spiral ridges on spire. Outline strongly waisted at top of last whorl, with inflated, bullet-like spire and inflated last whorl with strongly convex outer lip. Spire callus descends last whorl to upper fifth of outer lip height. Parietal callus with lightly concave left outline over last whorl, extending back around quarter-whorl of spire as a strongly convex, thick "tongue"; weakly grooved up spire above posterior end of aperture. Broad band very wide; depressed band narrow, very distinct; top and mid-fasciolar bands (combined) equal in width to basal band. Columellar base with 4 weak plaits. Anterior of aperture wide, deeply notched.

Waipipian (Opoitian?); Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type); common in shallow-water sandstone and shellbeds along the Wanganui-South Taranaki coast, but not known to us from elsewhere.

Amalda gulosa (Opoitian, southern Hawke's Bay) is shorter and still more inflated, and its parietal callus lacks the thick, convex, tongue-like margin of *A. oraria*, but the distinction is subtle and probably insignificant. The two (?) species differ from the Nukumaruan-Recent *A. mucronata* (Pl. 49g) in their marked waist at the top of the last whorl, below the spire. The relationship of these two (?) species to *A. mucronata* is unclear; specimens intermediate in size and shape between *A. mucronata* and *A. tholiculus* (type: Lillburnian, Island Creek, Waipaoa River, Gisborne district) occur commonly in shallow Kapitean-Waipipian facies from East Cape to Westland, but the ancestry of *A. mucronata* is unclear.

Figured specimen (Pl. 37k): holotype, Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (TM6821, NZGS; origin unknown, ?ex Marshall and Murdoch Collection) x 1.

Pl. 37 o. *Alcithoe (Leporemax) gatesi* Marwick, 1926 [*Fulguraria morgani* Marshall and Murdoch 1920, p. 133 (not of Cossmann and Pissarro, 1905); *Alcithoe gatesi* Marwick 1926a, p. 302 (new name for *Fulguraria morgani* Marshall and Murdoch, preoccupied)] (Volutidae: Zidoninae).

Small for genus (45–55 mm high), tall and narrow, with spire 0.66 height of aperture; aperture widely open anteriorly, with deep, moderately wide anterior notch forming low, narrow fasciolar ridge. Spire outline clearly but relatively weakly stepped, with gently rounded shoulder angle but tall, steep, deeply concave sutural ramp; last whorl weakly inflated below shoulder and weakly contracted lower down, with outer lip parallel to left outline of shell or more strongly flared, thickened, and lightly

reflected. Sculpture of narrowly crested, closely spaced axial costae, weak on sutural ramp but prominent from shoulder to base, about 20 per whorl. Inner lip lightly thickened, with 4 narrow columellar plaits. Protoconch as in *A. fusus* (Pl. 49i).

Waipipian (-Mangapanian?); Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (type); fairly common in shallow-water sandstone and shellbeds along the Wanganui-South Taranaki coast; uncommon in shelf mudstone facies in the Wairoa and Dannevirke districts, Hawke's Bay.

Alcithoe gatesi was apparently the ancestor of the *A. (Leporemax) brevis-fusus* lineage, in which costal prominence decreased fairly regularly; it possibly descended from such Late Miocene species as *A. rugosa* (Tongaporutuan), which has still more prominent costae. The apparently succeeding *A. brevis* (Nukumaru; Pl. 42m) has slightly less prominent axial costae and a more shallowly concave sutural ramp than *A. gatesi*, but the two are very similar, and the identity of Mangapanian specimens is unclear.

Figured specimen (Pl. 37o): lectotype of *Fulguraria morgani*, "holotype" of *Alcithoe gatesi*, Waipipi Shellbeds, Waverley Beach, west of Wanganui, Waipipian (TM6822, NZGS, ex Marshall and Murdoch Collection) x 1.5.

Pl. 37 p. *Alcithoe (Alcithoe) haweraensis* Marwick, 1926a [p. 302] (Volutidae: Zidoninae).

Moderately large for genus (80-100 mm high), elongate, with moderately tall spire (half height of aperture), straight columella, and wide, very shallow anterior notch. Spire outline strongly stepped by prominent shoulder angle (medial on spire whorls) and strongly concave sutural ramp; last whorl moderately inflated below shoulder and contracting gently to a shallowly concave neck. Sculpture of prominent, narrowly crested, widely spaced axial costae commencing abruptly at shoulder, extending to lower suture on spire and well down onto base on last whorl, becoming weak over last half-whorl; 15 on penultimate whorl. Aperture long, narrow, with thickened, narrowly reflected outer lip, and 5 narrow, strongly oblique columellar plaits. Protoconch similar to that of *A. arabica* (Pl. 49d) but a little smaller.

Opoitian-Waipipian; Waihi Beach, Hawera, South Taranaki, Waipipian (type); an uncommon species occurring in inner-shelf sandstone (with abundant *Phialopecten*, *Mesopeplum*, *Polinices*, *Austrofusus*, *Crepidula*, *Dosinia*, etc.) at Waihi Beach, Hawera, and nearby localities.

Alcithoe haweraensis is similar to the living *A. wilsonae* Powell (Dell 1978, fig. 21-32) but is more parallel-sided and still more prominently costate than the most extreme forms of *A. wilsonae*. The environment inhabited by *A. haweraensis* was strikingly different from that of the outer shelf to upper bathyal *A. wilsonae*. The ancestry of *A. haweraensis* is unclear.

Figured specimen (Pl. 37p): holotype, GS391, N28/f7459, Waihi Beach, Hawera, Taranaki, Waipipian (TM6825, NZGS) x 1.

Pl. 37 x. "*Marshallena*" *impar* Powell, 1942 [p. 83] (Turridae: Pseudotominae).

Large for genus (43 mm high), tall and narrow, with moderately tall spire (equal to height of aperture and canal) and long, weakly tapered last whorl with almost parallel-sided aperture and short, straight, very widely open anterior canal lacking fasciole. Spire outline strongly stepped because of prominent shoulder angle and strongly concave sutural ramp. Sculpture of prominent, narrow, rather widely spaced axial costae, commencing abruptly at shoulder angle and extending whole height of

spire whorls and onto base of first half of last whorl, becoming obsolete on last half of last whorl; crossed (without forming nodules) by low, wide spiral cords, indistinct below shoulder and on spire whorls but becoming progressively stronger lower down; entire surface covered with microscopic, closely spaced spiral threads. Outer lip thin; anal sinus shallow, widely v-shaped with a rounded apex, occupying sutural ramp. Protoconch conical, of 4.5 whorls, initially smooth but last whorl with fine spiral, and finally cancellate, sculpture.

Opoitian-Waipipian; GS2329, hill north of Whetukura, c. 3 km southeast of Ormondville, Dannevirke district, southern Hawke's Bay, Waipipian (type); uncommon in mid-outer shelf soft-bottom facies (blue-grey sandy mudstone) in the Wairoa district, northern Hawke's Bay (Opoitian-Waipipian), in shallow-water sandstone along the Wanganui-South Taranaki coast (Waipipian) and in the Awatere Valley, Marlborough (Waipipian), and in the Birch's Mill shell lens at Te Waewae Bay, Southland (early Opoitian).

The distinction from "*Marshallena*" *decens* (Ormond Formation, Gisborne, Opoitian) and "*M.*" *austrotomoides* (Waihi Beach, Hawera, Waipipian) is subtle and, when adult shells are compared, seen to be probably unrealistic; more material is needed of these rather uncommon species to understand their taxonomy. The distribution (above) assumes these three nominal taxa are conspecific. This is one of the latest members of a group of mid-late Cenozoic species belonging in one of the unnamed genera distinguished from *Marshallena* above, under *M. neozelanica* (Pl. 8 v). An unnamed, younger species differing from the above species in having prominent spiral cords occurs in diverse molluscan assemblages of mid-shelf facies in the Mangahao district, west of Pahiatua, northern Wairarapa (Mangapanian).

Figured specimen (Pl. 37x): GS1579, W19/f7485, Wahanui Road, Wairoa district, northern Hawke's Bay, Opoitian (NZGS) x 1.5.

Pl. 37 u. *Zemacies prendrevillei* Marwick, 1928 [p. 489] (Turridae: Turrinae).

Large for family (to ca. 100 mm high), very tall and slender; presumably, when complete, shaped as in *Z. elatior* Finlay (Pl. 26i). Whorl outline with prominent rounded shoulder angle, medial on spire whorls, wide, steep, strongly concave sutural ramp (corresponding to apex of anal sinus), and wide, very low subsutural fold; tapering regularly below shoulder angle to very slightly concave neck and long, straight anterior canal without fasciole. Sculpture of many fine, close spiral cords over whole surface other than concave area of sutural ramp, and about 20 regularly placed, low, narrow, opisthocline, short axial costae per whorl, developed only on shoulder angle, persisting onto last whorl. Anal sinus very deep, narrowly U-shaped; below it, lip swings forward well in front of its sutural origin; shallow, wide stromboid notch over neck region. Protoconch unknown, presumably as in *Z. elatior* (Pl. 26i).

Opoitian-Waipipian; Whenuataru Tuff, Tarawhenua Peninsula, northern Pitt Island, Chatham Islands, Waipipian (type), in a mixed assemblage of shallow-water and upper bathyal taxa; also uncommon in shallow-water shellbeds at Waipipi, Waverley Beach, west of Wanganui (Waipipian) and the head of Greek's Creek, Arahura Valley, Westland (Opoitian).

Zemacies prendrevillei is very similar to common large Miocene species such as *Z. lividorupis* (Otaian, Bluecliffs, South Canterbury) and *Z. elatior* (Altonian-Clifdenian,

Clifden, Southland; Pl. 26i) but differs in having finer spiral sculpture, a more prominent subsutural fold, and costae persisting onto the last whorl. An interesting return to the New Zealand fossil record of a genus common in Middle Eocene to Middle Miocene rocks, but not recorded from the Taranaki Series.

Figured specimen (Pl. 37u): holotype, GS10192, CH/f105, Whenuataru Tuff, Tarawhenua Peninsula, Pitt Island, Chatham Islands, Waipipian (TM6826, NZGS) x 1.

Pl. 37 y. *Clavatoma pulchra* Powell, 1942 [p. 107]. Type species of *Clavatoma* Powell, 1942 (Turridae: Crassispirinae).

Moderate-sized for family (20-25 mm high), solid and heavily sculptured, spire 1.3 times height of aperture and canal. Whorl outlines with rounded shoulder, medial on spire whorls, and strongly concave sutural ramp (corresponding to anal sinus). Sculpture of very weak subsutural fold (scarcely recognisable on most specimens); broad peripheral band of axially elongate nodules forming lower half of spire whorls, with 10-11 nodules per whorl; followed below by 3 nodulous spiral cords on last whorl (bearing 15-16 nodules per whorl) and several fine basal spiral threads. Outer lip thin, with moderately deep U-shaped anal sinus occupying sutural ramp; parietal lip strongly thickened. Anterior canal short, widely open, with only shallow anterior notch and oblique end. Protoconch tall and narrowly conical, of 3.5 smooth whorls.

Opoitian-Mangapanian; Waihua River, northern Hawke's Bay, Waipipian (type); common and widespread in mid-shelf, soft-bottom facies with diverse Mollusca in the Wairoa district, northern Hawke's Bay (Opoitian-Mangapanian), and rare in shallow-water sandstone and shellbeds at Waihi Beach, Hawera and Waipipi, Waverley Beach, on the Wanganui-South Taranaki coast.

Clavatoma pulchra is apparently one of few New Zealand members of the turrid subfamily Crassispirinae (the only other New Zealand genus assigned there at present is *Inquisitor*), a subfamily centred on tropical America. It differs from such taxa as *Crassispira* (*Moniliopsis*) in its taller protoconch, its thin outer lip, and its weaker subsutural fold (and so the resemblance in sculpture could be fortuitous). The four wide bands of large, low nodules make it very distinctive among New Zealand Turridae.

Figured specimen (Pl. 37y): holotype, GS1568, W19/f8482, Waihua River, southern Wairoa district, northern Hawke's Bay, Waipipian (TM5761, NZGS) x 2.

Pl. 37 r. *Awateria streptophora* Suter, 1917 [p. 57]. Type species of *Awateria* Suter, 1917 (Turridae: Borsoniinae).

Small for family (10-12 mm high), relatively short and stout, with moderately tall spire (1.5 times height of aperture and canal) and short anterior canal; very coarsely sculptured. Outer surface translucent and pale brown when well preserved; apparently calcitic. Sculpture of massive, wide, coarsely axially beaded subsutural fold, followed below by narrow, strongly concave sutural ramp (a spiral constriction) corresponding to apex of anal sinus, followed by very wide, raised, peripheral spiral band, followed in turn by 1 spiral cord on spire whorls and about 10 cords of anteriorly decreasing width and spacing on last whorl and base; all crossed by prominent, closely spaced axial costae, about 16 per whorl, forming prominent nodules at sculptural intersections. Aperture simple, with short, widely open canal; outer lip with wide, shallow, U-shaped sinus occupying sutural ramp. Protoconch unknown.

Waipipian (-Mangapanian?); left bank of Awatere River upstream from Seddon rail bridge, Marlborough, Waipipian (type); uncommon in deep-water siltstone in the Awatere Valley and in the Greta Stream-Motunau Beach area, North Canterbury.

The typical Pliocene species of *Awateria* are all closely similar (*A. streptophora*; *A. evanida*, from the type locality of *A. streptophora*, and from Lake Grassmere; and *A. retiolata* (= *A. mollyae*) from Palliser Bay, southern Wairarapa, Mangapanian). *A. evanida* and *A. retiolata* are similar, differing in the taller form and slightly narrower cords of *A. retiolata*; both differ from *A. streptophora* in their narrower subsutural cord and narrower spiral cords. Several Miocene species from bathyal siltstone in Wairarapa and northern Hawke's Bay appear to be congeneric (see also Maxwell 1988a, p. 67). Most typical Pliocene species occur in bathyal siltstone (deposited in 400-1000 m) with *Aeneator* (*Ellicea*) and *Falsilunatia*; a good bathyal index. B.A. Marshall (pers. comm. in Maxwell (1988a, p. 67)) recorded that "*Vexitomina*" *optabilis* (Murdoch and Suter 1906, p. 283, pl. 21, fig. 9) is very similar to, if not conspecific with, *A. retiolata*, and is a Recent species of *Awateria*; *A. optabilis* was described from 200 m, off Great Barrier Island. Suter (1917) gave a detailed protoconch description, but the apex is corroded in all Pliocene *Awateria* material we have examined; Suter was evidently describing the decorticated apical remnant.

Figured specimen (Pl. 37r): holotype, left bank of Awatere River upstream from Seddon rail bridge, Marlborough, coll. J. A. Thomson, 1912; Waipipian (TM6827, NZGS) x 4.

Pl. 37 w. *Phenatoma decessor* Marwick, 1928 [p. 491] (Turridae: Borsoniinae).

Small for genus (to 21 mm high), with tall, straight-sided spire and relatively short last whorl; whorls lightly but clearly angled (at lower third on spire whorls), coarsely sculptured. Sculpture dominantly of spiral cords; a prominent, wide subsutural fold is followed below by shallowly concave sutural ramp bearing 1 or 2 narrow cords, then by a prominent peripheral cord forming the shoulder angle, then 2 more cords on sides of spire whorls and 7 below shoulder on last whorl; all crossed by many low axial threads, producing fine but conspicuous granules at sculptural intersections; axials sinuous over sutural ramp in conformity with deep U-shaped anal sinus in outer lip. Aperture with smooth, unthickened lips; anterior canal short, widely open, deeply notched, with low fasciole. Protoconch tall and narrowly conical, of 3.5 smooth whorls.

Waipipian; Whenuataru Tuff, Tarawhenua Peninsula, northern Pitt Island, Chatham Islands (type), moderately common; also a few specimens from shallow-water sandstone with diverse Mollusca at Waihi Beach, Hawera, South Taranaki. (The ecology of the Whenuataru Tuff assemblages is discussed under *Mitrolumna granum* (below), Pl. 37v).

Phenatoma decessor is very similar to the Castlecliffian-living *P. rosea* (Pl. 49m), differing in its smaller size (*P. rosea* reaches at least 34 mm high), its clearly angled whorls, its lack of threads between the spiral cords, and its fewer spiral cords (12 to 14 cords on the last whorl of *P. rosea*). *P. precursor* (Mangapanian-Nukumaruan) has many low, smooth, narrow, closely spaced spiral cords, and appears to have been ancestral to the weakly sculptured Castlecliffian-Recent species *P. zealandica*. The Altonian *P. perlata* and *P. lawsi* are small (8-9 mm high) with simple coarse sculpture, and *P. lawsi* has smooth cords that suggest a relationship to *Tomopleura*.

Figured specimen (Pl. 37w): GS12164, CH/f25B, tip of Tarawhenua Peninsula, Pitt Island, Chatham Islands; Whenuataru Tuff, Waipipian (NZGS) x 5.

Pl. 37 v. *Mitrolumna granum* (Marwick, 1928) [*Mitrihara granum* Marwick 1928, p. 490] (Turridae: Mitromorphinae).

Small for family (8 mm high), stout and ovate-biconic, with spire a little shorter than aperture. Spire outlines weakly convex, last whorl with evenly convex central area, contracting very gently to very weakly concave base; outer lip extends anteriorly beyond inner one to form widely open, oblique anterior notch directed slightly to left, lacking true anterior canal or fasciole. Sculpture of wide, very low subsutural fold (bifid on later whorls) separated from lower cords by wide, very shallowly concave sutural ramp; uppermost cord, at lower margin of ramp, slightly more prominent than most others; remainder of surface bears low, narrow, widely spaced, indistinct spiral cords, 3-4 on spire whorls and 25 on last whorl. Low, indistinct axial costae form very low nodules at sculptural intersections on spire whorls, but fade out at shoulder on last whorl. Aperture long and narrow, with simple outer lip bearing a very shallow anal sinus just below suture; inner lip bears 2 low but wide and prominent folds, occupying whole columella below parietal area. Protoconch dome-shaped, of 2 smooth whorls.

Waipipian, Whenuataru Tuff, Tarawhenua Peninsula, Pitt Island, Chatham Islands (type and only known locality), uncommon. The Whenuataru Tuff contains a highly diverse fauna (more than 300 species of Mollusca) that lived in a variety of hard and soft-bottom environments on the mid and outer shelf and in the upper bathyal zone. Bathyal taxa such as *Volutomitra banksi* (specimen in Pl. 27k), *Coluzea aff. mariae* and *Galeodea triganceae* occur mixed with shelf taxa in the cliff-top outcrop north of The Point homestead, west of Flowerpot Harbour, and less commonly at the tip of Tarawhenua Peninsula. The assemblage at Motutapu Point, north-eastern Pitt Island is, in contrast, dominated by hard-ground taxa such as Arcidae. The explanation of the mixed ecologies seems to be that Whenuataru Tuff represents an upper bathyal accumulation of tuff and shells in a variety of situations close to a steep, rocky coast, where shells could arrive from shallow as well as deep environments and from a variety of substrates.

Other species of *Mitrolumna* occur rarely throughout the mid-late Cenozoic; most have simple spiral sculpture. The rare *M. brachyspira* (Altonian, Oamaru) is particularly close to *M. granum*, differing in its fewer axial costae (about 15, compared with about 20 in *M. granum*). The relatively common *M. gemmata* and other living species have coarsely cancellate sculpture. We agree with Cernohorsky (1975, p. 232) that *Mitrihara* Hedley, 1922 is a synonym of *Mitrolumna* Bucquoy, Dautzenberg and Dollfus, 1883.

Figured specimen (Pl. 37v): holotype, GS10193, CH/f106, tip of Tarawhenua Peninsula, Pitt Island, Chatham Islands; Whenuataru Tuff, Waipipian (TM6828, NZGS) x 8.

Pl. 37 z. *Zeacuminia planitas* Laws, 1940b [p. 56] (Terebridae).

Small for genus (12-30 mm high), very tall and slender, spire 3.5-4 times height of aperture and canal; whorls and whole spire outline flat-sided apart from 2 nodule rows. Sculpture of 2 low, narrow, very weakly defined spiral cords, 1 below suture and 1 at peribasal angle (immediately above suture on spire whorls), raised into prominent, narrowly rounded,

rather widely spaced nodules where crossed by axial costae, 11-15 per whorl; costae are low and ill-defined over wide median zone between nodules but swell into prominent nodules at upper and lower suture, fading out rapidly below periphery on last whorl. Last whorl increasing in diameter from suture to peribasal angle to maintain spire angle, then contracting abruptly to short, narrowly waisted neck and short, narrow, strongly twisted, widely open canal; fasciole defined only by its low, narrow bordering ridge. Aperture small, quadrate. Protoconch very small, conical, multispiral, with a narrowly pointed apex.

Opoitian-early Nukumaruan; Waihi Beach, Hawera, Waipipian (type), uncommon; uncommon in Waipipian and Mangapanian shellbeds of shallow-water facies along the Wanganui-South Taranaki coast; moderately common at a few localities in Wairoa district, northern Hawke's Bay (Opoitian-Mangapanian; notably in Waihua River) and in the Mangahao district, west of Pahiatua, northern Wairarapa (Mangapanian-early Nukumaruan).

The small size, straight outlines, very short base, and sculpture consisting essentially of only two rows of nodules make *Zeacuminia planitas* one of the most distinctive species of the genus; it apparently descended from the Early Miocene *Z. biplex* (Pl. 22u). The other reasonably common Pliocene species, *Z. murchisoni* (Opoitian-Mangapanian, Kaawa Creek, Wanganui and Hawke's Bay), is much larger, short and wide for the genus, with a long base and canal, evenly convex whorls, and sculpture of low axial costae only.

Figured specimen (Pl. 37z): GS1560, W19/f8480, Waihua River, northern Hawke's Bay, Waipipian (NZGS) x 4.

Pl. 37 t. *Kaweka fulta* Marwick, 1931 [p. 152]. Type species of *Kaweka* Marwick, 1931 (Terebridae).

Small for family (10-19 mm high), tall and narrowly fusiform, although very short and wide for family, with spire only about twice height of aperture. Sculpture of single narrow, weakly defined, angling spiral cord at periphery, and at mid-height on spire whorls, and low, wide spiral cord below suture, both bearing small, sharp nodules where crossed by low, narrow, widely spaced axial costae, 11-13 per whorl; costae die out shortly below periphery on last whorl. Aperture narrowly oval, relatively large, produced below into a short, widely open canal, deeply notched anteriorly and so forming low fasciole marked off by prominent, narrow ridge. Protoconch dome-shaped, of 1 smooth whorl, with a large rounded apex.

Opoitian; Mangatarehu Stream, two km south of Te Karaka, Gisborne (type); uncommon at many localities in the Gisborne district and in the Wairoa district, northern Hawke's Bay, in inner-mid shelf, soft-bottom facies with diverse Mollusca.

Adult shells of *Kaweka fulta* have slightly taller spires and shorter anterior canals than Marwick's (1931) immature holotype. The type species (the only reasonably common species of the genus) is easily recognised by its very low spire for a terebrid, its medially angled spire whorls, and its sharp little peripheral nodules. Other named species in *Kaweka* are a little narrower.

Figured specimen (Pl. 37t): GS1574, W19/f7481, Wahanui Road, Wairoa district, northern Hawke's Bay, Opoitian (NZGS) x 2.

CHAPTER 15. LATEST PLIOCENE—EARLY PLEISTOCENE FAUNAS (NUKUMARUAN STAGE): PLATES 38-42

INTRODUCTION

Nukumaruan rocks are very widespread in Wanganui Basin, the eastern North Island from northern Hawke's Bay to southern Wairarapa, and in North Canterbury; smaller areas occur at Five Fingers Peninsula, Dusky Sound, Fiordland (Turnbull et al. 1985) and at Titirangi, Chatham Island (Fig. 22). Depositional environments ranged from near-shore sands to bathyal flysch (in northern Hawke's Bay) and, as many localities are richly fossiliferous, a great diversity of Mollusca is known from rocks of this age. Diversity was further increased by the wide range of temperature regimes under which Nukumaruan faunas lived. The onset of marked Northern Hemisphere glaciation about 2.4 m. y. ago, at

a time of favourable paleogeographic conditions in eastern North Island (a long, continuous seaway was open from the present Palliser Bay to the present northern Hawke's Bay), initiated the Nukumaruan Stage when it allowed the proto-Southland Current to extend cold water further north than previously, allowing the planktonic larvae of subantarctic animals (notably the molluscs *Chlamys patagonica delicatula* and *Cominella nassoides otatauica*, and the crab *Jacquinitia edwardsii*) to metamorphose and grow to maturity in North Canterbury, Wairarapa, Wanganui Basin (Fleming 1953) and central Hawke's Bay (Fleming 1944; Beu et al. 1977, 1981; Beu 1985a). Northward of the range of the subantarctic fauna and in all mid-late Nukumaruan rocks

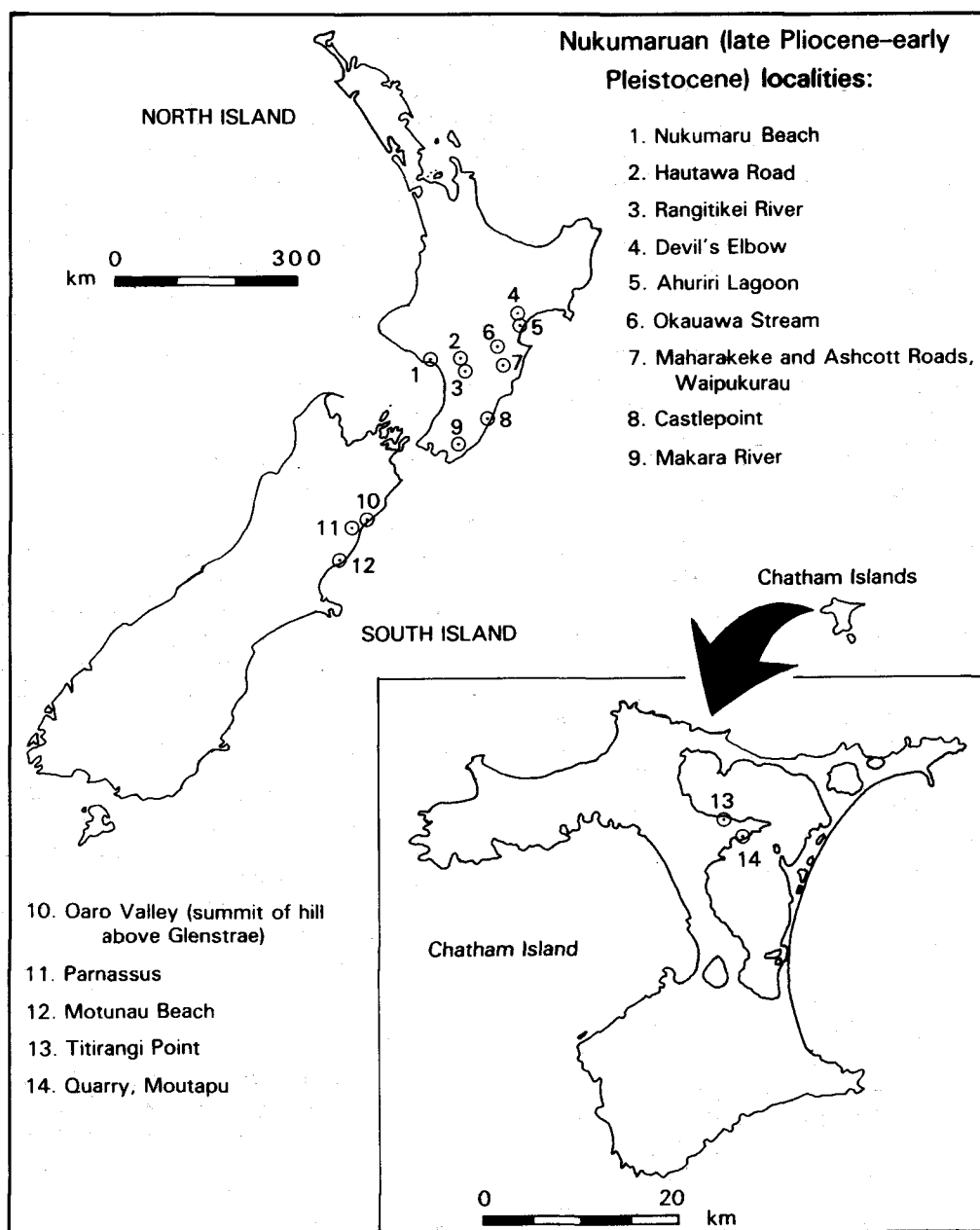


Figure 22 The main molluscan fossil localities of Nukumaruan (latest Pliocene and early Pleistocene) age.

of the North Island (i.e., those deposited after closure of the east coast seaway), Nukumaruan molluscan faunas had a high component of warm-water taxa that live only to the north of New Zealand at present. Such presumed warm-water genera as *Glycymeris* (sensu stricto), *Patro*, *Lutraria*, *Eumarcia*, *Lamprodomina* and *Zeacumina* are last known in Nukumaruan rocks. The extinction of warm-water genera during or at the end of Nukumaruan time records the continuing decline of temperatures and of the diversity of warm-water Mollusca in New Zealand from the Middle Miocene thermal maximum to the Pleistocene glacial-interglacial fluctuations; the Pliocene-Pleistocene boundary, as now defined in the section at Vrica, southern Italy (Aguirre and Pasini 1985), lies near the top of the Nukumaruan Stage.

Some of the most important molluscan localities of Nukumaruan age occur in the classical Wanganui coastal section, unconformably underlying the Castlecliffian type section in the cliffs at Nukumarua and Ototoka Beaches. The sequence was described in detail by Fleming (1953). The most important formations for Mollusca are Nukumarua Limestone and Nukumarua Brown Sand (the latter is the type formation of the Nukumaruan Stage). In the Rangitikei Valley sequence further eastward in Wanganui Basin, important Nukumaruan molluscan localities occur along the now disused Hautawa Road (sign-posted now as West Road) above Hautawa Stream, north of Hunterville and, in the main Rangitikei River section, in the Waipuru Shellbed and in other exposures near Vinegar Hill domain. Nukumaruan Mollusca are diverse and exceedingly widespread in Hawke's Bay, where sequences of alternating beds of mudstone and coquina limestone (glacio-eustatic sea-level cycles; Beu and Edwards 1984) provide a great range of depositional environments. Important localities are at Watchman Hill, a former island in Ahuriri Lagoon, near Napier; at Roro-o-kuri, a former promontory in Ahuriri Lagoon near Bay View, north of Napier; in road cuts on the main Napier-Wairoa highway on Devil's Elbow hill, 30 km north of Napier (particularly in the thick mudstone at the top of the east-west face of the hill, containing the most diverse Nukumaruan faunule we are aware of; Devil's Elbow mudstone of Beu and Edwards 1984); on Darkys Spur road where it descends the steep ridge from Kaiwaka Road, west of Devil's Elbow; around the base of Pukeora Hill, near Waipukurau, on Ashcott and Maharaakeke roads; and in the area around Okauawa Stream, on Kereru Road, in inland central Hawke's Bay. Shellbeds in Okauawa Stream, the neighbouring Whanakino Stream, and road cuts nearby contain diverse, shallow-water, late Nukumaruan faunules with many spectacular molluscs such as *Struthiolaria frazeri*. In southern Wairarapa, Nukumaruan molluscan-rich localities are as widespread as in Hawke's Bay. Important ones are in the five limestone beds and in the units between them in Mangaopari Stream and Makara River, White Rock Road, east of Martinborough. In the northern South Island, Nukumaruan Mollusca are locally common in small basins around Cheviot and Parnassus and at Motunau Beach, all in North Canterbury, and in the Hundalee Hills of southern Marlborough. The most important South Island locality is a large slip exposure on the summit of the hill east of Glenstrae woolshed, in Oaro Valley in the northern Hundalee Hills, where the

most diverse known late Pliocene bathyal molluscan faunule is found and, as noted above under bathyal faunas, evidently represents the fauna of a former submarine canyon (Beu 1979).

Nukumaruan molluscan faunas differ from Mangapanian ones by lacking the large, spectacular species *Maoricardium spatiosum* and *Polinices waipipiensis*. These represent genera that are abundant in New Zealand rocks of Oligocene to Pliocene age. Less common taxa such as *Sectipecten*, "*Marshallena*", *Clavatoma pulchra*, *Austrofusinus pagoda*, *Semicassis (Kahua) fibrata*, and *Zeacumina murchisoni* are also known last in Mangapanian rocks, and the abundant Pliocene species (and important biostratigraphic indices) *Crassostrea ingens* and *Phialopecten triphooki* survived for only the very earliest part of Nukumaruan time. The Mangapanian/Nukumaruan stage boundary is clearly *not* marked by the same kind of major generic turnover as occurred at the Waipipian/Mangapanian and Nukumaruan/Castlecliffian boundaries, and is more difficult to recognise than most other boundaries in the Wanganui Series.

In most areas of New Zealand with significant late Pliocene sequences (i.e., all except northern Hawke's Bay and eastern central Hawke's Bay) the Mangapanian/Nukumaruan boundary is adopted at the incoming of the cool-water molluscan fauna (in practice, the incoming of *Chlamys patagonica delicatula*). This coincides with the incoming of the planktonic foraminiferan *Globorotalia crassula*, which has proved to be the principal index of the base of the stage in deep-water sequences lacking Mollusca, and coincides with the incoming of *Chlamys patagonica delicatula* in most sequences of shelf facies (Hornibrook 1981). A few localities with *Chlamys patagonica delicatula* are conceivably as old as late Mangapanian: at Bull Creek and Clay Creek, in the Ruakokopātuna Valley in southern Wairarapa (Bull Creek Limestone; Vella and Briggs 1971); in mudstone between two limestone beds on Brookdale station, at Parnassus, North Canterbury; and in bathyal siltstone facies at Palliser Bay and in Greta Stream, North Canterbury. However, there is no compelling evidence at present for adopting an age older than Nukumaruan for any of these localities.

REPRESENTATIVE NUKUMARUAN MOLLUSCA

Pl. 38 a-c. *Acanthochitona (Notoplax) rubiginosa* (Hutton, 1872) [*Toncia rubiginosa* Hutton (ex Swainson MS) 1872, p. 180; *Acanthochites (Loboplax) costatus* A. Adams and Angas of Suter 1897a, p. 194 (not of A. Adams and Angas); *Plaxiphora terminalis* "Smith" of Wissel 1904, p. 609 (not of Smith); *Notoplax (Amblyplax) oliveri* Ashby 1926, p. 18; *Notoplax (Amblyplax) foveauxensis* Ashby 1926, p. 20; *Lophoplax finlayi* Ashby 1926, p. 30; *Acanthochiton foveauxensis* Mestayer 1926, p. 585; *Acanthochiton foveauxensis* var. *kirki* Mestayer 1926, p. 586; *Macandrellus oliveri* Mestayer 1926, p. 586; *Acanthochites rubiginosus*; *Acanthochites (Loboplax) rubiginosus*; *Craspedochiton rubiginosus*]. Type species of *Amblyplax* Ashby, 1926, and of *Lophoplax* Ashby, 1926 (both = *Notoplax* H. Adams, 1861) (*Acanthochitonidae*).

Shell moderate-sized (median valves to 10 mm wide and 4 mm long),

valves very short and wide; tegmental sculptural granules exceedingly variable in size and regularity. Most characters similar to those of *A. mariae* (Pl. 44a, d, h); differing in its considerably shorter and wider valves, its shorter insertion plates and sutural laminae, its much more widely triangular jugum on valves 2-8, bearing longitudinal grooves and ridges on many specimens (smooth or weakly pitted in *A. mariae* and *A. zelandica*), its ridges on most specimens between lateral and pleural areas of median valves, and its highly variable but, in most specimens, relatively weak radial ridges on anterior valves.

Nukumaruan-Recent; Recent, Kapiti Island, Cook Strait (type of *Tonicia rubiginosa*; Hutton (1872, p. 180) stated that the type was from William Swainson's collection, and the name a manuscript one given it by Swainson); Foveaux Strait, southern South Island (types of *Notoplax foveauxensis*, *Acanthochiton foveauxensis*, and *A. foveauxensis* var. *kiriki*); dredged between Kamoau and Tiritiri Islands, Hauraki Gulf, Auckland (type of *Notoplax oliveri*); Coromandel Peninsula, Hauraki Gulf (type of *Macandrellus oliveri*); dredged off Otago Heads, south-eastern South Island (type of *Lophoplax finlayi*, a juvenile *A. rubiginosa*).

Acanthochitona rubiginosa is one of New Zealand's most abundant living chitons, dredged in large numbers on all firm substrates (such as dead shells) all around New Zealand in about 10-100 m. Not surprisingly, it is also *much* the most common of Plio-Pleistocene fossil chitons, reflecting the deposition of most diverse shellbeds on the inner-mid shelf. Valves occur in large numbers in washings of central Hawke's Bay Nukumaruan siltstone (particularly in the outcrop on Ashcott Road at Pukeora Hill, Waipukurau), and small numbers have been examined from Nukumaruan rocks at Wanganui and from many Wanganui Castlecliffian localities and facies (shallow-water sandstone to shellbeds and offshore mudstone); also from Ohope Beach, Whakatane (Castlecliffian; National Museum of N.Z.) and Te Piki, Cape Runaway (Haweran, oxygen isotope stage 7; National Museum of N.Z.).

Iredale and Hull (1931, p. 69) thought this a normal species of *Craspedochiton*, and their assignment has been followed by almost all subsequent authors, yet their earlier figure (Iredale and Hull 1925, pl. 10, fig. 31) of the living tropical Australian *Craspedochiton jaubertensis* Ashby, 1924 shows that *Craspedochiton* is an unusual genus with the girdle narrowed posteriorly but widely expanded anteriorly, the anterior valve enlarged, and the girdle lacking spicules. Ashby (1926, p. 6-7) also hotly contested a position in *Craspedochiton* for any New Zealand species, as all lack the conspicuously fluted

insertion plates of such typical species as *C. jaubertensis*. *A. rubiginosa* has a narrow girdle all around, a normal-sized head valve, unfluted insertion plates, and a densely spiculous girdle, and seems a normal species of *A. (Notoplax)*, if one with an unusually wide tegmentum and narrow girdle. We agree with Leloup (1950, p. 3) that it belongs in *A. (Notoplax)*.

Figured specimens (Pl. 38a-c): GS4116, R22/f6436, Nukumar Brown Sand, Nukumar Beach, west of Wanganui, Nukumaruan (NZGS) x 10.5 (finely sculptured median and anterior valves, coarsely sculptured posterior valve).

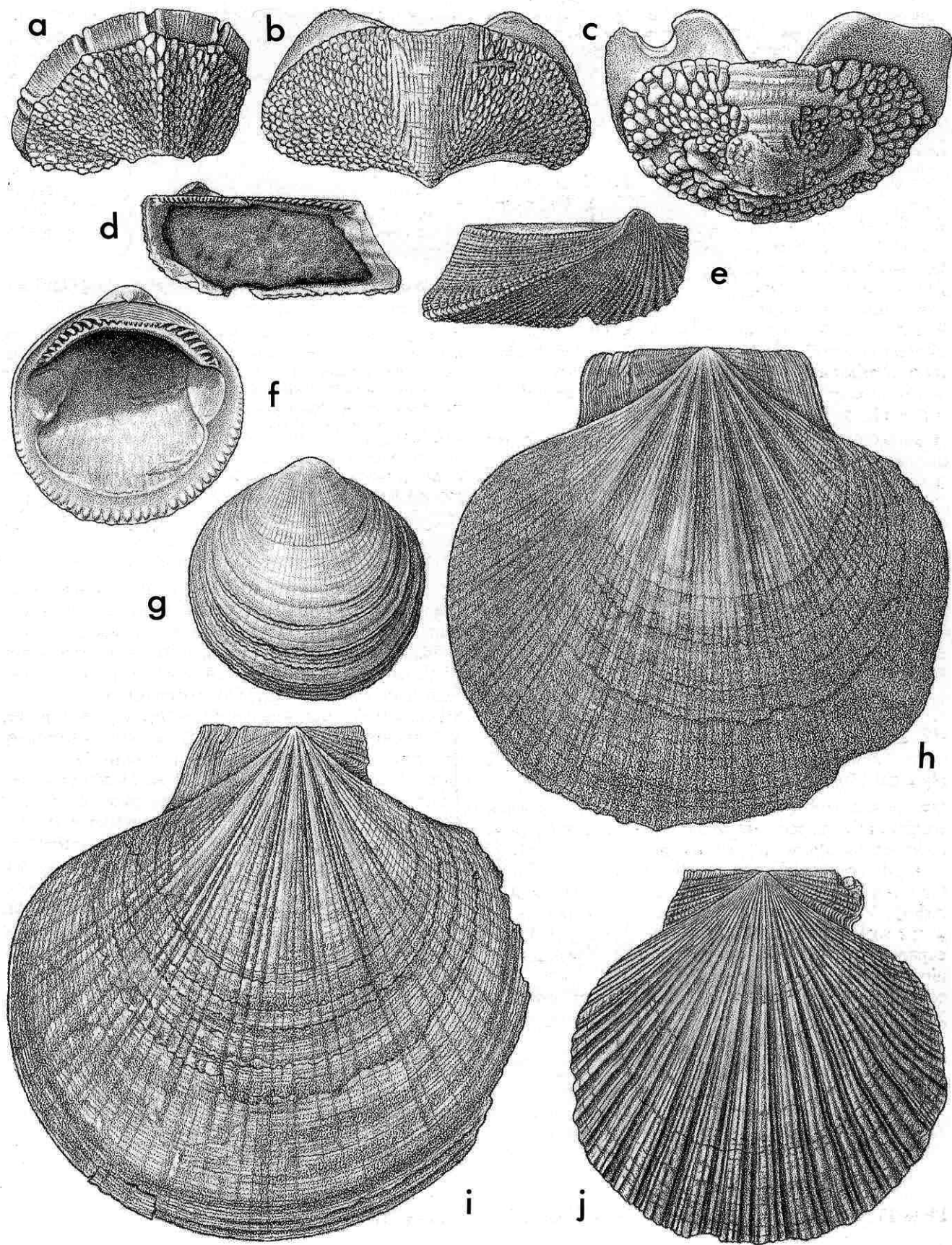
Pl. 38 d,e. *Arca cottoni* Waghorn, 1926 [p. 234] (Arcidae: Arcinae).

Small for genus (20-50 mm long), long and narrowly boat-shaped, with a long, shallow byssal excavation in mid-ventral margin, wide, horizontal ligamental area between hinge and narrow, protruding umbo, and very prominent, narrowly keeled ridge from umbo to postero-ventral corner. Hinge line straight, long; ventral margin parallel to hinge line; anterior end regularly curved below hinge; posterior margin quadrate, sloping backward ventrally. Sculpture of prominent, narrow radial costae over most of exterior, made scaly or finely nodulous by regular, low commarginal costellae; fine radial threads on postero-dorsal area, grouped into coarser costae. Hinge with many similar teeth, sloping radially outward at each end. Ligamental area with many shallow chevron-shaped grooves (diamond-shaped in articulated shells); up to 30 chevrons in large specimens. Adductor scars elevated, slightly roughened, subquadrate, with obvious growth tracks; no pallial sinus.

Opoitian(?); Waipipian-Castlecliffian; Ruakokopatuna Valley, northern Aorangi Range, southern Wairarapa (type) (Beu 1973b, p. 312 thought the type locality is probably Bull Creek, Haurangi Road, in the upper Ruakokopatuna Valley; possibly Mangapanian rather than Nukumaruan). Abraded specimens reported from Kaawa Creek, southwest Auckland (Laws 1936a, p. 46) are apparently this species (Opoitian); moderately common in the Waipipi Shellbeds at Waverley Beach, west of Wanganui (Waipipian); rare in Nukumaruan siltstone between Petane limestone beds in central Hawke's Bay glacio-eustatic cycles, except that *A. cottoni* is common in a thin lens in the centre of the outcrop of Devil's Elbow mudstone, at the top of the east-west face of Devil's Elbow hill, Napier-Wairoa highway (Nukumaruan); uncommon in shallow-water siltstone on Wainui Stock Route, Ohiwa Harbour, Whakatane (Castlecliffian; NZGS and National Museum of N.Z.). Modern *Arca* species live byssally attached to hard substrates (rock, coral) in shallow water, often in crevices and surface hollows, and this was presumably also the

Plate 38 Nukumaruan (late Pliocene-early Pleistocene) Mollusca (1).

- a-c *Acanthochitona (Notoplax) rubiginosa* (Hutton), x 10.5.
- d,e. *Arca cottoni* Waghorn, x 1.5.
- f,g. *Glycymeris (Glycymeris) shrimptoni* Marwick, x 1.
- h,i. *Sectipecten mariae* (Finlay), x 1.
- j. *Chlamys* (sensu lato) *patagonica delicatula* (Hutton), x 1.



habitat of New Zealand fossils, as all have wide byssal gapes in the centre of the ventral margin and were certainly byssally attached. The collection of much better material than the types shows that *A. pittensis* (Waipipian, Whenuataru Tuff, Pitt Island, Chatham Islands) differs from *A. cottoni* in its slightly shorter and wider form, wider ligamental area, more prominent umbonal-posterior keel, and weaker sculpture on the posterior area. The Early Miocene *A. subvelata* was possibly ancestral to *A. cottoni*, and differs in its slightly shorter and wider form and fewer ligamental chevrons. A species of a very different group, *A. chambersi*, occurs sympatrically with *A. cottoni* at Waipipi; it is much shorter and wider and has only three to five ligamental chevrons.

Figured specimen (Pl. 38d, e): GS5435, V21/f8565, siltstone outcrop below Mason Ridge road, Maraekakaho, central Hawke's Bay, Nukumaruan (TM5118, NZGS) x 1.5.

Pl. 38 f, g. *Glycymeris (Glycymeris) shrimptoni* Marwick, 1923 [p. 75] (Glycymerididae: Glycymeridinae).

Small for genus (40-60 mm high), thick and solid, almost circular to slightly elongate (either dorso-ventrally or antero-posteriorly elongated), moderately well inflated, with low umbo and very weak sculpture. Sculpture of low, close, exceedingly fine, radial threads and grooves over whole exterior, every 8th or 10th groove slightly more prominent than the others. Evenly and closely chevron-grooved ligamental area fills low, wide triangle between umbo and hinge, growing downwards to obliterate central hinge teeth of large shells. Hinge plate wide, thick, and symmetrically arched, with many similar, low, narrow, elongate teeth along whole hinge; teeth vertical, straight, and short in central 0.2-0.3, but shallowly V-shaped and sloping outward radially over anterior and posterior ends. Interior of ventral margin deeply and coarsely crenulate. Adductor scars almost identical; no pallial sinus.

Mangapanian?; Nukumaruan. "Shrimpton's" i.e., Kikowhero Stream, Matapiro Station, north of Ngaruroro River, central Hawke's Bay, Nukumaruan (type); abundant in shallow-water, high-energy environments (i.e., commonly found in coquina limestone) of Nukumaruan age throughout Wanganui basin, Hawke's Bay, Wairarapa, and North Canterbury.

The Waipipian *Glycymeris waipipiensis* is markedly larger and more consistently antero-posteriorly elongate than *G. shrimptoni*; Mangapanian specimens are difficult to distinguish from both *G. waipipiensis* and *G. shrimptoni*. Extinction of the subgenus *G. (Glycymeris)* in the New Zealand area is an important index of the end of Nukumaruan time.

Figured specimen (Pl. 38f, g): holotype, GS191, V21/f8463, "Shrimpton's", Kikowhero Stream, Matapiro Station, Ngaruroro River, central Hawke's Bay, Nukumaruan (TM4145, NZGS) x 1.

Pl. 39 d, f. *Patro undatus* (Hutton, 1885) [*Anomia undata* Hutton 1885b, p. 324]. Type species of *Prismatro* Marwick, 1948 (= *Patro* Gray, 1850) (Anomiidae: Anomiinae).

Large for family (60-98 mm long), oyster-like, calcitic, very thick and heavy for family; most specimens regularly oval to circular in outline, with almost flat right (lower) valve and moderately arched left (upper) valve, both with shallow, saddle-shaped flexure in commissure at posterior end. Left valve coarsely lamellar in structure, whereas right (lower) valve very thick and prismatic (breaking into many fibrous crystals at right-angles to valve surface). Exterior smooth, except for very weak radial threads on some small specimens, and lamellar growth ridges. Right

valve with deep, circular byssal notch closed off to slit in mid-dorsal margin, tightly enclosing calcified byssal plug; above byssal notch, at dorsal margin, is a large, strongly protruding resilial process with saddle-shaped dorsal surface. Central, roughly circular, thin, white, aragonitic layer surrounds resilifer, byssus, and large, central, circular or oval, adductor muscle scar. In left valve, large resilial scar lies inside weakly protruding umbo; central, irregularly oval, aragonitic layer surrounds 3 muscle scars arranged roughly in a straight line (not a triangle, as in *Anomia*); upper and middle muscle scars (scars of divided byssal retractor muscle) both oval, upper one moderate-sized, middle one small; valve adductor (lowest) scar almost circular and much the largest.

Kapitean-Opoitian ?; Waipipian-Nukumaruan. Limestone, "Petane", i.e., hillside north of mouth of Esk River, 20 km north of Napier, Hawke's Bay (type); common in Pliocene shellbeds and shelf sandstone to mudstone facies, oyster banks, and coquina limestone throughout New Zealand, and particularly in the Waipipi Shellbeds, Waverley Beach, west of Wanganui (Waipipian), and Mangapani and Wilkies Shellbeds, Wanganui basin (Mangapanian), Nukumaruan Limestone (where the most complete right valves are found, at Fishing Rock) and Nukumaruan Brown Sand at Nukumaruan Beach, Wanganui, and the Petane Group mudstone and limestone cycles throughout Hawke's Bay (Nukumaruan). The time range is unclear; Kapitean-Opoitian anomiiids (particularly from the coast between Te Araroa and East Cape, Kapitean) include some specimens that seem to be *P. undatus*.

Patro undatus is the largest of New Zealand Anomiidae, easily recognised by the thick, prismatic right valve retaining the byssal plug by constriction. Yonge (1977) greatly clarified knowledge of the Anomiidae, confirming the generic status of *Patro*. *Anomia* has a loose byssal plug, the right valve of lamellar (rather than prismatic) structure, the muscle scars in the left valve in a triangle (the uppermost (one of the two byssal retractors) much the largest), and is much more irregular in shape. Middle Cenozoic species of *Pododesmus* have the relatively small byssal plug fused into the shell, a lamellar rather than prismatic right valve, and only two muscle scars in the left valve (the byssal retractor is not subdivided). *Anomia* lives today attached to rocks and shells in crevices and on rough surfaces, and has an irregular shape, but *Patro undatus* appears to have been attached only while small, and to have been free-lying on the sea-bed when more than about 30 mm in diameter.

Figured specimen (Pl. 39 d, f): Nukumaruan Brown Sand, Nukumaruan Beach, west of Wanganui, Nukumaruan (TM3922, NZGS) x 0.67.

Pl. 38 j. *Chlamys (sensu lato) patagonica delicatula* (Hutton, 1873) [*Pecten delicatula* Hutton 1873b, p. 30; *Chlamys subantarctica* Hedley 1916, p. 23; *Chlamys campbellica* Odhner 1924, p. 61; *Chlamys instar* Iredale 1925, p. 251; *Chlamys tiirangiensis* Marwick 1928, p. 458; *Chlamys delicatula*; *Chlamys (Zygochlamys) delicatula*] (Pectinidae).

Much the largest Pliocene-Recent *Chlamys* of the New Zealand region (50-95 mm high), thick and solid; left valve slightly more inflated than right. Small specimens (to ca. 40 mm high) higher than long, obliquely extended postero-ventrally, with strongly unequal ears, and with ctenolium and large, functional byssal notch in right valve; changing with growth to free-lying, swimming adult with equidimensional disc (or length even exceeding height in some large shells) and much more nearly equal ears, with byssal notch shallow and not functional. Radial costae 22 to 34, narrow to moderately wide, of low triangular section;

initially simple and almost smooth, but increasing in number by both subdividing (symmetrically, in most specimens, each major costa having a secondary costa on each side) and intercalation of fine tertiary and quaternary costellae; all bearing scale-like spines where crossed by fine commarginal lamellae.

Mangapanian?; Nukumaruan-Recent. Castlepoint, eastern Wairarapa coast, Nukumaruan (type of *Pecten delicatula*); Macquarie Island, subantarctic, Recent (type of *Chlamys subantarctica*); Campbell Island, Recent (type of *Chlamys campbellica*); southern Tasmania, late Pleistocene (type of *Chlamys instar*; Beu 1985a); Titirangi, Chatham Island, Nukumaruan (type of *Chlamys titirangiensis*). Possibly Mangapanian at a very few localities (mudstone between two limestone beds, Brookdale Station, Parnassus, North Canterbury; ? Bull Creek Limestone, Haurangi Road, Ruakopkopatuna Valley, southern Wairarapa) but Nukumaruan at almost all its very numerous fossil localities, in Wanganui basin (Hautawa Shellbed, from Hautawa Road, north of Hunterville, westward to the Mangawhero River), northern Ruahine Range (Napier-Taihape Road, notably on Mts Kohinga and Miroroa; Ohara Depression; and summit of main range west of Big Hill; Beu et al. 1977, 1981), southern Hawke's Bay (in Kumeroa Limestone beds), central and southern Wairarapa (notably abundant in many beds in Mangaopari Stream and Makara River, east of Martinborough), widespread in North Canterbury (particularly along the sea cliffs south of Conway River, in the Cheviot-Parnassus district, and in the extensive canyon-head debris deposits at Motunau Beach), and rare in the Titirangi Sand, Chatham Island. One locality (but only one immature valve collected) of Castlecliffian age: Leader River on Mendip Hills Station, west of Parnassus, North Canterbury (with *Pecten kupei*); also common in late Pleistocene (20 000 yrs old) concretions in Cook Strait (Boreham and Fleming 1975). Abundant today around the Subantarctic Islands south of New Zealand (The Snares to Macquarie) up to Otago Peninsula, southern South Island (where it is abundant enough to be fished commercially) and uncommon in Pegasus Bay, Canterbury, and so clearly a cold-water form, although a few living specimens have been found as far north as Cook Strait. A very important indicator of early-mid Nukumaruan (late Pliocene) glaciations, when low temperatures allowed larvae to metamorphose as far north as the central North Island.

Chlamys patagonica delicatula differs only in its narrower costae and paler coloration from the southern South American *C. patagonica patagonica* (King and Broderip) (late Pliocene?; Pleistocene-Recent). Ancestral forms in New Zealand are *C. seymouri* (early Opoitian, Momoe-a-Toa shellbed, Chatham Island), with much narrower radial costae and a functional byssus in adults, and an unnamed species (Whenuataru Tuff, Pitt I., Chatham Islands, Waipipian) intermediate between *C. seymouri* and *C. patagonica*. [See Fleming 1944; Beu 1985a].

Figured specimen (Pl. 38j): Rafa Downs, sea cliffs south of Conway River mouth, North Canterbury, Nukumaruan (NZGS, from an old collection) x 1.

Pl. 38 h,i. *Sectipecten mariae* (Finlay, 1927) [*Pecten semiplicatus* Hutton 1873b, p. 30 (not of Alth in Favre, 1869); *Pallium mariae* Finlay 1927b, p. 526 (new name for *Pecten semiplicatus* Hutton, preoccupied); *Kaparachlamys mariae*] (Pectinidae).

Large for family (80-110 mm high); length variable, from slightly greater than to slightly less than height; left valve markedly more inflated than right, but even left valve little inflated, right valve almost flat. Ears almost equal on the 2 valves, slightly asymmetrical; posterior margin of posterior ears sloping backward moderately, anterior margin of anterior ears sloping slightly backward, sinuous, with broad, shallow, byssal sinus but no ctenolium in right valve. Sculpture of 6 or 7 very low radial folds near umbo of both valves, lower and wider on right valve than on left, fading out by mid-height of large shells; superimposed on them are many low, wide, flat-topped, closely spaced radial costae on right valve (becoming obsolete before outer margin of large shells) and many low, narrow, relatively widely spaced radial costae on left valve (becoming low and wide before outer margin of large shells). Interior features not seen (all are either articulated shells, or in hard limestone).

Waipipian?; Mangapanian-Nukumaruan. Scinde Island Limestone, Napier, Hawke's Bay, early Nukumaruan (lectotype of *Pecten semiplicatus*; Boreham 1965, p. 27); the other syntype(s?) are from Castlepoint, west Wairarapa coast (also early Nukumaruan) where the species is common. Common also in limestone bed "C" of Pukenui Limestone (Nukumaruan) in Makara River, east of Martinborough, southern Wairarapa, and as common as *Phialopecten triphooki* in Te Aute Limestone (Mangapanian) at the summit of Towai Road, Puketoi Range, southern Hawke's Bay; widely distributed but uncommon in shallow-water shellbeds and coquina limestone in Hawke's Bay, Wairarapa, and North Canterbury. *Sectipecten mariae* was apparently a free-living, actively swimming species of hard-ground environments.

Careful examination of the highly variable Momoe-a-Toa (northern Chatham Island) population of *Sectipecten allani* (Pl. 33c) has shown that the narrowly costate end-members of *S. allani* are distinguishable from *S. mariae* only by their slightly more prominent radial folds, and persistence of right-valve costae almost to the valve margin; the existence of marked finely and coarsely costate end-members in the Momoe-a-Toa population therefore appears to indicate that this is almost the only direct record in New Zealand Cenozoic rocks of a molluscan lineage branching event, and that *S. mariae* evolved from early *S. allani*. As noted above, *S. allani* appears to have become adapted to progressively more near-shore, high-energy environments through the Pliocene, whereas *S. mariae* appears to have, to some extent, occupied the niche of Late Miocene *Sectipecten*. The type species of *Kaparachlamys*, "*Placopecten*" *hectori* (Waipipian, Pitt I., Chatham Islands) lacks radial folds and has many, very uniform, fine radial costae on both valves, but agrees with *K. mariae* in having the left valve a little more inflated than the right, and in ear shape. It appears that *S. mariae* would be better referred to *Sectipecten* than to *Kaparachlamys*, leaving only *K. hectori* in *Kaparachlamys*. *K. hectori* closely resembles American *Placopecten* species, but the byssal notch is a little shallower in *K. hectori* than in *Placopecten*, so the close similarity of *K. hectori* to *Placopecten* may be superficial, but needs more study.

Figured specimen (Pl. 38h, i): GS5491, S28/f6594, *Pellicaria rugosa*-*Chlamys patagonica delicatula* beds at east side of mouth of Whangaimoana Stream, Palliser Bay, southern Wairarapa, early Nukumaruan (TM2922, NZGS) x 1.

Pl. 39 b. *Xenostrobus huttoni* (Suter, 1914) [*Modiolus huttoni* Suter 1914, p. 39] (Mytilidae: Modiolinae).

Large for genus (to 70 mm long), thick-shelled, with rounded, inflated anterior end and weakly protruding, clearly subterminal umbones, smooth except for weak growth ridges; prominent umbonal ridge extends to posterior ventral margin; markedly concave area present below ridge on most specimens. Edentulous; other interior features not visible. Black periostracum remains on many specimens; on others, calcitic shell stained pale brown. Dorsal and ventral margins diverge at low angle; large shells develop a "humped", angled dorsal outline and concave ventral outline.

Waipipian-Castlecliffian; conglomeratic shellbeds, Lower Waipara Gorge near Greenwood's Bridge, North Canterbury, Waipipian (type); also Middle Waipara River near "The Deans", Waipipian or Mangapanian; common in several very shallow-water formations in Wanganui basin (Nukumaruan and Castlecliffian) and in several estuarine mudstone beds in Hawke's Bay and Wairarapa (Nukumaruan). An estuarine "mussel", occurring with *Barytellina*, *Cyclomactra*, *Zeacumantus* and, at some localities, *Austrovenus* and *Amphibola*.

Despite the lack of knowledge of the musculature, there is little doubt that Wilson's (1967, p.292) assignment of *Modiolus huttoni* to *Xenostrobus* is correct. The large size distinguishes *X. huttoni* from all modern species, but the umbonal shape is similar to that of the southern Australian Recent species *X. inconstans* (Dunker); large shells develop a more curved, "humped" outline than *X. inconstans*, resembling in outline the Australian and New Zealand Recent species *X. securis*. The ecological station favoured by *X. huttoni* appears to have been very similar to that of *X. securis*, which lives in large numbers in brackish lakes. The other New Zealand Recent species, *X. pulex* (Lamarck), forms dense carpets byssally attached to exposed intertidal rocks. We note above that *X. altijugatus* (Pl. 28d) appears to be an earlier species of *Xenostrobus* with a still more curved, "humped" outline than *X. huttoni*.

Figured specimen (Pl. 39b): GS12857, V20/f136, estuarine beds with common *Barytellina* and *Mactrona*, Kaiwaka South Road, south-west of Devil's Elbow, 30 km north of Napier, Nukumaruan (NZGS) x 1.

Pl. 39 a,c. *Pleuromeris hectori* Powell, 1938b [p. 160] (Carditidae: Venericardiinae).

Very large for New Zealand members of the genus (to 24 mm high), subcircular, with only slightly protruding umbo slightly in front of centre. Sculpture of about 20-24 prominent radial costae; low and wide, with weakly convex crests, on most specimens; varying from very closely spaced, with only narrow grooves between (on largest specimens) to having flat-bottomed, almost smooth interspaces half the width of 1 costa. Commarginal sculpture of low, rounded, narrow, closely spaced

ridges on the surface of each radial costa, crossing radial interspaces on most specimens. Lunule shallowly impressed, long and narrow on most specimens but becoming short, relatively wide, and steeply inclined beneath umbo of large specimens. Interior of ventral margin coarsely crenulate. Hinge short; with large, smooth, triangular median cardinal tooth, 2 cardinal sockets, and weak anterior lateral tooth and socket in right valve; 2 narrowly triangular cardinal teeth, large median pit, and very small anterior lateral tooth in left valve. Adductor muscle scars oval, subequal; pallial line without sinus.

Mangapanian-Nukumaruan (-Castlecliffian?); Castlepoint, west Wairarapa coast, Nukumaruan (type); common in shallow-water coquina limestone and mudstone throughout New Zealand, wherever late Pliocene rocks are preserved.

The taxonomy of New Zealand *Pleuromeris* species is poorly understood, and the status of *Pleuromeris hectori* and of the closely similar *P. finlayi* is in doubt. Small specimens in the same collections appear identical to the Castlecliffian and living *P. zelandica* whereas large specimens have lower, wider, and more closely spaced radial costae. It is possible that *P. hectori* is merely based on large specimens of *P. zelandica*.

Figured specimen (Pl. 39a, c): GS2312, U22/f9488, Ashcott Road at foot of Pukeora Hill, near Waipukurau, Hawke's Bay, Nukumaruan (NZGS) x 3.

Pl. 40 b,f. *Talabrica senecta* Powell, 1931a [p. 109] (Crassatellidae).

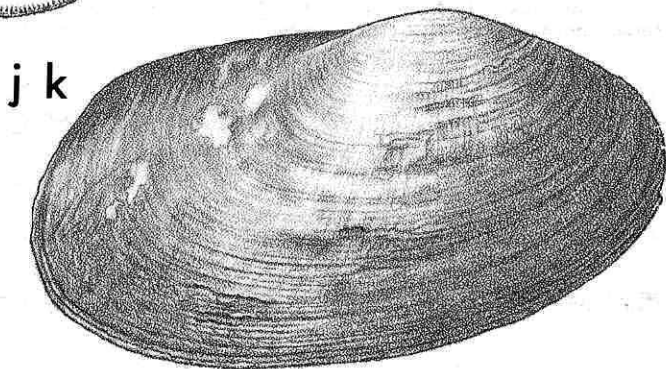
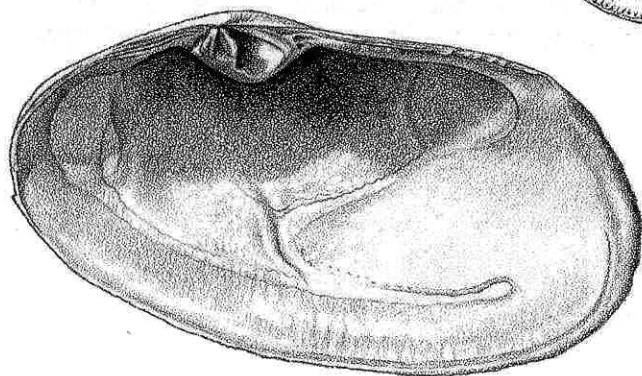
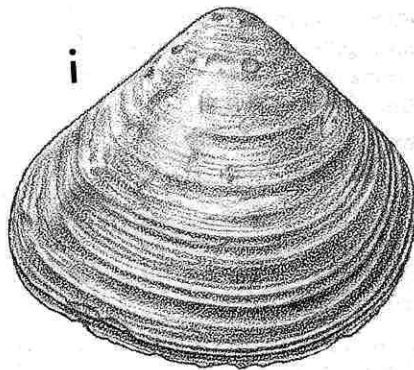
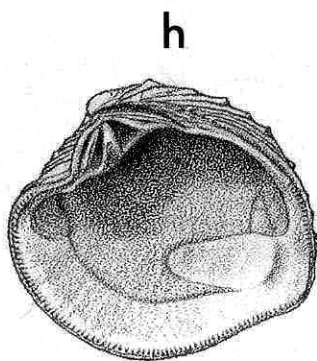
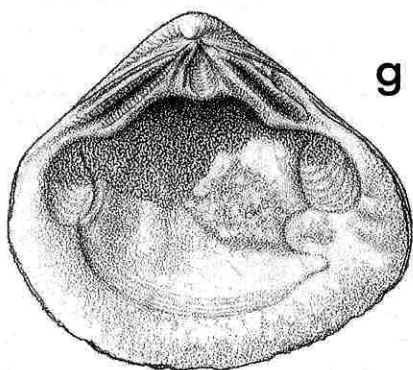
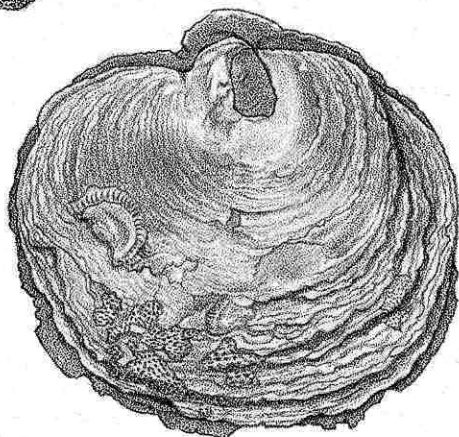
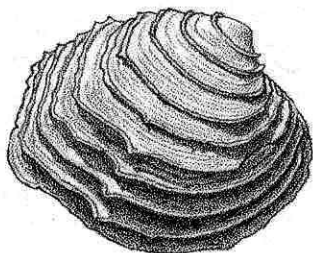
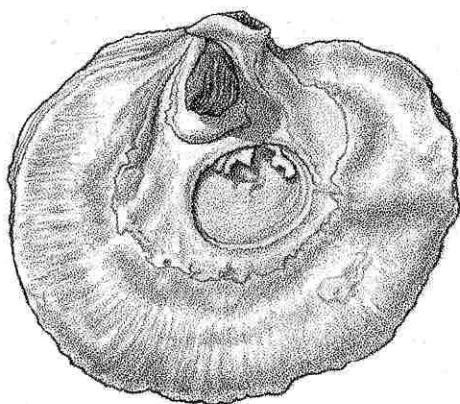
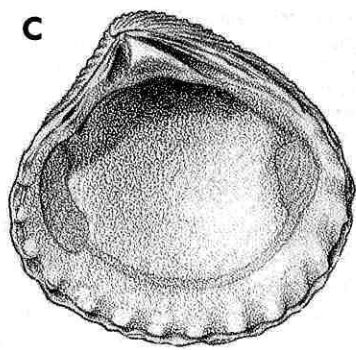
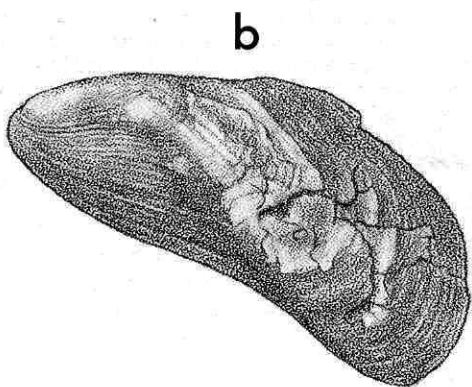
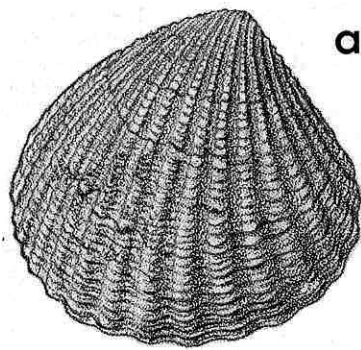
Small for family (15-19 mm long), weakly inflated, oval, with umbo central to slightly behind centre. Sculpture of even, relatively coarse, wide commarginal ridges with strongly convex cross-section and narrow interspaces. Interior of ventral margin smooth. Hinge deep and solid; umbonal region filled, not hollow. Tall, narrowly triangular, central resilifer is flanked on posterior by long, narrow, ligamental groove; and on anterior by 2 narrow, cardinal teeth and long, narrow, anterior lateral tooth on valve margin in right valve, and by 1 narrow cardinal tooth and 2 long, narrow, anterior lateral teeth in left valve. Adductor scars oval, almost equal; no pallial sinus.

Mangapanian-Nukumaruan; Castlepoint, west Wairarapa coast, Nukumaruan (type), common; uncommon in shelf mudstone and muddy shellbeds in Wanganui basin and Wairarapa.

The living *Talabrica bellula* (A. Adams) has weaker, rather irregular commarginal sculpture, whereas other named species (*T. nummaria*, Nukumaruan; *T. inornata*, Nukumaruan) have considerably weaker sculpture than *T. bellula*. Early and middle Cenozoic Crassatellidae are much larger than *Talabrica*, and belong in *Eucrassatella* or *Spissatella*, except for the tiny (3-8 mm long) species of *Salaputium*.

Plate 39 Nukumaruan (late Pliocene-early Pleistocene) Mollusca (2).

- a,c. *Pleuromeris hectori* Powell, x 3.
- b. *Xenostrobus huttoni* (Suter), x 1.
- d,f. *Patro undatus* (Hutton), x 0.67.
- e,h. *Bassina parva* Marwick, x 2.
- g,i. *Spisula (Spisulona) crassitesta* (Finlay), x 1.
- j,k. *Lutraria solida* Hutton, x 0.67.



Figured specimen (Pl. 40b, f): GS1820, U26/f6451, Castlepoint, west Wairarapa coast, Nukumaruan (NZGS) x 2.

Pl. 39 g,i. *Spisula (Spisulona) crassitesta* (Finlay, 1927) [*Hemimacra crassa* Hutton 1885b, p. 322; *Macra (Mactroderma) crassa* of Suter 1915, p. 57 (secondary homonym of *Macra crassa* Turton, 1822); *Macra crassitesta* Finlay 1927b, p. 531 (new name for *Macra crassa* (Hutton), preoccupied)]. Type species of *Spisulona* Marwick, 1948 (Mactridae: Mactrinae).

Moderate-sized for genus (43–57 mm long), subtrigonal, very thick and solid, moderately inflated, almost equilateral, with short, straight antero-dorsal margin, slightly longer, straight, postero-dorsal margin, and strongly convex ventral margin. Exterior smooth except for prominent growth ridges and weak ridge extending from umbo to postero-ventral corner. Hinge very thick, with 2 long, very thick, coarsely transversely striated lateral teeth on each side in right valve and 1 on each side in left valve, and beneath umbo deep, narrow, spoon-shaped resilifer and (presumably) very small, thin cardinal teeth (broken off all known material). Adductor scars oval, almost identical, deeply impressed. Pallial sinus very small, rounded, at anterior end of posterior adductor scar.

Nukumaruan; “Wanganui”, type; the precise locality has never been discussed or resolved, but the most probable horizons are Nukumar Limestone and Nukumar Brown Sand at Nukumar Beach. A restricted but uncommon Nukumaruan species, occurring in high-energy, shallow-water (e.g., coquina limestone) or estuarine deposits in Wanganui basin and Hawke’s Bay; two valves were collected with many *Barytellina*, *Mactrona*, *Xenostrobus* and *Zeacumantus* and a few valves of *Cyclomactra* in the estuarine bed on Kaiwaka South Road, central Hawke’s Bay.

The very thick shell, solid hinge with coarsely ridged lateral teeth, and evenly trigonal shape make *Spisula crassitesta* easily recognised. The Waipipian *S. couttsi* (Otahuhu Brewery well) is longer, less evenly triangular, and with a much thinner shell; slightly thinner, more oval, but less equilateral specimens from the late Nukumaruan Maxwell beds at Ototoka Beach, Wanganui may represent a further species distinct from *S. crassitesta*. The species group of *S. (Crassula) aequilatera* (Tongaporutuan-Recent; abundant now on oceanic sand beaches) is readily distinguished by its much more strongly trigonal form, with a prominent umbonal-ventral ridge at the posterior end, and by its smooth lateral teeth. Typical *Spisula* species have transversely striated lateral teeth, and *S. aequilatera* is possibly not closely related to *Spisula* (sensu stricto).

Figured specimen (Pl. 39g, i): GS12857, V20/f136, Kaiwaka South Road, southwest of Devil’s Elbow, 30 km north of Napier, central Hawke’s Bay, Nukumaruan (NZGS) x 1.

Pl. 39 j,k. *Lutraria solida* Hutton, 1873 [*Lutraria solida* Hutton 1873b, p. 19; *Mesodesma grandis* Hutton 1873b, p. 20] (Mactridae: Lutrariinae).

Large for family (110–130 mm long), elongate; umbo at anterior third; dorsal and ventral margins lightly curved, weakly diverging, ventral margin sloping slightly downwards towards posterior; anterior end gaping narrowly all around (allowing rocking of valves for burrowing), posterior end slightly truncated and widely gaping postero-dorsally. Exterior smooth apart from growth ridges and periostracal wrinkles. Hinge narrow apart from large, very thick, postero-ventrally inclined, triangular resilifer protruding down below umbo; 2 thin, narrowly

separated cardinal teeth in right valve (posterior one at anterior edge of resilial pit; anterior one partly fused with short but very prominent anterior lateral tooth), single small bilobed cardinal tooth in left valve; 1 or 2 short, indistinct posterior lateral teeth in right valve, 1 in left valve; no right anterior lateral tooth. Adductor scars large. Pallial sinus wide, very deep, extending forward almost to beneath umbo.

Waipipian-Nukumaruan; conglomeratic shellbeds near Greenwood’s Bridge, Lower Waipara Gorge, North Canterbury, Waipipian (type of *L. solida*); “East Coast, Wellington”, precise locality and age unknown (type of *Mesodesma grandis*). The two types were illustrated by Boreham (1965, pl. 18, fig. 7; pl. 19, fig. 1–4) who commented that the matrix of the holotype of *M. grandis* contains *Zethalia* (implying the large *Z. coronata* or *Z. zelandica* rather than the small Opoitian *Z. russelli*). Examination of the holotype (NZGS, TM2905) showed that at least 16 fragmentary *Zethalia* specimens, fragments of a large, smooth brachiopod (*Neothyris*?), barnacle plates, and a few small bivalve fragments occur in the matrix of hard, coarse, grey sand. Partial dorsal surfaces have been newly prepared on three *Zethalia* specimens, revealing a smooth surface with no subsutural gemmae, indicating a Nukumaruan age. We are not aware of any localities for *Lutraria solida* in Wairarapa district, and it seems likely that “Wellington” should be interpreted in a very broad sense (remembering the publication date of 1873), and that the provenance was Hawke’s Bay.

Lutraria solida is common in the Waipipi Shellbeds at Waverley Beach, west of Wanganui (Waipipian), uncommon in several Mangapanian shellbeds in Wanganui basin (Makokako Shellbed, Mangapani Shell Conglomerate), and common in Nukumar Limestone and abundant and well preserved in Nukumar Brown Sand at Nukumar Beach, Wanganui (Nukumaruan); it was also recorded from several Nukumaruan localities in the Rangitikei Valley by Te Punga (1953). In Hawke’s Bay, it is common at a few semiestuarine sand localities of Nukumaruan age (notably in Kikowhero Stream, Matapiro Station, north of the Ngaruroro River, the former “Shrimpton’s” of early collectors, and a possible source of the holotype of *Mesodesma grandis*; and in the Okauawa Stream area, Kereru Road). In North Canterbury, it seems to occur only in Lower Waipara Gorge and in Middle Waipara River opposite “The Deans” (both probably Waipipian; “The Deans” locality is possibly Mangapanian).

The Otaian-Altonian *L. trapezoidalis* is a little smaller than *L. solida*, with more nearly parallel dorsal and ventral margins and more rounded ends. The extinction of the genus at the end of Nukumaruan time is a useful biostratigraphic index. However, there are no records from rocks between Altonian and Waipipian, suggesting either that its shallow habitat is not preserved (the more likely alternative), or that the two species represent distinct dispersals to New Zealand.

Figured specimen (Pl. 39j, k): GS1164, R22/f6348, Nukumar Brown Sand, Nukumar Beach, Wanganui, Nukumaruan (TM2903, NZGS) x 0.67.

Pl. 40 c,d. *Paphies porrecta* (Marwick, 1928) [*Amphidesma (Taria) porrectum* Marwick 1928, p. 468] (Mesodesmatidae).

Large for genus (83–93 mm long), moderately thick, relatively low, with

long rounded anterior end but moderately short, only weakly convex posterior end and lightly angled postero-ventral extremity. Weak ridge extending from umbo to postero-ventral extremity; postero-dorsal area protruding and lightly convex. Exterior sculpture of low growth ridges only. Hinge thick but narrow, with deep, long, vertical, narrowly spoon-shaped resilifer beneath umbo, 1 long, thin, anterior cardinal tooth in each valve, fused with anterior lateral tooth in right valve but separated from it by deep groove in left valve (all other cardinal teeth broken off all material examined); 1 relatively short, thin, anterior and posterior lateral tooth in each valve. Adductor scars subequal, weakly impressed. Pallial line only weakly sinuous, apart from a moderately deep, upward-directed sinus with rounded corners, in front of posterior adductor scar.

Nukumaruan; Titirangi Sand, Titirangi Point, Karewa Peninsula, Chatham Island, Nukumaruan (type), abundant; also abundant in Titirangi Sand in the quarry at Moutapu Point, Chatham Island.

A similar form to *Paphies porrecta* still lives today on the sand beaches of Petre Bay, Chatham Island, but Smith et al. (1989) demonstrated that this is a form of *P. subtriangulata*. Closely similar forms are also abundant in Tangoio limestone (Nukumaruan) near Napier, Hawke's Bay. The relationship of *P. porrecta* to the similar but shorter and higher, more heavily hinged *P. donacina* needs further study; *P. donacina* is the abundant "southern tuatua" living now on sandy beaches throughout most of New Zealand, and occurring fossil in Mangapanian(?) to Castlecliffian sandy beach facies. *P. porrecta* is also similar in many characters to the "toheroa", *Paphies ventricosa* (Castlecliffian-Recent), but is much smaller and with less nearly parallel dorsal and ventral margins than *P. ventricosa*.

Figured specimen (Pl. 40c, d): holotype, Titirangi Sand, Titirangi, Chatham Island, Nukumaruan (TM4738, NZGS) x 1.

Pl. 40 a,e. *Paphies crassiformis* (Marshall and Murdoch, 1920) [*Amphidesma* (*Taria*) *crassiformis* Marshall and Murdoch 1920, p. 136] (Mesodesmatidae).

Large for genus (80 mm long), exceedingly thick and solid, with long, rounded anterior end but very short, squarely truncated posterior end. Anterodorsal, ventral, and posterior margins all lightly curved, meeting at almost right angles at umbo and postero-ventral corner. Prominent, weakly bi-angled ridge extending from umbo to postero-ventral corner; exterior otherwise sculptured only with weak growth ridges. Hinge exceedingly thick and deep (much the thickest of any mesodesmatid we are aware of), with long, narrow, deep, vertical, parallel-sided resilifer below umbo, thin anterior cardinal lamella above top of resilifer in each valve (other cardinal teeth broken off all specimens seen), and in right valve 2 exceedingly massive anterior and 2 similar posterior lateral teeth, each pair margining an exceedingly wide, deep socket for equally massive lateral teeth of left valve. Adductor scars almost equal, deeply impressed. Pallial line only weakly sinuous, except for small, shallow, almost square sinus in front of posterior adductor scar.

Nukumaruan; "blue clays", Nukumar Beach, Wanganui (type), almost certainly from the Tewkesbury Formation; rare at Nukumar, and in Okauawa Stream, Kereru Road, inland central Hawke's Bay.

Paphies crassiformis is an extremely unusual species, easily recognised by its thick shell and massive hinge; it is known only from near-estuarine muddy facies, so may have inhabited an unusual environment that was rarely preserved.

Figured specimen (Pl. 40a, e): holotype, Nukumar Beach, Wanganui, Nukumaruan (TM4736, NZGS) x 1.

Pl. 41 e,f. *Barytellina crassidens* Marwick, 1924 [*Barytellina crassidens* Marwick 1924a, p. 26; *Barytellina*

anomalous Finlay 1924b, p. 473]. Type species of *Barytellina* Marwick, 1924 (Tellinidae: Tellininae).

Moderate-sized for family (28-35 mm long), with very thick shell for family, variable in shape from almost equidimensional to relatively long and narrow; exterior almost smooth, lightly polished, with weak growth ridges, weakly flexed to right at posterior end, and with prominent rounded ridge down the dorsal posterior angle of right valve. Hinge unusually large and thick for family, with very large, thick, triangular, posterior cardinal tooth in right valve and 2 narrower ones in left valve, no anterior lateral teeth but large, prominent posterior lateral teeth in both valves. Adductor scars small, deeply impressed; pallial sinus extremely deep, extending to anterior adductor scar, lower margin confluent with pallial line.

Waipipian(?) - Haweran; Nukumar Beach, west of Wanganui, Nukumaruan (type of *B. crassidens*), presumably from either Tewkesbury Formation or, more probably, an estuarine horizon in the Maxwell beds (uppermost Nukumaruan, and estuarine to non-marine); Rissington, Hawke's Bay, Nukumaruan (type of *B. anomalous*). It is uncertain whether an earlier (Waipipian-Nukumaruan) more elongate species (*B. tertia*) can be distinguished from a later, shorter one (Nukumaruan-Haweran); Marwick (1948, p. 20) referred to the variability and consequent taxonomic difficulty of the genus, and subsequent collections have only made the situation more clouded. We are inclined to recognise only one species. Common in the Otahuhu well shellbed, Auckland (Waipipian); in a few estuarine beds high in the type Nukumaruan section at Nukumar, Wanganui; in estuarine gravelly mudstone (with common *Macrona* and *Zeacumantus*) on Kaiwaka South Road, near Devil's Elbow, Hawke's Bay; and in estuarine mudstone at the top of the marine sequence in Makara River, downstream from Hautotara Bridge, east of Martinborough, Wairarapa (Nukumaruan); also scattered at many Nukumaruan localities in Hawke's Bay and Wairarapa. Abundant at one Castlecliffian locality in the Rangitikei Valley, and a single fresh, large valve is known from Haweran (oxygen isotope stage 9) marine terrace cover beds on Brunswick Terrace, west of Wanganui.

Barytellina crassidens is easily recognised by its thick shell, its smooth, often polished exterior, and unusually massive hinge for a tellinid; the very large, triangular cardinal tooth of the right valve and the large posterior tooth are particularly distinctive.

Figured specimen (Pl. 41e, f): GS2620, S27/f8459, "Barytellina mudstone" downstream from Hautotara Bridge, Makara River, southern Wairarapa, Nukumaruan (NZGS) x 1.5.

Pl. 41 a,b. *Austrovenus stutchburyi* forma *crassitesta* (Finlay, 1924) [*Venus stutchburyi* Gray in Wood 1828, fig. 4; *Venus zelandica* Quoy and Gaimard 1835, p. 522; *Venus dieffenbachii* Gray 1843, p. 250; *Chione macleayana* T. Woods 1879, p. 38 (see Hedley 1902, p. 77); *Chione crassitesta* Finlay 1924b, p. 478; *Chione* (*Austrovenus*) *aucklandica* Powell 1932a, p. 68; *Austrovenus stutchburyi* of Fischer-Piette and Vukadinovic 1977, and of Jones 1979, p. 157; *Chione stutchburyi*]. Type species of *Austrovenus* Finlay, 1926 (Veneridae: ? Chioninae).

Moderate-sized for family (15-65 mm long), exceedingly variable in shell thickness, shape, inflation, height, and sculptural prominence; subcircular, weakly trigonal, or elongate-oval in outline, with umbo low to strongly protruding. Most forms inflated and thick-shelled; one of very few New Zealand Veneridae with both radial and commarginal

sculpture prominent (commarginal lamellae are relatively weak on some forms from low-salinity environments). Radial costae low, wide, and flat-topped; becoming weak near ventral margin of large shells. Commarginal lamellae thin, moderately prominent, widely spaced, regular and prominent near umbo but irregular near ventral margin of large specimens. Interior of ventral margin complexly crenulate, with 2 orders of crenulating ridges. Hinge wide, with long, prominent ligamental nymph, and escutcheon defined only by an unsculptured area above nymph; right valve with 2 thick, bifid cardinal teeth, thin posterior cardinal tooth, and short, knob-like anterior lateral tooth; left valve with 2 thick, bifid cardinal teeth, weak posterior lateral ridge, and only anterior lateral socket. Adductor scars deeply impressed, anterior slightly narrower than posterior. Pallial sinus short, narrow, triangular.

Opoitian(?)—Recent. Recent, New Zealand (types of *Venus stutchburyi*, *Venus zelandica*, *Venus dieffenbachi*; ? and of *Chione macleayana*, either an introduced Tasmanian specimen or a wrongly localised New Zealand one); Recent, Auckland Islands, subantarctic (type of *Chione aucklandica*); Clifton, Cape Kidnappers, Hawke's Bay (from the young "*Austrovenus* beds" high in the Castlecliffian (-Haweran ?) coastal cliff section east of Clifton—probably from the Te Awanga beds in Clifton Gully or Gordon Gully inland from the coast section), type of *Chione crassitesta*.

Austrovenus stutchburyi is the superabundant edible "cockle", living partially buried (the posterior end of the shell protrudes, and so is usually bored by the polychaete *Polydora*) in sand, gravel, or muddy sand in the low-tidal zone of New Zealand's present-day estuaries and enclosed bays, varying greatly with the salinity, substrate and food supply. It is the dominant infaunal bivalve in the upper parts of estuaries, and in brackish streams pure populations (or at some places with *Xenostrobus securis* and *Melanopsis trifasciata*) can consist of shells of very small maximum size, perhaps only 15 mm long. Faunules consisting of 100% *A. stutchburyi* (or nearly so) are encountered in many sand and mud flats in the upper parts of estuaries, with shells in the size range of 20–50 mm long. Large shells (40–60 mm long) are found abundantly in the outer parts of bays with higher salinity and more diverse faunas (including such bivalves as *Dosinia subrosea* and *Ruditapes largillierii*). The genus is unknown in fully marine situations (with such bivalves as *Dosinia anus* or *Spisula aequilatera*). Many fossil estuarine faunules from Nukumaruan, Castlecliffian and (in particular) Haweran rocks contain 100% *A. stutchburyi*, clearly implying deposition in the mid-upper reaches of an estuary. However, fossil assemblages are also often encountered that consist of *A. stutchburyi* (with or without other estuarine taxa) as well as open-ocean taxa such as *Dosinia anus*; these assemblages seem to

represent accumulation in a bay-bar or similar situation, with shells contributed from several environments. *A. stutchburyi* is certainly one of the most abundant of all late Neogene macrofossils.

The taxonomy of the genus is poorly understood. We illustrate the form Finlay (1924b) regarded as the "species" *A. crassitesta*, and that some authors have thought to be a restricted Nukumaruan taxon (Marwick 1927, p. 621); this is, however, the most common form in Haweran shellbeds along the Wanganui-South Taranaki coast, is presumably Castlecliffian (but possibly Haweran) at its type locality, and can be matched in modern faunas. The species is so exceedingly variable according to ecological station that we doubt that any named forms are species distinct from *A. stutchburyi*, with the possible exception of *A. tamakiensis* (Waipipian, Otahuhu Brewery well; low, weakly sculptured, and with a relatively prominent escutcheon). The genus is first known to us in Waitakian rocks (a near-shore faunule in the Maitara River, Southland, near Brydone) when it was represented by very small, short, upright shells sculptured much as in *A. stutchburyi*. However, records from pre-Wanganui Series rocks are extremely scarce.

Jones (1979) found the anatomy of *A. stutchburyi* abundantly distinct from that of American *Chione* species, proving that the resemblance in shell characters is due to convergence.

Figured specimen (Pl. 41a, b): GS1164, R22/f6348, Tewkesbury Formation, Nukumar Beach, Wanganui, Nukumaruan (NZGS) x 1.

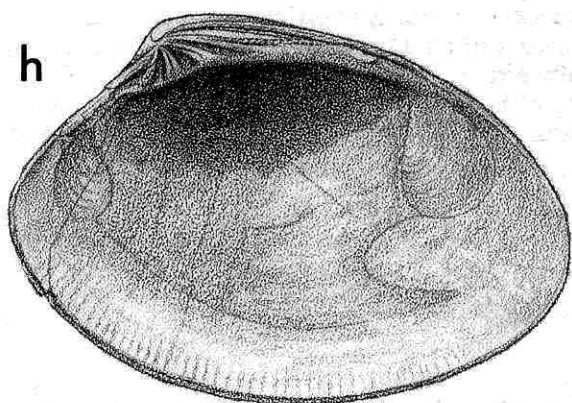
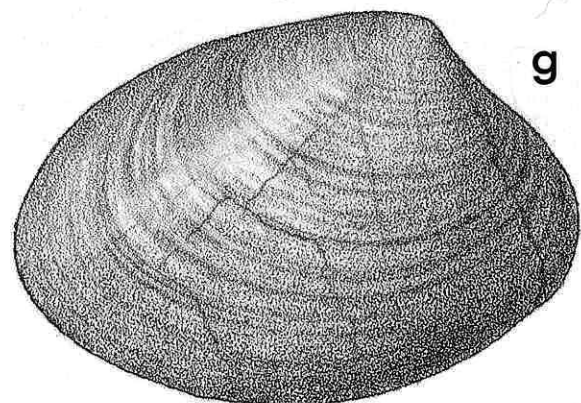
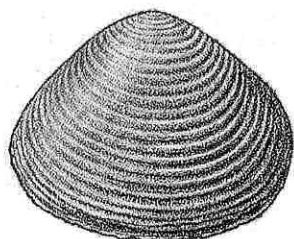
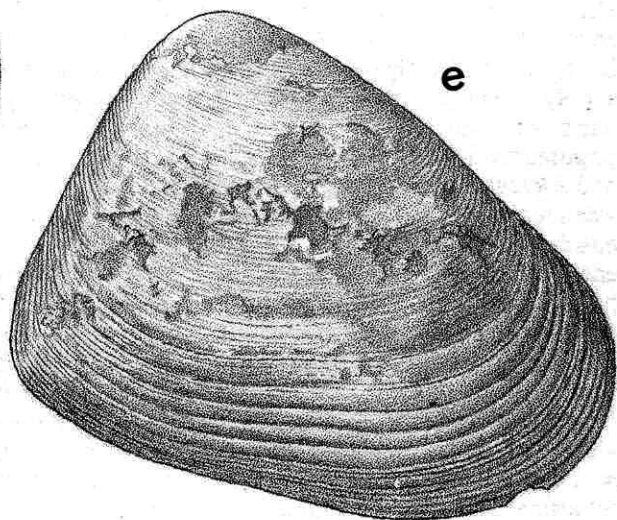
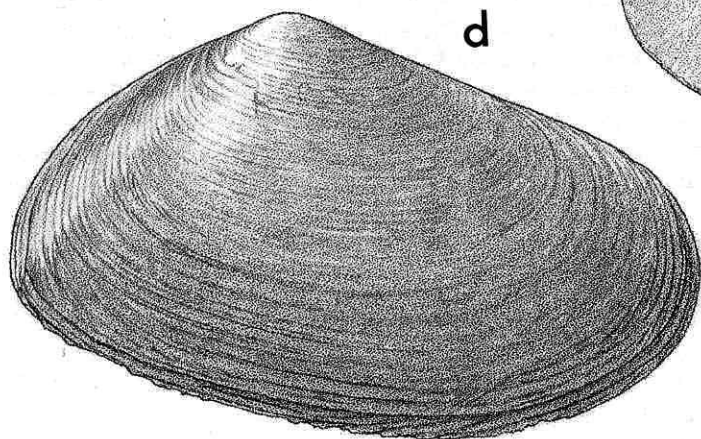
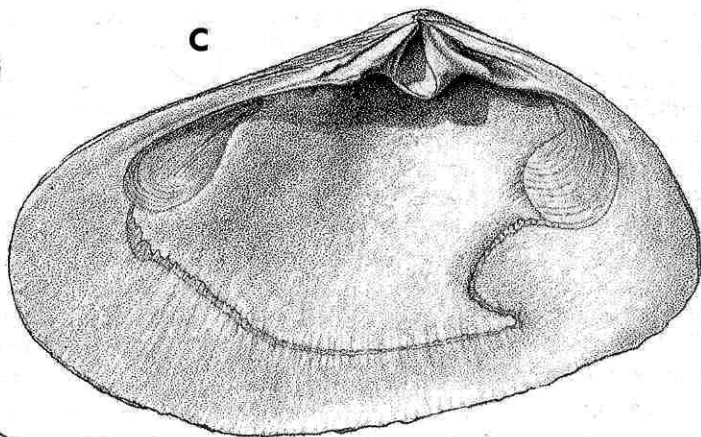
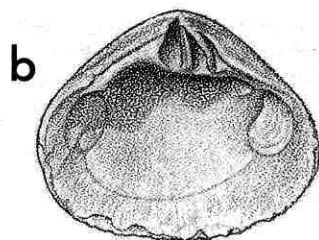
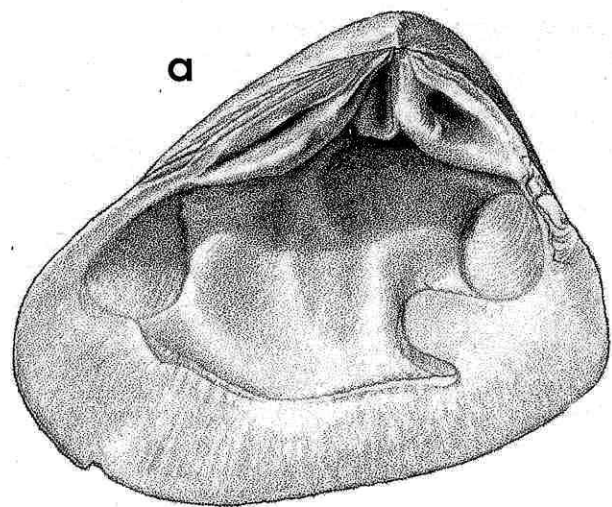
Pl. 39 e,h. *Bassina parva* Marwick, 1927 [p. 619] (Veneridae: Chioninae).

Very small for genus (13–21 mm long), moderately elongate, with strongly prosogyrous umbo, strongly concave and deeply impressed lunule, evenly rounded anterior end, quadrate posterior end, lightly concave posterior ventral margin but evenly convex anterior ventral margin, and a prominent angulation from umbo to postero-ventral corner. Sculpture of few, widely spaced, high, thin, frilled, commarginal lamellae, concave dorsally in cross-section, bearing short spine-like flutes down posterior ridge and another, faintly defined, radial ridge slightly behind middle of length. Interior of ventral margin finely but deeply crenulate. Hinge short, deep, strongly inclined downward towards anterior; right valve with very narrow, grooved posterior cardinal tooth, median wide, triangular one and thin anterior cardinal one parallel to lunule; left valve with long, vertical, narrow anterior cardinal tooth, stout grooved median one, and lamellar posterior cardinal fused to nymph. Adductor scars very small, subcircular. Pallial sinus deep, narrowly triangular.

Mangapanian-Nukumaruan; Okauawa Stream, Kereru Road, inland central Hawke's Bay, Nukumaruan (type);

Plate 40 Nukumaruan (late Pliocene-early Pleistocene) Mollusca (3).

- a,e. *Paphies crassiformis* (Marshall and Murdoch), x 1.
- b,f. *Talabrica senecta* Powell, x 2.
- c,d. *Paphies porrecta* (Marwick), x 1.
- g,h. *Eumarcia* (*Eumarcia*) *plana* Marwick, x 1.



known from one Mangapanian locality (base of sand zone upstream from rail viaduct, Mohaka River, northern Hawke's Bay; with *Bassina yatei*, *Austrofuscus pliogenicus*, *Pellicaria* n. sp. aff. *zelandiae*, *Struthiolaria* n. sp. aff. *frazieri*); abundant at many Nukumaruan localities in Wanganui basin, Hawke's Bay, Wairarapa, and North Canterbury, always in shallow-water sandstone with diverse Mollusca.

Bassina parva is commonly sympatric with the much larger, more oval *B. yatei* (Waipipian-Recent), which lacks the median "speighti rib" of *B. parva* and older species; apparently descended from the slightly larger, more inflated *B. katherinae* (Waipipian-(?)Mangapanian); much smaller and with closer lamellae and a weaker median radial ridge than *B. speighti* (Pl. 10 h; Duntroonian-Tongaporutuan). *Bassina* species are discussed in more detail under *B. speighti*.

Figured specimens (Pl. 39e, h): holotype, GS1089, V21/f8482, Okauawa Stream, Kereru Road, Hawke's Bay, Nukumaruan (TM2207, NZGS) x 2 (Pl. 39e, exterior); GS3339, S27/f576, Makara River, east of Martinborough, southern Wairarapa, Nukumaruan, sympatric with *B. yatei* (NZGS) x 2 (Pl. 39h, interior).

Pl. 40 g,h. *Eumarcia (Eumarcia) plana* Marwick, 1927 [p. 627] (Veneridae: Tapetinae).

Large for genus (60-100 mm long), elongate-oval, with low umbo at anterior quarter of length; lunule only a slightly concave area, not marked off by groove; interior ventral margin smooth; exterior smooth and polished except for weak growth lines. Hinge narrow; right valve with long, low, weak, posterior cardinal lamella on nymph edge and 3 other almost equally long, more anterior cardinals, the median and posterior ones grooved; left valve with 3 prominent cardinal teeth only, the posterior one not separated from nymph by a groove, the median one deeply grooved. Anterior adductor scar small, oval; posterior adductor scar of similar shape to but much larger than anterior one. Pallial sinus short but deep, with pointed anterior end a short distance in front of posterior adductor scar.

Waipipian-Nukumaruan; "boat-landing, Nukumarua" (i.e., Nukumarua Beach, west of Wanganui, almost certainly from Nukumarua Brown Sand), Nukumaruan (type); abundant in relatively few shallow-water, near-shore, soft-bottom facies, particularly in some Nukumaruan limestone beds in Hawke's Bay, and in the Waipipi Shellbeds (Waipipian), Waverley Beach, and the Nukumarua Brown Sand (Nukumaruan), Nukumarua Beach, both west of Wanganui; also found in other Waipipian-Nukumaruan shellbeds and limestone in Wanganui, Hawke's Bay, Wairarapa, North Canterbury, and Titirangi, Chatham Islands (Nukumaruan). The extinction of the genus in New Zealand is a useful marker of the end of Nukumaruan time.

Eumarcia plana is much the most common and widespread large, smooth *Eumarcia* species in New Zealand; the South Canterbury *E. pareoraensis* (Otaian-Altonian) is smaller and more elongate, and other *Eumarcia (Eumarcia)* species are rare. Species of subgenus *Eumarcia (Atamarcia)* have a sunken, groove-bounded lunule, and many have prominent commarginal sculpture (see *E. thomsoni*, Pl. 28e and *E. benhami*, Pl. 36a, b). Figured specimen (Pl. 40g, h): shellbed on north bank of Mangahao River 1.6 km south of Mangahao, northern Wairarapa, Nukumaruan (M33633, National Museum of N.Z.) x 1.

Pl. 41 c,d. *Marama (Marama) murdochi* Marwick, 1927 [*Marama murdochi* Marwick 1927, p. 604; *Marama murdochi marwicki* Beu 1970a, p. 121]. Type species of *Marama* Marwick, 1927 (Veneridae: Venerinae).

Moderate-sized for family (40-55 mm long), thin, regularly oval, moderately to very highly inflated, very finely sculptured. Lunule exceedingly large and prominent, pouting above its bounding groove, extending almost to anterior end of shell. Sculpture of very low, very thin, closely spaced commarginal lamellae, 2-4 per mm, largely abraded off many specimens. Interior of ventral margin very finely crenulate. Hinge narrow, with short, tubercular anterior lateral tooth, triangular anterior cardinal tooth, unequally divided median cardinal, and long, straight posterior one separated from nymph by a groove in left valve; right valve with moderately deep anterior lateral pit, narrow anterior cardinal tooth, median cardinal unequally grooved, and posterior cardinal very large, deeply grooved. Pallial sinus moderately deep, narrowly triangular.

Kapitean-Nukumaruan. Waihi Beach, Hawera, South Taranaki, Waipipian (type of *Marama murdochi*); Upton Brook, Awatere Valley, Marlborough, Kapitean (type of *M. murdochi marwicki*). Common in mudstone (i.e., it burrowed in soft substrates) deposited in mid-shelf to upper bathyal depths, throughout New Zealand.

The slightly more elongate Kapitean-Opoitian form for which Beu (1970a) erected the subspecies *Marama murdochi marwicki* is no more different from "typical" Waipipian shells than are the short, highly inflated Nukumaruan shells common in southern Wairarapa; there seems little point in subdividing this variable species. *M. hurupiensis* (Tongaporutuan) is larger, less inflated, more coarsely sculptured, and has a lower, narrower lunule; *Dosina* species are more coarsely sculptured, have very much smaller lunules and typically have a much shorter pallial sinus. Extinction of the genus and species is a useful index of the end of Nukumaruan time.

Figured specimens (Pl. 41c, d): Waihi Beach, Hawera, South Taranaki, Waipipian (NZGS, from an early collection—Marshall and Murdoch Collection ?) x 1 (Pl. 41d, exterior); paratype, GS1173, Q21/f6495, Waihi Beach, Hawera, Waipipian (TM4519, NZGS) x 1 (Pl. 41c, interior).

Pl. 41 g,j. *Tawera subsulcata* (Suter, 1905) [*Venus sulcata* Hutton 1887, p. 226 (in part only); *Chione subsulcata* Suter 1905b, p. 205; *Cytherea subsulcata*] (Veneridae: Chioninae).

Large for genus (30-35 mm long), weakly trigonal in outline (with only lightly convex antero-dorsal and postero-dorsal margins), moderately inflated. Sculpture of many coarse, prominent, commarginal ridges, 7-8 per cm near ventral margin, narrower and weakly anastomosing near anterior and posterior ends; each ridge concave dorsally and strongly convex ventrally in cross-section, crossed by very fine radial threads, and (an unusual character for *Tawera*) separated from neighbouring ridge by a gap about half the width of 1 costa. Lunule narrow, slightly concave, marked off by deep groove. Interior of ventral margin finely crenulate. Hinge moderately deep, with 3 narrow cardinal teeth in each valve, median one deeply grooved in left valve, and both posterior and median ones grooved in right valve. Adductor scars large, oval. Pallial sinus short and very narrow.

Nukumaruan (-Haweran?). Nukumarua Beach, west of Wanganui (presumably from either Nukumarua Brown Sand or Tewkesbury Formation), Nukumaruan, lectotype of *Chione subsulcata*; Marwick (1927, p. 616) identified this specimen as a "neotype" in the text, but as a "lectotype" in the figure caption; the specimen cannot be found in NZGS (Keyes 1972, p. 81) and its status is in doubt. Suter (1905b, p. 205) stated that his name *Chione*

subsulcata was a new name for *Venus sulcata* Hutton of Pliocene usage (i.e., not the much larger "Miocene" taxon Hutton also included under this name, = *Eumarcia benhami*). However, Suter's action constitutes proposal of a new species, and as Suter did not select a holotype, all the specimens he had before him must be construed as syntypes. As the lectotype(?) selected by Marwick (1927) is lost, a new lectotype should be selected from remaining Suter syntypes, if any can be positively identified. As the taxonomy of *Tawera* is subtle and poorly understood, care is needed to be sure the name is conserved in its present usage.

Tawera subsulcata (as used at present, assuming the lectotype comes from Nukumarū) is a little taller and considerably larger, thicker, and more coarsely sculptured than the common near-shore, Castlecliffian and living, mainland *T. spissa*, but not as tall or nearly circular as the southern living *T. marionae* Finlay and *T. bollonsi* Powell; the Hawke's Bay Nukumaruan *T. assimilis* is longer and lower than *T. subsulcata*, whereas the Chatham Islands Nukumaruan *T. marthae* is considerably larger but more finely sculptured than *T. subsulcata*. Really typical *T. subsulcata* (with spaces between the commarginal ridges) occurs only in Nukumarū Limestone, Nukumarū Brown Sand, and Tewkesbury Formation at Nukumarū Beach, west of Wanganui (Nukumaruan), but similar shells occur in the Nukumaruan of Wairarapa and North Canterbury and in many Haweran terrace faunas around Wanganui, in Cook Strait, and around the eastern South Island; always in extremely shallow-water, soft-bottom facies.

Figured specimen (Pl. 41g, j): GS1164, R22/f6438, Tewkesbury Formation, Nukumarū Beach, west of Wanganui, Nukumaruan (NZGS) x 1.5.

Pl. 41 k,m. *Myadora stephaniae* Carter, 1972 [*Myadora striata stephaniae* Carter 1972, p. 310] (Myochamidae).

Large for genus (34-37 mm long), low and elongate, with right valve weakly convex and left valve flat, and with highly convex anterior dorsal outline, opisthogyrous beaks, straight or weakly concave posterior dorsal outline, and evenly convex ventral outline; 2 prominent ridges below posterior dorsal margin in right valve. Sculpture of prominent, narrow, commarginal ridges on right valve, but little on left valve except near anterior and posterior ends. Interior nacreous, with smooth margin, 2 nearly equal adductor scars, small pallial sinus, and hinge that is smooth apart from small, prominent, triangular resilifer.

Mangapanian-Nukumaruan; tributary of Te Ekaou Creek, near Pohangina, eastern Wanganui basin, late Mangapanian or early Nukumaruan (type); widespread but uncommon in near-shore sand facies in Wanganui basin and Hawke's Bay.

Although it was proposed as a "subspecies" of the Nukumaruan to Recent *Myadora striata*, in our opinion *M. stephaniae* is a distinct species. *M. stephaniae* is longer and much lower than the equally large *M. striata*, and has much more prominent commarginal ridges. *M. striata* lives buried in sand in a few metres of water off quiet beaches. All other species of *Myadora* are much smaller than these two.

Figured specimen (Pl. 41k, m): GS2773, T23/f6488, Mangatuatua Stream, near Pohangina, eastern Wanganui basin, Nukumaruan (NZGS) x 1.5.

Pl. 41 o,p. *Panopea wanganuica* Powell, 1950 [p. 80] (Hiattellidae).

Large for genus (90-110 mm long), long and relatively low, with narrow anterior gape and very wide posterior gape; dorsal and ventral margins almost straight, parallel or converging slightly towards posterior. Sculpture of prominent, irregular, commarginal folds. Margins smooth. Hinge without teeth, but with prominent narrow resilifer behind the umbo, and (in well preserved shells) long, thin, curved apophysis protruding at right angles to hinge. Anterior adductor scar tall and narrow, posterior smaller and more equidimensional; pallial line wide and obvious, with very deep sinus extending forward to below umbo.

Waipipian(?)-Castlecliffian (-Recent ?). Castlecliff, Wanganui (CL10d = pelecypod shellbed member of Kupe Formation), Castlecliffian (type); widespread in New Zealand in rocks of Pliocene to middle Pleistocene age.

Panopea zelandica (Kapitean ?-Recent) has a much shallower pallial sinus, less than half the length of that of *P. wanganuica*, and most specimens are taller and more squarely truncated at the posterior end than in *P. wanganuica*. Powell (1950, p. 76-80) distinguished two deep-sinused species, the fossil *P. wanganuica* and the living *P. smithae*, differing in shell shape, but *Panopea* species are notoriously variable in shape, depending on the substrate they burrow in, and the great variation of both the fossil and living shells makes two species difficult to separate. *P. zelandica* is a shallow-water species, burrowing 0.7 m or more into sand in large bays and on the inner shelf, in water up to about 30 m deep; *P. smithae* lives in a greater variety of sediments (coarse shell gravel to muddy sand) and in a greater depth range (e.g., in Wellington Harbour, but in deeper water than *P. zelandica*, to outer shelf). Both *P. zelandica* and *P. wanganuica* are commonly found fossil in life position, with conjoined valves normal to bedding; *P. zelandica* is the more common in shallow facies, and *P. wanganuica* is the more common in deeper facies. Typical large, cylindrical *P. smithae* occurs fossil in sand below the Cascade Moraine on the north side of Cascade Point, south of Jackson Bay (late Haweran). The Miocene *P. orbita* is more narrowly cylindrical, with more prominent commarginal folds, but age ranges are unclear.

Figured specimen (Pl. 41o, p): paratype (figured by Powell 1950, p. 79, fig. 8), Nukumarū Brown Sand, Nukumarū Beach, west of Wanganui, Nukumaruan (TM4775, NZGS) x 0.67.

Pl. 41 l. *Antalis nana* (Hutton, 1873) [*Dentalium nanum* Hutton 1873b, p. 1; *D. huttoni* Kirk 1880, p. 306; *D. marwicki* Mestayer 1926, p. 587; *Dentalium (Antalis) nanum*] (Dentaliidae).

Small for genus (15-37 mm long), most specimens around 20-25 mm long at maturity; tubular, narrow, gently tapered to a narrow apex, and lightly curved; open at both ends. Sculpture of simple, low, narrow-crested, longitudinal costae with shallowly concave interspaces; number of costae varying from 6 to 13, but most specimens having 8 or 9, and so roughly octagonal in section.

Altonian(?)-Recent. Shakespeare Cliff, Wanganui, Castlecliffian (type of *D. nanum*; Recent, New Zealand, "from the stomach of a trumpeter (*Latris hecateia*)" (type of *D. huttoni*); Castlecliff, Wanganui, "lower bed", Castlecliffian (type of *D. marwicki*). Abundant today buried with only the narrower apex protruding from soft substrates in shallow to moderately deep water (15-300 m; as shallow as 5 m or less in a few sheltered environments such as Orua Bay, Manukau Harbour) all around New Zealand; equally common in most New Zealand Pliocene and Pleistocene fine-grained rocks that

were deposited in this depth range; superficially similar specimens occur at Ardgowan and Target Gully, Oamaru (Altonian) but may not be conspecific.

The much larger (60-100 mm long) *Fissidentalium zelandicum*, common in Kapitean-Recent offshore facies, has coarser and much more numerous longitudinal costae than *Antalis nana*, and has a deep slit in the apical end. The only other moderately large scaphopod common in Pliocene rocks is *Antalis pareorensis* (Kapitean-Waipipian), a large, very gently tapered, almost smooth species (typical Pliocene specimens have fine longitudinal costae near the apex).

Figured specimen (Pl. 41l): GS10849, V20/f8572, Devil's Elbow mudstone, near top of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 2.

Pl. 41 i. *Taxonía suteri* (Marwick, 1924). [*Ataxocerithium suteri* Marwick 1924c, p. 195]. Type species of *Taxonía* Finlay, 1926 (Cerithiidae).

Small for family (10-18 mm high), very tall and narrow, with small aperture, very tall spire of 8 short whorls, weakly impressed suture, and almost flat-sided whorls. Sculpture of 3 prominent, wide spiral cords per whorl, crossed by prominent, closely spaced axial costae, 14 on early whorls, 16 on penultimate and 17 on last whorl, forming large, subcircular, radially flattened nodules at sculptural intersections; an interstitial, nodulous spiral cord develops between uppermost 2 primary cords on last whorl. Anterior canal short, narrowly open, strongly twisted but without obvious fasciole. Aperture with 3 very prominent, wide spiral ridges inside outer lip (2 high up and 1 near base), 2 similar ridges on parietal area, and 1 on base of columella. Protoconch not known.

Mangapanian-Nukumaruan; Okauawa Stream, Kereru Road, inland central Hawke's Bay, Nukumaruan (type). A very distinctive little shell, known only as severely abraded, clearly transported shells in very shallow-water facies, common in Okauawa Stream, Hawke's Bay, and in Tangoio Limestone at Petane, north of Napier, and found uncommonly in a few Mangapanian-Nukumaruan estuarine beds; *Taxonía* was apparently an estuarine genus.

The Waipipian *Taxonía tesserata* is larger than *T. suteri*, with subtly different sculpture (recorded only from Otahuhu Brewery well, Auckland). The Tongaporutuan *T. gudrunae* from Mt Bruce, northern Wairarapa, is

smaller than *T. suteri*, with a more convex spire outline. Very similar, unnamed species occur in estuarine mud lenses in conglomerate at Putangirua Stream, Palliser Bay (early Tongaporutuan) and in the Enys Formation (Altonian) in Porter River, Castle Hill Basin, Canterbury. Figured specimen (Pl. 41i): holotype, GS1063, V21/f8476, Okauawa Stream, Kereru Road, central Hawke's Bay, Nukumaruan (TM6769, NZGS) x 2.

Pl. 42 f. *Struthiolaria (Struthiolaria) frazeri* Hector in Hutton, 1885b [p. 329] (Struthiolariidae).

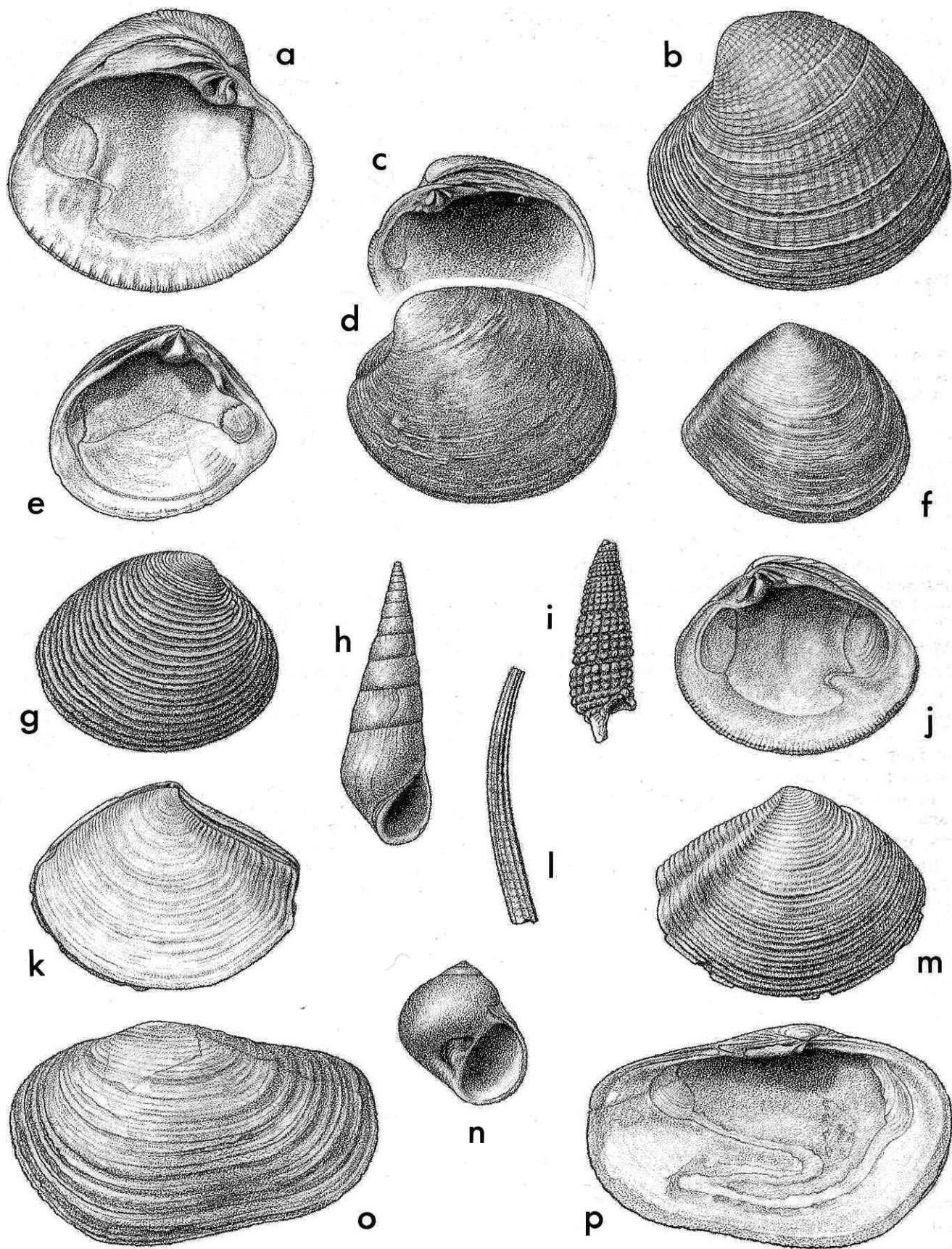
Large for genus (65-90 mm high), with very tall spire for family (slightly taller than aperture), strongly shouldered whorls, and a normal round *Struthiolaria* aperture with heavily thickened, strongly sinuous outer lip, heavily thickened and relatively wide inner lip with wide parietal callus, and shallow anterior notch. Sculpture of very prominent, wide spiral cords of almost square section, 3 closely spaced on sutural ramp, 1 particularly prominent (bifid and weakly nodulous on most specimens) around shoulder angle, 4 widely spaced on whorl sides, and a further 6 or 7 decreasing in prominence down base. Protoconch not seen, but presumably as in *S. papulosa* (Pl. 47r).

Nukumaruan; Kikowhero Stream, Matapiro Station, north side of Ngaruroro River, Hawke's Bay, Nukumaruan (type); common at very many localities of shallow-water, sandy facies (usually found as concentrated monospecific lenses) throughout the Nukumaruan rocks of central Hawke's Bay, and particularly abundant in a shellbed (the lower of two *Struthiolaria*-dominated shellbeds; the upper contains only *S. papulosa*) cropping out widely in road cuts on Kereru Road and in Okauawa and Whanakino Streams, inland central Hawke's Bay. Extensive collecting by many people over more than 100 years has produced only one or two specimens from Wanganui basin; we are aware of none from localities further south than the Kereru district, Hawke's Bay (the record from North Canterbury (Marwick 1924b, p. 182) has never been confirmed).

Struthiolaria frazeri is similar to the Mangapanian-Recent *S. papulosa* (Pl. 47r) but differs in its much taller spire, very much more prominent spiral sculpture, and more heavily thickened aperture. An apparently ancestral, unnamed species is smaller and has narrower spiral cords (abundant in Mangapanian sandstone between the Napier-Taupo road and Mohaka River, Hawke's Bay).

Plate 41 Nukumaruan (late Pliocene-early Pleistocene) Mollusca (4).

- a,b. *Austrovenus stutchburyi* (Gray) forma *crassitesta* (Finlay), x 1.
- c,d. *Marama (Marama) murchisoni* Marwick, x 1.
- e,f. *Barytellina crassidens* Marwick, x 1.5.
- g,j. *Tawera subsulcata* (Suter), x 1.5.
- h. *Eulima (sensu lato) christyi* Marwick, x 3.
- i. *Taxonía suteri* (Marwick), x 2.
- k,m. *Myadora stephaniae* Carter, x 1.5.
- l. *Antalis nana* (Hutton), x 2.
- n. *Taniella planisuturalis* (Marwick), x 2.
- o,p. *Panopea wanganuica* Powell, x 0.67.



An extremely distinctive index species of Nukumaruan age.

Figured specimen (Pl. 42f): GS1098, V21/f8490, one of the specimens collected by Marwick and Uttley in 1924 from "a sandy pocket of the clays not far below the [Nukumaruan] limestone at Maraekakaho, Ngaruroro River", central Hawke's Bay, Nukumaruan (TM5766, NZGS) x 1.

Pl. 42 e. *Pellicaria acuminata* (Marwick, 1924) [*Struthiolaria sulcata* Hector 1886, p. 50 (in part; not of Jonas, 1829); *Struthiolaria acuminata* Marwick 1924b, p. 185; *Struthiolaria media* Marwick 1924b, p. 187; *Pellicaria mangaoparia* Vella 1953, p. 40; *Pellicaria rotunda* Vella 1953, p. 41; *Struthiolaria (Pellicaria) wellmani* Neef 1970, p. 472] (Struthiolariidae).

Large for genus (25-60 mm high), highly variable in spire height, from markedly shorter than to markedly taller than aperture; with narrow to moderately wide, flat to weakly concave sutural ramp, evenly convex to weakly quadrate whorls, and normal, wide *Pellicaria* aperture with weakly sinuous, varicate outer lip meeting thickened, smooth, narrow inner lip at shallow anterior notch. Spiral sculpture highly variable, but all forms with 3 prominent, wide, widely spaced spiral cords on spire whorls and 4 cords plus a few fine intermediate threads and about 4-6 basal cords on last whorl; most specimens have very low, rounded nodules on major spiral cords of last 2-3 whorls. Protoconch typical of genus (see *P. convexa*).

Latest Mangapanian-early Nukumaruan. Te Awaite Cutting, White Rock Road, east of Martinborough, southern Wairarapa, early Nukumaruan (type of *S. acuminata*); Castlepoint, east Wairarapa coast, early Nukumaruan (type of *S. media*); high outcrop of Mangaopari Mudstone with three prominent concretionary horizons on south bank of Mangaopari Stream c. 500 m upstream from junction with Makara River, southern Wairarapa, late Mangapanian (type of *P. mangaoparia*); junction of Whakarua Stream and first southern tributary, Whakarua Road, one km east of Martinborough-Gladstone road, Whangaehu Valley, southern Wairarapa, early Nukumaruan (type of *P. rotunda*); upper Marima Sandstone, north side of large, narrow bend of Mangahao River c. one km northeast of Marima, Mangahao district, west of Pahiatua, northern Wairarapa, late Mangapanian (loc. 1022, Neef 1970, p. 443, fig. 5; type of *P. wellmani*).

Pellicaria acuminata is exceedingly variable in size, spire height, shell width, prominence of the spiral cords, width and depth of the sutural ramp or shallow sutural channel, and prominence of nodules on the spiral cords. Wide shells with relatively low spires from the early Nukumaruan of southern Wairarapa were named *P. rotunda* by Vella (1953), small specimens with relatively quadrate whorl-section from deep-water facies of late Mangapanian age in southern Wairarapa were named *P. mangaoparia* by Vella (1953), and a rather small specimen from the early Nukumaruan of Castlepoint, Wairarapa was named *Struthiolaria media* by Marwick (1924), but large samples from these areas show that all these forms intergrade, and there is no doubt that they are all part of the variation of a single biospecies. There is no doubt that the holotype of *S. media* is simply a specimen of *P. acuminata* (if slightly smaller than the type of *P. acuminata*) but consistently much smaller populations in Makara River, younger than the zone of *P. acuminata*, may prove to be a separate taxon. As first revisers, we

select the name *P. acuminata* as the name to be used for the species named both *Struthiolaria acuminata* and *Struthiolaria media* by Marwick (1924b).

Neef (1970) described an evolutionary sequence in the Mangahao district, north-western Wairarapa, from the Waipipian *P. canaliculata* (Pl. 36q), with a deeply channelled suture and extremely high cords with undercut edges, through the early Mangapanian *P. clarki*, similar to *P. canaliculata* but with a shallower sutural channel and square-sided cords, and the mid-Mangapanian *P. marima*, with a shallow sutural channel and spiral cords only slightly more prominent than in *P. acuminata*, to a late Mangapanian form of *P. acuminata* (named *P. wellmani* by Neef) with a slightly wider sutural ramp than early Nukumaruan shells. This fine biostratigraphic zonation is, unfortunately, not known outside the Mangahao district. In our opinion a single strongly corded, highly variable species occurs in a large range of facies of late Mangapanian-early Nukumaruan age in Wairarapa and Hawke's Bay. In central Hawke's Bay, *P. acuminata* overlaps with (and blends with, in Petane siltstone at Watchman Hill, Ahuriri Lagoon; Napier) *P. convexa* in early (but not earliest) Nukumaruan rocks; *P. acuminata* occurs alone in early Nukumaruan siltstone underlying all Petane limestone beds (notably at Redcliffe, near Taradale). *P. acuminata* is widespread and common from central Hawke's Bay and the northern Ruahine Range (Napier-Taihape Road) to southern Wairarapa, but rare in Wanganui basin and in North Canterbury.

Figured specimen (Pl. 42e): GS6677, T27/f6762, Maurioho Stream, east of Martinborough, southern Wairarapa, early Nukumaruan (NZGS) x 1.5.

Pl. 42 b. *Pellicaria convexa* (Marwick, 1924) [*Struthiolaria convexa* Marwick 1924b, p. 188] (Struthiolariidae).

Moderately large for genus (40-55 mm high), with moderately tall spire (slightly shorter than aperture), smoothly abutting suture to narrow, horizontal sutural ramp, evenly convex whorls, and normal, wide *Pellicaria* aperture with weakly sinuous, varicate outer lip meeting thick, smooth inner lip at shallow anterior notch. Sculpture of many low, narrow, widely spaced spiral threads only; in some specimens threads are grouped in positions corresponding to those of spiral cords of older species such as *P. acuminata*; weak axial ridges cross much of surface without forming nodules. Protoconch typical of genus, an initial large, low, slightly irregular, smooth dome of half a whorl followed by 1 whorl with horizontal, flattened upper surface and obvious shoulder angle, blending into rounded first spire whorl.

Mid-late Nukumaruan. Okauawa Stream, Kereru Road, inland central Hawke's Bay, late Nukumaruan (type); very widespread and abundant in blue-grey siltstone throughout Hawke's Bay, northern Wairarapa and the Rangitikei river section, Wanganui basin; rare in southern Wairarapa. Specimens recorded from Castlecliffian rocks at Cape Kidnappers (Maraetotara Sand; Fleming in Kingma 1971) and at Castlecliff, Wanganui (Kupe Formation; Fleming 1953) are in our opinion *P. vermis flemingi*, a northern warm-water subspecies restricted at present to the Bay of Plenty (see below).

Pellicaria convexa succeeds, and partly overlaps with, the much more strongly sculptured *P. acuminata* (see above) and partly overlaps with and is partly succeeded in latest Nukumaruan rocks of Hawke's Bay by *P. fossa*. The complex of *P. convexa* and *P. fossa* (discussed below) is succeeded in Castlecliffian to Recent faunas by *P. vermis*

(Pl. 47u), which differs from *P. convexa* in having slightly stronger sculpture, more strongly shouldered whorls, and a higher incidence of shoulder nodules.

Figured specimen (Pl. 42b): holotype, GS1089, V21/f8482, Okauawa Stream, Kereru Road, central inland Hawke's Bay, late Nukumaruan (TM5763, NZGS) x 1.5.

Pl 42 a. *Pellicaria fossa* (Marwick, 1924) [*Struthiolaria fossa* Marwick 1924b, p. 189] (Struthiolariidae).

Moderately small to large for genus (35-50 mm high), with short to moderately tall spire (markedly to slightly shorter than aperture), wide, slightly concave to deeply channelled sutural ramp, evenly convex whorls on early spire but vertical whorl sides and a weak peribasal angulation on last whorl, and normal, wide *Pellicaria* aperture with weakly sinuous, varicate outer lip meeting thick, smooth inner lip at shallow anterior notch. Sculpture of many low, narrow, closely spaced spiral cords on early spire, variable in development lower on shell; most specimens with only low, narrow, widely spaced spiral threads on whorl sides, but more strongly corded base, with only weak axial growth ridges, but some with more prominent spiral cords and weak nodules below shoulder. Protoconch typical of genus (see *P. convexa*).

Late Nukumaruan only; "Shrimpton's", Kikowhero Stream, Matapiro Station, north of Ngaruroro River, central Hawke's Bay (type); widespread and, at some localities, extremely abundant in blue-grey siltstone in central Hawke's Bay (particularly in the Tangoio-Devil's Elbow block, north of Napier, and in the Okauawa Stream-Mangatahi River area, Kereru Road, west of Maraekakaho); uncommon in southern Hawke's Bay and northern Wairarapa.

The relationship of *Pellicaria fossa* to *P. convexa* is complex and interesting. *P. fossa* appears to evolve gradually from *P. convexa* in the mid-late Nukumaruan Devil's Elbow-Darkys Spur-Tangoio Valley sequence, north of Napier: typical *P. convexa*, with evenly convex whorls and no subsutural platform, occurs (with rare *P. acuminata*) in siltstone at the base of the sequence, in both Tangoio Valley in the south of the area and Arapaoanui River in the north. Typical, highly developed *P. fossa*, with vertical whorl sides and a deep, wide subsutural channel, occurs in the two highest siltstone units in the sequence (Te Ngaru Mudstone and Devil's Elbow Mudstone of Beu and Edwards 1984, fig. 6); and intermediate populations, with a gradually developing sutural channel, occur in the two intervening siltstone units. However, on Kereru Road near the bridge over Okauawa Stream, inland central Hawke's Bay, a thick mudstone unit with abundant *P. fossa* is interbedded with two thin, shallow-water, sandier beds containing common large *P. convexa* with a very narrow sutural shelf (type locality of *P. convexa*). Although its status is uncertain, it seems likely that *P. fossa* is a late Nukumaruan offshore ecomorph of *P. convexa*, and that the Devil's Elbow sequence demonstrates that the basin was sinking faster than it was being filled with sediment, so that each successive siltstone unit (deposited during the interglacial, high sea-level part of each glacio-eustatic cycle) was deposited in progressively deeper water. It is clear that the Devil's Elbow gradation from *P. convexa* to *P. fossa* is not an evolutionary sequence.

Figured specimen (Pl. 42a): GS10849, V20/f8572, Devil's Elbow mudstone (highest siltstone unit of Tangoio-Devil's Elbow sequence) on north face of Devil's Elbow hill, Napier-Wairoa highway, late Nukumaruan (NZGS) x 1.5.

Pl. 42 c. *Pellicaria rugosa* (Marwick, 1924) [*Struthiolaria rugosa* Marwick 1924b, p. 189] (Struthiolariidae).

Moderate-sized for genus (45-48 mm high), with moderately tall spire (a little shorter than aperture), narrow horizontal sutural ramp, evenly and weakly convex whorls, and normal *Pellicaria* aperture with weakly sinuous, varicate outer lip meeting thick, narrow, smooth inner lip at very shallow anterior notch. Sculpture of low, narrow, well defined, closely spaced spiral cords, about 10 on spire whorls and 25 on last whorl, crossed and made finely and regularly nodulous by many low, narrow axial costellae about the same distance apart as spiral cords. Protoconch typical (see *P. convexa*).

Early Nukumaruan only; "Patea", South Taranaki coast (wrong; Patea is a Waipipian locality, where *P. rugosa* has not been recollected), type. Widespread in southern Hawke's Bay to North Canterbury in a very short-lived zone near the base of early Nukumaruan time, almost always with *Chlamys patagonica delicatula* (Hutton); common in a thin zone in Mangaopari Stream at Birch Hill bridge, near the junction with Makara River; at the mouth of Whangaimoana Stream, Palliser Bay (both in southern Wairarapa); and at Motunau Beach and in *Chlamys patagonica delicatula* beds on Gower River (both in North Canterbury). The holotype (TM4898, NZGS) is an unusually coarsely sculptured specimen, with matrix of grey sandy mudstone (hard in the aperture but soft around the spire suture) and appears to have come from North Canterbury (perhaps from Motunau Beach) rather than a North Island locality.

A possibly ancestral species, *Pellicaria monilifera*, rare in the Opoitian-Waipipian of Marlborough and North Canterbury, has a taller spire, wider spiral cords and coarser nodules than *P. rugosa*. The most similar species is *P. convexa*, which bears only very narrow spiral threads and no axial costellae or nodules.

Figured specimen (Pl. 42c): GS2855, U24/f6440, Waitahora Road, Mangaotero, southern Hawke's Bay, early Nukumaruan (NZGS) x 1.5.

Pl. 41 n. *Taniella planisuturalis* (Marwick, 1924) [*Natica planisuturalis* Marwick 1924d, p. 550; *Natica haweraensis* Marwick 1924d, p. 551] (Naticidae: Naticinae).

Small for family (10-16 mm high), with moderately low to tall spire; suture inconspicuous, tangential, so spire outline almost straight, or in some specimens slightly concave below suture. Last whorl very large, rounded, enveloping most of earlier whorls, with smoothly rounded base and simple, D-shaped aperture. Outer lip slightly retracted to suture at top. Inner lip thickened over parietal area but thin below, fused with large, smooth, subcircular funicle that fills central third to half of large, circular umbilicus; funicle separated from last whorl by wide groove, varying in width from half width of funicle to equal in width to funicle. Surface smooth and polished apart from a few faint growth lines. Protoconch small, very low, of 1.6 smooth, weakly inflated whorls, with a minute apex.

Opoitian-Castlecliffian. Okauawa Stream, Kereru Road, central Hawke's Bay, late Nukumaruan (type of *Natica planisuturalis*); Waihi Beach, Hawera, South Taranaki, Waipipian (type of *N. haweraensis*). Widespread but uncommon in Pliocene to Nukumaruan rocks throughout New Zealand; rare in early Castlecliffian rocks at Wanganui and at Cape Kidnappers (Maraetotara Sand); common at several localities in mid-Castlecliffian sandstone and mudstone at Ohope Beach, Whakatane (B.A. Marshall Colln., National Museum of N.Z.); almost always in shallow-water sandstone or sandy coquina limestone.

The last appearance of *Taniella planisuturalis* has

commonly been used in the past as an index of the end of Nukumaruan time, although a few undoubted early Castlecliffian specimens are known in central and southern North Island, and the species is among several (e.g., *Arca cottoni*) that remained common at Ohope, Bay of Plenty, during Castlecliffian time, after they became extinct in Wanganui Basin. Differences regarded by Marwick (1924d) as distinguishing *T. haweraensis* from *T. planisuturalis* (principally a difference in funicle diameter) are now seen to intergrade, and we regard these names as synonyms. As first revisers, we select the name *Taniella planisuturalis* as the name for the species named both *Natica planisuturalis* and *N. haweraensis* by Marwick (1924d, p. 550-551). *T. planisuturalis* is larger and has a taller spire, straighter spire outlines, and a smaller funicle than earlier species of *Taniella*.

Figured specimen (Pl. 41n): GS5311, W21/f8518, base of Maraetotara Sand, Cape Kidnappers, Hawke's Bay, early Castlecliffian (NZGS) x 2.

Pl. 42 d. *Cominella (Eucominia) nassoides otakaica* Powell, 1946b [p. 143] (Buccinidae).

Large for genus (45-65 mm high), tall and narrow, with tall, straight-sided spire, but short last whorl with short, strongly twisted, widely open canal, producing short, wide fasciole margined by narrow ridge. Sculpture of a prominent, wide spiral cord below suture and many low, narrow, closely spaced spiral cords from shoulder angle to base, leaving narrow, weakly sculptured area around strongly concave sutural ramp; crossing moderately prominent, closely spaced axial costae of rounded section, narrow and high on spire whorls but becoming less prominent on later whorls, and obsolete on last whorl of large shells; forming low, rounded nodules on subsutural cord and shoulder angle. Aperture wide, oval, with thick lips, lirate inside outer lip of small specimens but smooth in large ones. Protoconch large, dome-shaped, of 2 smooth whorls.

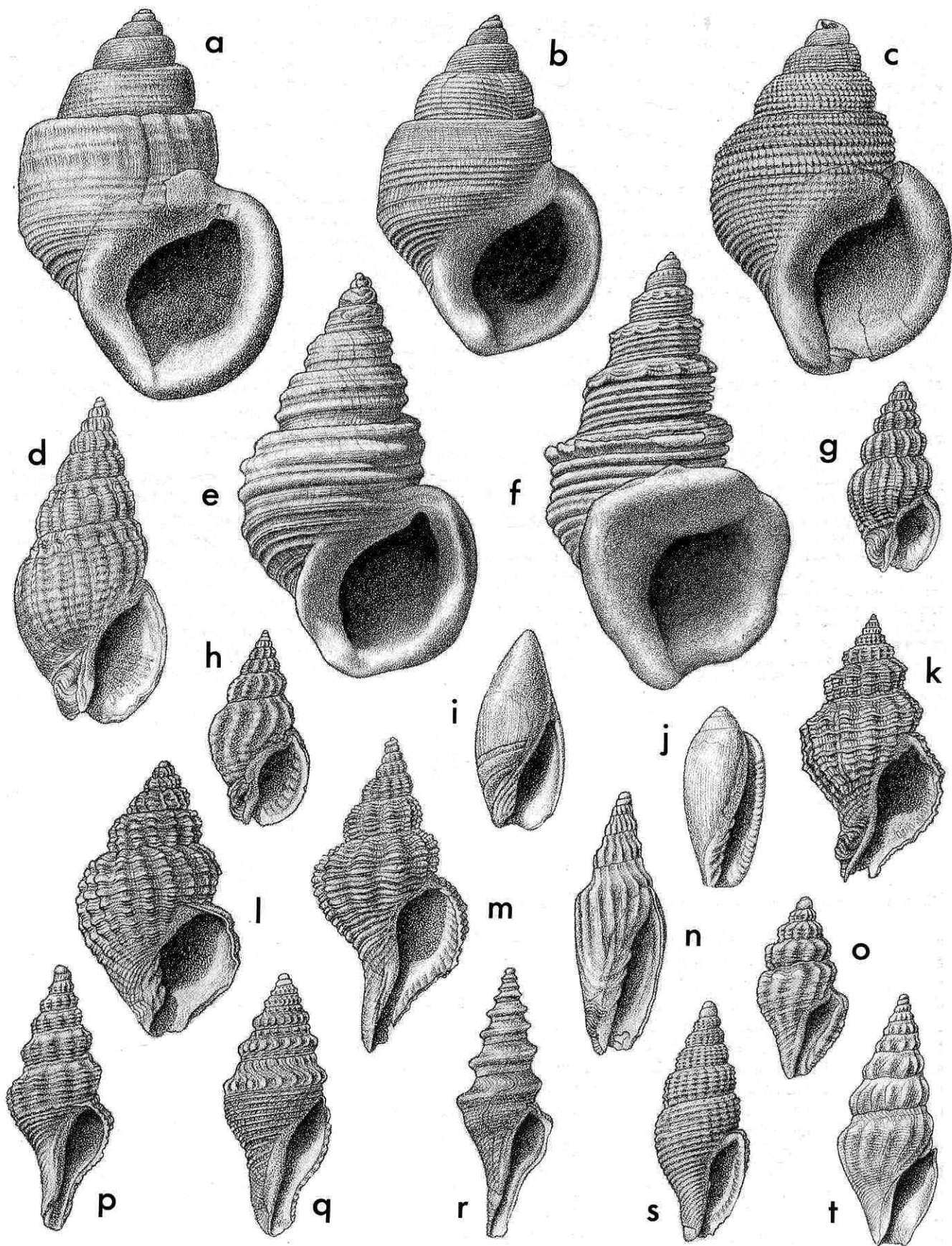
Mangapanian?; early Nukumaruan-Recent. Recent, trawled off eastern Otago (type); common in shelf and submarine canyon mudstone facies in Marlborough and Cheviot area, Canterbury (Mangapanian?; common in Nukumaruan) and in shallow-water Castlecliffian of the Leader River, near Cheviot; rare in southern Wairarapa.

The cold-water, southern members of *Cominella (Eucominia)* are characterised by their prominent sculpture of spiral cords and axial costae, with a strongly concave sutural ramp and a nodulous shoulder; more temperate species (*C. mirabilis*; and in particular, *C. elegantula*, Castlecliffian; Pl. 49e) have much smoother shells but most still have a subsutural cord and concave shoulder. *C. nassoides otakaica* differs from the living, shallow-water, Stewart Island "subspecies" *C. nassoides nassoides* (Reeve) only in its much larger size and more weakly sculptured last whorl, and is probably merely a deep-water ecomorph of no taxonomic significance. This cold-water species lives only in southern New Zealand today, the "subspecies" *otakaica* occurring only on the continental shelf and slope off eastern Otago and in Pegasus Bay, Canterbury, and its extension northward to North Canterbury, Marlborough and (rarely) southern Wairarapa during Nukumaruan time is further evidence of the glaciations indicated by the northward range expansions of *Chlamys patagonica delicatula* to central North Island.

Figured specimen (Pl. 42d): GS10337, O32/f8843, Oaro submarine canyon faunule, summit of hill east of Glenstrae homestead, northern Hundalee Hills, southern Marlborough, Nukumaruan (NZGS) x 1.5.

Plate 42 Nukumaruan (late Pliocene-early Pleistocene) Mollusca (5).

- a. *Pellicaria fossa* (Marwick), x 1.5.
- b. *Pellicaria convexa* (Marwick), x 1.5.
- c. *Pellicaria rugosa* (Marwick), x 1.5.
- d. *Cominella (Eucominia) nassoides otakaica* Powell, x 1.5.
- e. *Pellicaria acuminata* (Marwick), x 1.5.
- f. *Struthiolaria (Struthiolaria) frazeri* Hector in Hutton, x 1.
- g. *Cominella (Eucominia) hamiltoni* (Hutton), x 2.
- h. *Cominella (Cominella) excoriata* (Finlay), x 1.
- i. *Amalda (Gracilispira) novaezelandiae* (Sowerby), x 3.
- j. *Serrata kirki* (Marwick), x 3.
- k. *Austrofusus (Austrofusus) taitae* (Marwick), x 1.5.
- l. *Bonellitia (Bonellitia) lacunosa* (Hutton), x 3.
- m. *Glaphyrina plicata* Powell, x 1.5.
- n. *Alcithoe (Leporemax) brevis* Marwick, x 1.
- o. *Antiguraleus abnormis* (Hutton), x 6.
- p. *Comitas allani* Powell, x 2.
- q. *Bathytoma (Micantapex) murdochi murdochi* (Finlay), x 2.
- r. *Paracomitas (Paracomitas) protransenna* (Marshall and Murdoch), x 2.
- s. *Antizafra pisanopsis* (Hutton), x 4.
- t. *Splendrillia (Splendrillia) aequistriata* (Hutton), x 2.



Pl. 42 g. *Cominella (Eucominia) hamiltoni* (Hutton, 1885). [*Clathurella hamiltoni* Hutton 1885b, p. 316; *Cominella huttoni* "Kobelt" of Suter 1915, p. 25 (not of Kobelt); *Cominula attenuata* Fleming 1943, p. 203; *Cominula hamiltoni*] (Buccinidae).

Small for subgenus (15-18 mm high), tall and narrow, with tall spire, but short last whorl with short, widely open, strongly twisted canal forming a prominent short, wide fasciole. Sculpture of narrow, clearly defined, prominent, relatively widely spaced axial costae, 12-14 per whorl, crossed by many fine, low, closely spaced spiral cords, 8 on penultimate whorl, lowest 5 or 6 on base more prominent than others; without subsutural cord, obvious shoulder, or nodules. A few low, short lirae inside outer lip. Protoconch relatively large, dome-shaped, of 2.5 whorls, smooth except for axial costae on last whorl.

Nukumaruan; "Petane", i.e., Tangoio limestone outcrops on hillside north of Petane Pa, north side of Esk River near mouth, central Hawke's Bay, Nukumaruan (type of *Clathurella hamiltoni*); east bank of Manawatu River three km northeast of Kumeroa, southern Hawke's Bay, early Nukumaruan (type of *Cominula attenuata*). Common in near-shore to mid-shelf mudstone facies in central and southern Hawke's Bay, less common in Wanganui basin and southern Wairarapa.

Cominella hamiltoni appears to be closely related to the small, relatively simply sculptured, offshore, modern species of *C. (Eucominia)* such as *C. mirabilis* (Powell), and particularly the northern North Island form *C. mirabilis mirabilis*, but differs in its smaller size and slightly coarser spiral sculpture. Relatively tall-spined specimens, named *C. attenuata* by Fleming (1943), appear to be tall individuals in the *C. hamiltoni* population.

Figured specimen (Pl. 42g): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa Highway, central Hawke's Bay, Nukumaruan (NZGS) x 2.

Pl. 42 h. *Cominella (Cominella) excoriata* (Finlay, 1926). [*Eucominia excoriata* Finlay 1926b, p. 241] (Buccinidae).

Moderate-sized for genus (33-40 mm high), moderately tall, with moderately tall spire, large last whorl, and short, widely open, strongly twisted canal, forming wide fasciole bordering narrow umbilical chink. Sculpture of very prominent, narrow, widely spaced, weakly sinuous axial costae of rounded cross-section, 12 on penultimate whorl, unique among those of New Zealand *Cominella* species in being strongly opisthocline, not collabral; crossed at an angle of 10°-15° by regular, microscopic growth ridges; crossed (without forming nodules) by low, wide, indistinct, strap-like, widely spaced spiral cords, 4 to 6 on spire whorls and about 9 on last whorl. Aperture wide, oval, with smooth, thickened lips. Protoconch large, dome-shaped, of 2.5 smooth whorls.

Nukumaruan; "Shrimpton's", i.e., Kikowhero Stream, Matapiro Station, north side of Ngaruroro River, central Hawke's Bay (type); common in offshore mudstone facies in central Hawke's Bay, but we are not aware of specimens from any other district.

Cominella excoriata is a member of a group of warm-temperate species of relatively large *Cominella*, containing also the modern eastern North Island *C. tologaensis* Ponder (a distinct species with coarser spiral cords and wider and less markedly opisthocline axial costae than *C. excoriata*) and the modern southern Australian *C. eburnea* (Reeve).

Figured specimen (Pl. 42h): GS10849, V20/f8572, Devil's Elbow hill, Napier-Wairoa highway, central Hawke's Bay, Nukumaruan (NZGS) x 1.

Pl. 42 k. *Austrofusus (Austrofusus) taitae* (Marwick,

1924). [? *Siphonalia nodosa* var. *conoidea* Hutton 1893, p. 41 (? not *Purpura conoidea* Zittel 1864, p. 37; same taxon or secondary homonym); *Aethocola taitae* Marwick 1924c, p. 197] (Buccinidae).

Rather small for genus (30-50 mm high, but rarely over 40 mm high), moderately tall, with stepped spire and moderately long, strongly twisted canal with prominent, long, scaly fasciole bordered by narrow ridge. Whorls with weakly concave sutural ramp, sharp shoulder angle at 0.7 height of spire whorls, lightly contracted below shoulder to moderately prominent peribasal angulation. Sculpture of prominent, narrow, widely spaced spiral cords, 1 below suture and about 10 on shoulder angle, sides, and base of last whorl more prominent than others, with narrow secondary thread in centre of each interspace; all thickened into moderately high to very prominent, narrowly rounded, spine-like nodules where they cross the prominent, widely spaced axial costae. Nodule size highly varied (figured specimen is more weakly sculptured than most others, as most strongly sculptured shells have broken apertures and canals). Outer lip weakly thickened, lirate within. Protoconch small, narrowly conical, of 3.5 smooth whorls.

Nukumaruan. "Petane, Matapiro" (types of *Siphonalia nodosa* var. *conoidea*); "blue clays below limestone, Kikowhero Creek, Ngaruroro River", Matapiro Station, central Hawke's Bay (type of *Aethocola taitae*).

Nukumaruan species of *Austrofusus* (*A. taitae*, Hawke's Bay; *A. cottoni*, southern Wairarapa) are considerably smaller than and have more prominent fascioles than the Castlecliffian-Recent *A. glans* (Pl. 49c); *A. cottoni* has low, rounded nodules, whereas most *A. taitae* have large, sharply pointed, "prickly" nodules.

Hutton (1893, p. 41) seems to have been using Zittel's species name rather than proposing a new taxon when he stated that his variety *conoidea* was "perhaps the same as" *Purpura conoidea* Zittel, but the two taxa have different type localities of different ages ("Petane, Matapiro", Nukumaruan, for *Siphonalia nodosa* var. *conoidea*; Awatere Valley, Opoitian or Kapitean, for *Purpura conoidea*) and as both have been referred in modern times to *Austrofusus*, they are at least secondary homonyms, and Marwick's name *A. taitae* is preferred for the species that is so widespread and abundant in mudstone facies in Hawke's Bay.

Figured specimen (Pl. 42k): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa Highway, Nukumaruan (NZGS) x 1.5.

Pl. 42 s. *Antizafra pisanopsis* (Hutton, 1885) [*Columbella pisanopsis* Hutton 1885b, p. 314; *C. pisanopsis*, corrigenda to volume 17 of TNZI; *Anachis pisanopsis*]. Type species of *Antizafra* Finlay, 1926 (Columbellidae).

Small for family (10-12 mm high), tall and narrow; spire moderately tall; last whorl long and narrow, tapering gradually to moderately long (for family), straight, widely open canal without fasciole. Whorls with narrow, rounded shoulder just below suture, weakly inflated below. Sculpture of prominent, smooth, moderately wide, widely spaced spiral cords, 5 or 6 on spire whorls and about 25 on last whorl; on spire whorls and earlier half of last whorl, cords cross low, wide, gently rounded axial folds without forming nodules; axial folds obsolete on last half-whorl. Aperture long and narrow; inside of thickened outer lip bears 10 to 12 low nodules; base of columella bears a single, wide, prominent plait. Protoconch tall dome-shaped, of 1.5 smooth polished whorls.

Nukumaruan; "Petane", i.e., Tangoio limestone outcrops on hillside north of Petane Pa, north side of Esk River near mouth, central Hawke's Bay (type); widespread and moderately common in blue-grey mudstone facies in central and southern Hawke's Bay.

The slightly taller, more coarsely cancellate *Antizafra*

cancellaria (Hutton) and the shorter, more weakly sculptured *A. speighti* (Marwick) are sympatric with, but less common than, the widespread *A. pisanopsis*; all three species occur in shallow to moderately offshore mudstone facies in Hawke's Bay, and are restricted to the Nukumaruan (common in mudstone overlying the Te Aute Limestone of Pukeora Hill on Ashcott Road, near Waipukurau). Other species referred to *Antizafra* are shorter, more weakly sculptured and lack the columellar fold, and so are probably not congeneric; the genus appears to be restricted to Hawke's Bay Nukumaruan rocks.

The list of Corrigenda bound between the title page and contents list of Volume 17 of "Trans. N. Z. Inst.", 1885 (the volume Hutton's *Columbella pisanopsis* appeared in) includes "page 314, line 22, for *pisanopsis* read *pisanopsis*", so although this correction has not been adopted previously, it is presumably a correction of a typographical error, and we adopt it here.

Figured specimen (Pl. 42s): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, north of Napier, Hawke's Bay, Nukumaruan (NZGS) x 4.

Pl. 42 m. *Glaphyrina plicata* Powell, 1929 [*Glaphyrina plicata* Powell 1929, p. 97; *Glaphyrina marwicki* Beu 1965a, p. 145] (Fascioliidae).

Large and wide for genus (36-55 mm high), with tall spire and moderately long, slightly curved canal. Whorls strongly inflated. Sculpture of many narrow, well raised spiral cords with intermediate threads, crossing very prominent, wide axial folds of evenly rounded cross-section, with evenly concave interspaces, each the same width as 1 axial fold; folds extend well down on base of whole of last whorl; all crossed by fine axial threads. Interior of outer lip lightly thickened, with many low, narrow ridges; inner lip thin, smooth. Protoconch prominent, tall, of 2 medially keeled, slightly irregular whorls, with tall, pointed apex (presumably a remnant of an only partly calcified embryonic shell) (see under *G. caudata*, Pl. 49j, k).

Nukumaruan-Recent; Recent, dredged off Cuvier Island, east of Auckland (type of *Glaphyrina plicata*); Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa Highway, Hawke's Bay, Nukumaruan (type of *G. marwicki*). Widespread but uncommon in blue-grey mudstone facies in central Hawke's Bay, particularly at Devil's Elbow and in Mangatahi River near the junction with Okauawa Stream, Kereru Road (both late Nukumaruan); rare in the inner-mid shelf fauna of north-eastern North Island at present, and so apparently a warm-water species.

Glaphyrina plicata differs from the more common Castlecliffian(?) -Recent *G. caudata* (Pl. 49j, k) in its wider shape, fewer and much more prominent axial folds, and straighter anterior canal. The differences between *G. plicata* and *G. marwicki* appear to be individual only. A presumed ancestral species is the uncommon, relatively coarsely sculptured *G. excelsa* from Target Gully Shellbed, Oamaru (Altonian).

Figured specimen (Pl. 42 m): holotype of *G. marwicki* Beu, GS 2220, V20/f8462, Devil's Elbow, Napier-Wairoa Highway, Hawke's Bay, Nukumaruan (TM 3798, NZGS) x 1.5.

Pl. 42 i. *Amalda (Gracilispira) novaezelandiae* (Sowerby, 1859) [*Ancillaria novaezelandiae* G. B. Sowerby II 1859, in 1842-1877, p. 65; *Ancilla (Aenaulax) nana* Watson 1886,

p. 230; *Ancilla bicolor* "Gray" of Suter 1913c, p. 453 (error for *A. tricolor* Sowerby, but not that sp.); *Ancilla crystallina* Brookes 1926, p. 433; *Baryspira (Gracilispira) firthi* Olson 1956, p. 26; *Baryspira novaezelandiae*]. Type species of *Gracilispira* Olsson, 1956 (Olividae: Ancillinae).

Small for genus (10-15 mm high, a few specimens to 25 mm high), tall and narrow, with tall, weakly inflated spire and very narrowly rounded apex. Lower margin of spire callus an obvious spiral line just below top of outer lip, descending to left of aperture in weakly sigmoidal line to fuse with inner lip. Depressed band narrow, at 0.7 lip height on left side of inner lip, descending around last whorl to produce low nodule on outer lip just above anterior end. Top fasciolar band and mid fasciolar band weakly separated, the 2 combined equal in width to basal fasciolar band; basal band separated from base of columella by deep, narrow groove; columellar base bearing 5 low plaits.

Opoitian-Recent. Recent, New Zealand (types of *A. novaezelandiae*, *A. nana*, *A. crystallina*); Livingstone Bridge, Rangitikei River, Wanganui basin, Nukumaruan (type of *B. firthi*). Abundant and widespread throughout New Zealand in all shelf soft-bottom facies of Pliocene and Pleistocene age.

We can see no differences between the types of *Baryspira firthi* Olson (23.8 mm high; holotype) and the larger specimens of *Amalda novaezelandiae*, and there is no reasonable doubt that these names are synonyms. Another probable synonym is *Baryspira rimuensis* Olson (1956, p. 27) (Mangapanian, Te Rimu Sand, Wanganui River); Olson gave no criteria for distinguishing *B. rimuensis* from *A. novaezelandiae* and we can see no distinguishing characters, but more material of pre-Nukumaruan age is needed to be sure of the variation of *A. novaezelandiae*. In many fossils, the original colour is retained to some degree (pale brown whorl sides, as far down as mid-fasciolar band; spire, inner lip and base white).

Figured specimen (Pl. 42i): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, late Nukumaruan (NZGS) x 3.

Pl. 42 n. *Alcithoe (Leporemax) brevis* (Marwick, 1926) [*Alcithoe brevis* Marwick 1926a, p. 299; *A. subgracilis* Marwick 1926a, p. 300; *A. mackayi* Marwick 1926a, p. 300; *Leporemax brevis*] (Volutidae: Zidoninae).

Small for genus (45-80 mm high), with moderately short to very tall spire, long last whorl, deeply concave sutural ramp and (on most specimens) sharply angled shoulder. Sculpture of prominent, narrow-crested, concave-sided axial costae, extending full height of spire whorls and 0.5-0.7 of last whorl of many smaller specimens, but shorter to obsolete on last whorl of some large shells. Aperture long and parallel-sided, with thickened outer lip, 4 prominent columellar plaits, and wide, moderately deep anterior notch that forms low but obvious fasciole margined by low, very narrow ridge. Protoconch relatively large, of 2 smooth whorls, dome-shaped with an almost flat apex.

Mangapanian-Nukumaruan; Castlepoint, east Wairarapa coast, early Nukumaruan (type of *A. brevis*); "clays below limestone, Petane", i.e., hillside north of Petane Pa, north of mouth of Esk River, central Hawke's Bay, mid-Nukumaruan (type of *A. subgracilis*); "Shrimpton's", i.e., Kikowhero Stream, Matapiro Station, north of Ngaruroro River, central Hawke's Bay, late Nukumaruan (type of *A. mackayi*); common in shallow to moderately deep-water sandstone and mudstone throughout New Zealand.

Alcithoe brevis is highly variable in width, inflation, spire height, and prominence of axial costae. Some variants

have received names; illustrated (Pl. 42n) is the *subgracilis* form; smaller specimens with short spires are "typical" *brevis*; and specimens with very tall spires are *mackayi*; but (as shown by the protoconch, and known in the modern species) all *Alcithoe* species have direct development and so can be expected to be highly varied, and the named forms intergrade. The apparently ancestral *A. gatesi* (Opoitian-Waipipian; Pl. 37o) has more consistent, more even, more narrowly crested axial costae, and the succeeding *A. fusus* (Castlecliffian-Recent; Pl. 49i) has weaker costae.

Figured specimen (Pl. 42n): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 1.

Pl. 42 j. *Serrata kirki* (Marwick, 1924) [*Marginella kirki* Marwick 1924e, p. 324; *M. (Volvarina) kirki*] (Marginellidae).

Large for New Zealand species of the family (11.5 mm high), tall and narrow, with low spire of convex outline but tall for New Zealand members of genus, and with very long, narrow, weakly inflated last whorl. Exterior smooth and polished, protoconch and suture hidden by callus. Aperture long and narrow; outer lip thickened, with shallow sinus at top and about 25 low, rounded nodules on inner edge; inner lip thin over upper 0.7 height, thickened below, bearing 4 prominent, narrow plaits and a much weaker 5th plait or denticle above, not extending far inside aperture.

Nukumaruan; "clays below limestone, Petane", i.e., hillside north of Petane Pa, north of mouth of Esk River, central Hawke's Bay (type); uncommon at most localities in blue-grey siltstone in central Hawke's Bay, not uncommon at a few localities (notably mudstone in a road cut on Ashcott Road at the north end of Pukeora Hill, overlying Te Aute Limestone, near Waipukurau).

Serrata kirki is sympatric with *Haluginella marwicki*, which differs in its lower spire, more inflated last whorl, and weaker outer-lip nodules; the two are much larger than most other New Zealand Cenozoic marginellids. *Serrata flemingi* (Waiauian, Greymouth) is smaller than *S. kirki* and has a taller spire; both species differ from other New Zealand marginellids in having a fifth, weak denticle anterior to the four columellar plaits.

Figured specimen (Pl. 42j): largest paratype (with thicker outer lip than holotype), "Petane", hillside north of Petane Pa, north of mouth of Esk River, north of Napier, Hawke's Bay, Nukumaruan (TM6830, NZGS) x 3.

Pl. 42 l. *Bonellitia (Bonellitia) lacunosa* (Hutton, 1885) [*Cancellaria lacunosa* Hutton 1885b, p. 320] (Cancellariidae: Admetinae).

Small for family (15-18 mm high) but largest of New Zealand *Bonellitia* species, with strongly inflated whorls, moderately tall spire (slightly taller than aperture), and short, inflated last whorl with wide, shallow siphonal notch (but no canal) forming very low fasciole. Suture deeply impressed. Sculpture of low, wide spiral cords, 4 on spire whorls and 8 or 9 on last whorl, each bearing 2-4 narrow, prominent spiral threads, and interspaces between uppermost 5 cords each with 1 central spiral thread; cords decreasing in prominence down last whorl to merge over base into general background of spiral threads; all crossing prominent, narrowly rounded, slightly prosocline axial costae, 16-17 per whorl, extending from suture to well down on base, with only very low, rounded nodules at sculptural intersections. Aperture large, oval, with simple thin outer lip; columella curved to right at base, then truncated by anterior notch, bearing 3 equally prominent plaits. Protoconch small, of only 1 whorl, with bulbous apex, bearing many finely malleate, microscopic spiral lirae.

Nukumaruan; "Petane", i.e., hillside behind Petane Pa,

north of mouth of Esk River, north of Napier, central Hawke's Bay (type); widespread and not uncommon in Nukumaruan blue-grey siltstone in Hawke's Bay: Devil's Elbow mudstone at top of Devil's Elbow hill, Napier-Wairoa highway; "Petane corner", junction of Napier-Wairoa and Napier-Taupo highways; Bayview-Eskdale inland road; Watchman Hill and Roro-o-kuri, Ahuriri Lagoon; Ashcott Road at foot of Pukeora Hill and Maharakeke Road, Pukeora Hill, near Waipukurau.

The living *Bonellitia superstes* Finlay, 1930 is smaller and has slightly larger nodules than *B. lacunosa*; the Opoitian-Mangapanian *B. fundata* has fewer, coarser spiral cords and markedly larger nodules.

Figured specimen (Pl. 42l): GS12501, V20/f17, siltstone in high outcrop at junction of Napier-Wairoa and Napier-Taupo highways, north of Napier, Nukumaruan (NZGS) x 3.

Pl. 42 q. *Bathytoma (Micantapex) murchisoni murchisoni* Finlay, 1930 [*Pleurotoma tuberculata* Kirk 1882, p. 409 (not of Gray, 1839); *Pleurotoma (Hemipleurotoma) nodilirata* Murdoch and Suter 1906, p. 284 (not of E. A. Smith, 1878; new name for *P. tuberculata* Kirk, preoccupied); *Bathytoma murchisoni* Finlay 1930a, p. 46 (new name for *P. nodilirata* Murdoch and Suter, preoccupied); ?*Micantapex finlayi* Powell 1940, p. 245; *Micantapex murchisoni*] (Turridae: Borsoniinae).

Moderate-sized for genus (23-27 mm high), relatively short and wide, biconic, with moderately tall spire and moderately long, open, lightly curved canal with low fasciole. Low, finely nodulous subsutural fold and prominent, wide, rounded, coarsely nodulous peripheral keel are the most obvious sculpture; sutural ramp deeply concave, smooth except for growth lines; below periphery, many highly variable, narrow spiral cords have 1 or few intermediate threads in some forms. Anal sinus wide, V-shaped, with apex at peripheral nodulous keel. Aperture long, oval, with thin, smooth lips. Protoconch relatively large, dome-shaped, of 1.5 smooth whorls.

Mangapanian(?) - Nukumaruan (-Recent?). "Tertiary beds near Petane, Hawke's Bay", i.e., hillside north of Petane Pa, north of mouth of Esk River, north of Napier, Nukumaruan (type of *Pleurotoma tuberculata*, renamed *Pleurotoma nodilirata* by Murdoch and Suter (1906) (preoccupied), renamed *Bathytoma murchisoni* by Finlay (1930a)); Recent, off Great Barrier Island, north-eastern New Zealand (type of *M. finlayi*). Typical, relatively finely sculptured *B. murchisoni* is common in blue-grey siltstone throughout central and southern Hawke's Bay (Nukumaruan), but many similar forms have been named in Opoitian to Recent faunas from throughout New Zealand, and it is unclear how many are valid species; forms named from southern Wairarapa Mangapanian-Nukumaruan (*B. paucispiralis*; *B. murchisoni prior*) have more prominent basal cords but seem to intergrade with "typical" Hawke's Bay Nukumaruan *B. murchisoni*.

Now that *Bathytoma (Bathytoma) finlayi* (Clifden, Southland, Altonian-Clifdenian) and *B. (Micantapex) finlayi* (Recent) are placed in the same genus, the latter is clearly a secondary homonym of the former. However, the modern population is much more variable than Powell (1942, p. 56) thought when he distinguished *M. finlayi* from *M. murchisoni* "by having fewer peripheral nodules, only 13-16 per whorl, and narrower basal spirals, the upper ones being much wider spaced" (*M. murchisoni* was said to have 20-22 nodules per whorl). Comparison of

collections showed no apparently consistent differences between *B. murdochi* and the Recent form named *B. finlayi* (not of Laws), and it appears unlikely that a new name is necessary for the Recent form. The taxonomy of the subgenus is greatly in need of revision.

Figured specimen (Pl. 42q): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 2.

Pl. 42 p. *Comitas allani* Powell, 1942 [p. 59] (Turridae: Turritinae).

Small for genus (26-33 mm high), tall and narrow, with tall stepped spire and long, almost straight canal without fasciole (canal incomplete on most specimens). Axial sculpture of short, only slightly opisthocline costae at and below shoulder, 12-14 per whorl, prominent and extending whole whorl height on early whorls but shorter lower down, reduced or absent on last half-whorl of large shells; crossed by relatively prominent, coarse, rounded spiral cords, 5-7 on spire and about 25 on last whorl and canal, with 1 lower cord filling each interspace on whorl sides; sutural ramp almost smooth, apart from weak subsutural fold. Anal sinus narrowly rounded, relatively deep, occupying narrow zone on sutural ramp below subsutural fold. Protoconch of 2 smooth whorls, apex dome-shaped; ending in a few axial costae.

Opoitian-Nukumaruan; "Devil's Elbow, Napier-Wairoa Road", Nukumaruan (type); uncommon in Opoitian-Waipipian blue-grey mudstone in Wairoa district, northern Hawke's Bay; widespread and not uncommon in Nukumaruan blue-grey mudstone throughout central and southern Hawke's Bay. At Devil's Elbow, *C. allani* is not uncommon in the Devil's Elbow mudstone at the top of the north face of the road exposure, but we have not seen specimens from any other horizon, so the Devil's Elbow mudstone is assumed to be the type horizon.

Comitas allani has weaker axial sculpture and more prominent spiral cords than other New Zealand species; also, it is much smaller than the widespread Oligocene-Miocene *C. fusiformis* and Pliocene-Recent *C. onokeana*.

Figured specimen (Pl. 42p): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, north of Napier, Nukumaruan (NZGS) x 2.

Pl. 42 r. *Paracomitas (Paracomitas) protransenna* (Marshall and Murdoch, 1923) [*Surcula protransenna* Marshall and Murdoch 1923, p. 126] (Turridae: Turritinae).

Small for family (13-17 mm high), tall and narrow. The only prominent sculpture is a protruding, rounded shoulder carina; a much weaker spiral cord forms a peribasal angulation on last whorl; surface on and below shoulder carina bears many close, very low, wide spiral cords; faint growth lines form the only axial sculpture. Anal sinus deep and evenly concave, occupying strongly concave sutural ramp; outer lip swings strongly forward below sinus. Canal long and narrow, straight, open, without fasciole. Protoconch of 1.5 whorls, with dome-shaped, smooth apex but tall second whorl, with prominent, narrow median keel developing after first half-whorl.

Nukumaruan; Waikopiro Stream, southeast of Takapau, southern central Hawke's Bay (type); widespread and not uncommon in blue-grey siltstone deposited in c. 30-60 m throughout central and southern Hawke's Bay; uncommon in southern Wairarapa. We are not aware of records from Wanganui basin, but this is a distinctive biostratigraphic index of Nukumaruan age in Hawke's Bay.

The ancestry of *Paracomitas protransenna* is unknown; it is succeeded by *P. gemmea* (Castlecliffian; Pl. 49q) and *P. augusta* (Murdoch and Suter) (Recent), both of which

have nodules around the shoulder carina. This is one of several taxa of Turridae that seem to have appeared abruptly in New Zealand early in Nukumaruan time.

Figured specimen (Pl. 42r): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 3.

Pl. 42 t. *Splendrillia (Splendrillia) aequistriata* (Hutton, 1886) [*Drillia aequistriata* Hutton 1886a, p. 334; *Drillia (Crassispira) aequistriata*] (Turridae: Drillinae).

Large for New Zealand members of the genus (23-26 mm high), fusiform, with tall spire but relatively short, open anterior canal, lacking fasciole. A narrow, vertical subsutural zone is followed (downwards) by narrow, markedly concave sutural ramp, gently rounded shoulder formed by low nodules on tops of axial costae, and moderately convex whorl sides that taper gradually to canal. Almost entire surface crowded with narrow spiral cords, but over the shoulder cords are only half the width and height of those lower down. Axial costae evenly rounded, moderately prominent, 11-14 on last whorl, becoming short shoulder nodules over last half-whorl of some large specimens. Moderately deep, relatively wide anal sinus occupies whole sutural ramp, and is constricted by large parietal tubercle at top of inner lip. Protoconch dome-shaped, of 1.5 smooth whorls.

Nukumaruan; "Petane", i.e., hillside north of Petane Pa, north of mouth of Esk River, north of Napier (type); widespread and common in blue-grey siltstone in central and southern Hawke's Bay; rare in Wanganui basin. Largest and most common in Devil's Elbow mudstone around Devil's Elbow and the Arapaoanui Valley, north of Napier.

Splendrillia aequistriata is markedly larger, a little wider, and with more prominent axial costae and more of the surface bearing spiral cords than all other New Zealand species of *Splendrillia*, and (except for its relatively weak subsutural fold) closely resembles the typical Australian modern species of *Splendrillia*.

Figured specimen (Pl. 42t): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 2.

Pl. 42 o. *Antiguraleus abnormis* (Hutton, 1885) [*Clathurella abnormis* Hutton 1885b, p. 316; *Mangilia abnormis*] (Turridae: Mangeliinae).

Small for genus (6.0-6.5 mm high), relatively short and wide for family. Protoconch of 1.5 apparently smooth whorls (microscopically granulous), dome-shaped with low initiation. Whorls with narrow, almost horizontal sutural ramp just below suture, but weakly inflated below shoulder angle, spire clearly stepped; last whorl and canal short, canal open, with oblique anterior end. Sculpture of 3 spiral cords below shoulder on spire and about 12 on last whorl, interspaces filled by several orders of fine spiral threads; crossing prominent, rounded, widely spaced axial costae, about 12 per whorl, without forming nodules (except rounded ones around shoulder angle). Outer lip varicose, markedly opisthocline (as are axial costae), with shallowly concave but obvious anal sinus forming horizontal area of sutural ramp.

Mangapanian-Nukumaruan; Castlecliffian? "Petane", i.e., hillside north of Petane Pa, north of mouth of Esk River, north of Napier, Nukumaruan (type); widespread and moderately common in Nukumaruan blue-grey siltstone throughout Hawke's Bay and northern Wairarapa; uncommon in Mangapanian and Nukumaruan offshore, soft-bottom facies in Wanganui basin. The records from early Castlecliffian formations of the Castlecliff section, Wanganui, by Fleming (1953) appear to be based on related but distinct species.

Antiguraleus abnormis occurs sympatrically in Hawke's

Bay Nukumaruan mudstone with the narrower and more narrowly ribbed *A. deceptus*; other named species (including most modern ones) are taller and narrower and occupy deeper water than *A. abnormis*.

The shell form of *Antiguraleus* is very similar to that of *Oenopota* species figured by Bouchet and Warén (1980) and we can see no differences between the protoconchs of *Oenopota* and *Antiguraleus*; the possibility needs investigation that *Antiguraleus* is a synonym of *Oenopota* Mörch, 1852.

Figured specimen (Pl. 42o): GS10849, V20/f8572, Devil's Elbow mudstone, top of north face of Devil's Elbow hill, Napier-Wairoa highway, Nukumaruan (NZGS) x 6.

Pl. 41 h. *Eulima* (sensu lato) *christyi* Marwick, 1924c [p. 195] (Eulimidae).

Very large for New Zealand fossil members of the family (17-18 mm high); smooth and polished, with straight sides (or, in a few specimens, lightly curved early whorls), very tall, narrow spire, and evenly rounded base. Protoconch very small and narrow, but damaged in all material seen. Aperture with weakly sigmoidal outer lip and lightly thickened inner lip; the only sculpture is faint, low, sigmoidal traces of former outer lips, randomly situated up spire.

Nukumaruan; Okauawa Stream, Kereru Road, inland central Hawke's Bay, Nukumaruan (type); uncommon in shellbeds and near-shore mudstone in central Hawke's

Bay only. Other late Cenozoic species assigned to *Eulima* are all much smaller (4-8 mm high).

The generic classification of the smooth, tall and narrow, rather featureless, obligate ectoparasites of the Eulimidae has always been very difficult. Warén (1984) and Bouchet and Warén (1986) have shown that some progress can be made with meaningful subdivision of this huge group of very similar shells if the anatomy and host are known (most species are ectoparasitic on echinoderms). As these are not known for most New Zealand species and can never be known for fossil species, we have adopted a rather arbitrary classification—the larger, more thick-shelled, non-umbilicate species, most of which have a straight spire, are included in *Eulima* (in the broad sense), whereas most of the smaller, thin-shelled non-umbilicate species, most of which have a curved or twisted spire, are included in *Melanella* Bowdich, 1822 (which Warén has shown is an earlier synonym for *Balcis* Leach in Gray, 1847). One species, however, is included in *Fusceulima* Laseron, 1955, another in *Hypermastus* Pilsbry, 1899; umbilicate species are retained in *Niso* Risso, 1826. This classification is not intended to imply any precision or finality.

Figured specimen (Pl. 41h): holotype, GS1089, V21/f8482, Okauawa Stream, Kereru Road, central Hawke's Bay, Nukumaruan (TM6834, NZGS) x 3.

CHAPTER 16. MID-LATE PLEISTOCENE FAUNAS (CASTLECLIFFIAN AND HAWERAN STAGES): PLATES 43-49

INTRODUCTION

The classical localities for fossils of Castlecliffian age are exposed in the continuous coastal section extending from Ototoka Beach to Castlecliff, west of the mouth of Wanganui River, and were described in detail by Fleming (1953) (Fig. 23). A range of environments is represented in the sea cliffs, from offshore shelf siltstone and a shellbed with a particularly diverse faunule, formed by offshore current winnowing of sediment (Tainui Shellbed), to sandstone deposited just off an ocean beach. Fossils are abundant in almost all beds. Fossils are also common at many inland localities around Wanganui, in stream banks and road cuts. The uppermost formation of the Castlecliffian Stage has recently been designated as Putiki Shellbed, in the roadside exposure east of Putiki

Pa, just east of Wanganui city (Beu et al. 1987), and the diverse fossil locality at Landguard Bluff, east of the mouth of Wanganui River, is now included in the overlying Haweran Stage. Other good exposures of Castlecliffian fossiliferous marine rocks can be seen in the extensive Rangitikei River section, inland from Bulls, western North Island; at Ohope Beach to Ohiwa Harbour and in the coastal cliffs west of Matata, Bay of Plenty; in the lowest part of the young rocks overlying the Black Reef Sandstone just west of Black Reef, Cape Kidnappers, southern Hawke's Bay; and in the Leader River on "Mendip Hills" station, west of Parnassus, North Canterbury (the only area of fossiliferous Castlecliffian marine rock exposed on land in the South Island).

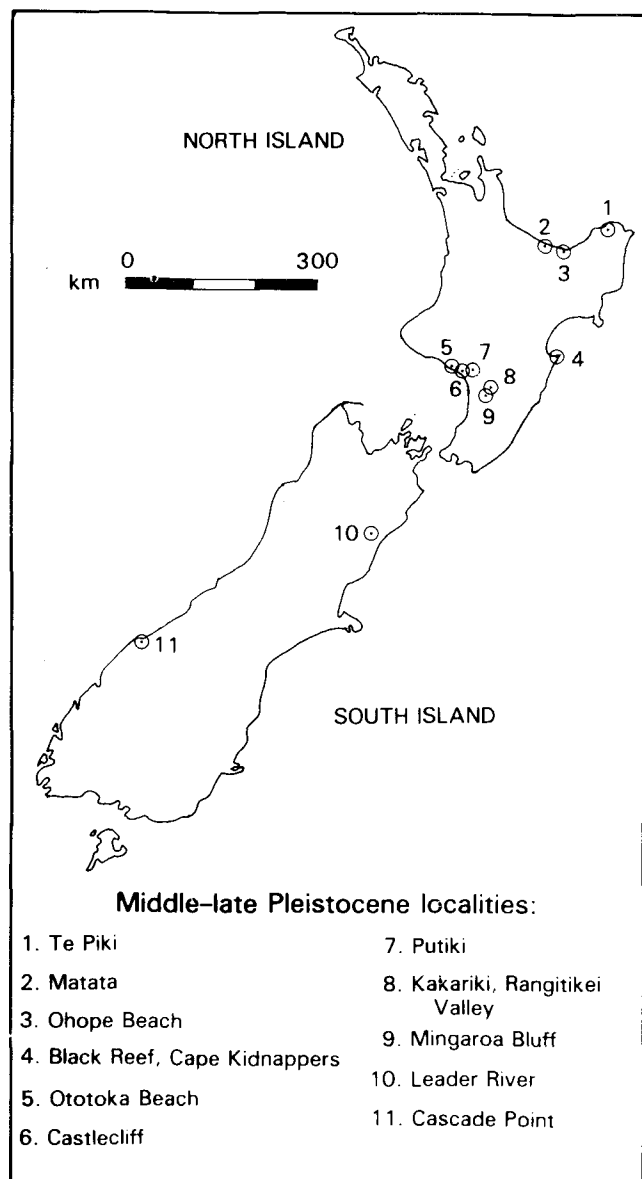


Figure 23 The main molluscan fossil localities of Castlecliffian and Haweran (mid-late Pleistocene) age.

The beautifully preserved and highly diverse fauna of the Te Piki beds, exposed in main highway road cuts about six km east of Cape Runaway, near East Cape, has formerly been assigned a late Castlecliffian age (Powell 1934; Grant-Mackie and Chapman-Smith 1971). Recent research has shown that these beds were deposited during oxygen isotope stage 7, about 200,000 years ago, during Haweran time (Beu and Edwards 1984). The fauna of the Te Piki beds provides the only evidence of the mid-Pleistocene molluscan fauna of the warm-water, north-eastern North Island faunal province, and is unique among post-Miocene fossil localities in New Zealand in including such warm-water taxa as *Coralliophila*, *Agnewia*, and *Heliacis*.

Other fossil localities of Haweran age have faunules of much lower diversity than the Te Piki beds. The only other faunules known in situ in marine sandstone and siltstone are in the youngest marine rocks of Wanganui Basin, overlying Putiki Shellbed, in a narrow zone extending from the mouth of Wanganui River to the

Rangitikei River, where they are exposed between Kakariki Bridge and Mingaroa Bluff. By far the greatest number of Haweran fossil localities are beach deposits containing shallow-water, near-shore faunules representing the intertidal zone of either estuaries or rocky shores. They occur in the cover beds of the uplifted marine terraces that are found around much of the New Zealand coast. Terraces are particularly wide and laterally extensive along the Wanganui-South Taranaki coast (Pillans 1983), from where the moderately diverse faunas of the Brunswick, Rapanui and Hauriri terraces were listed by Fleming (1953).

Castlecliffian molluscan faunas differ from Nukumaruan ones by lacking 17 genera and subgenera that are present in Nukumaruan and older rocks, including such characteristic Nukumaruan taxa as *Glycymeris* (sensu stricto), *Glycymerita* (*Manaiia*), *Limopsis*, "*I.*" *zealandicus* (Suter) belongs in an unnamed genus], *Patro*, *Pteromyrtea*, *Marama*, *Eumarcia* (sensu stricto) and *E.* (*Atamarcia*), *Lutraria*, *Taxonia*, *Hartungia*, *Lamprodomina*, and *Zeacuminia*. Together with the many species that became extinct at the end of Nukumaruan time, or evolved into different species by Castlecliffian time, the difference between Nukumaruan and Castlecliffian molluscan faunas constitutes one of the most dramatic of faunal turnovers in the New Zealand Cenozoic fossil record. Also, many genera and species that are familiar members of the modern New Zealand molluscan fauna appeared first in Castlecliffian rocks, including *Pecten* (sensu stricto), *Dosinia* (*Phacosoma*) *subrosea*, *Paphies ventricosa*, *Calliostoma selectum*, *Trochus* (*Thorista*) *viridis*, *Turbo smaragdus*, *Crepidula costata*, *Pellicaria vermis*, *Cabestana spengleri*, *Murexsul octogonus*, *Lepsiella scobina*, *Austrofusus glans*, *Cominella adpersa*, and *Alcithoe* (*Leporemax*) *fuscus*. A few taxa are restricted to Castlecliffian rocks, including *Pecten benedictus marwicki*, *Haliotis powelli*, *Opalia* n. sp., *Aeneator delicatulus*, *Buccinulum caudatum*, *Paracomitas gemma*, and *Splendrillia annectens* (all illustrated here).

Haweran time saw the apparent arrival of an appreciable proportion of the present molluscan fauna of New Zealand and, although much of this diversity increase was undoubtedly caused by the poor preservation of near-shore, high-energy environments at earlier times, some was just as undoubtedly caused by dispersal to New Zealand of planktonic larvae in the East Australian and circum-Antarctic currents. Among abundant modern taxa first recorded from Haweran rocks are *Mytilus edulis aoteanus*, *Irus* (*Notopaphia*) *elegans*, *Pseudarcopagia disculus*, *Scutus antipodes*, *Argobuccinum pustulosum tumidum*, *Haustorium haustorium*, and *Bulla quoyi*. A particularly interesting and biostratigraphically useful element in the Haweran fauna is the small group of species that survived into Haweran time from earlier times, but became extinct (at least in the New Zealand region) during Haweran time. These include *Barytellina crassidens*, first recorded in Pliocene (Waipipian?) rocks; the genus and subgenus *Mioawateria* and *Neoguraleus* (*Fusiguraleus*), which extend from Miocene time; and *Anadara trapezia* and *Pecten tainui*, first known in Castlecliffian rocks. Among the few species restricted in New Zealand to Haweran rocks are *Stiracolpus vigilax*, *Eunaticina linnaeana* and *Capulus uncinatus*.

The well known opisthobranch *Tenuiactaeon ambiguus* (which is known earliest by a very few specimens in latest Nukumaruan rocks of Wanganui and southern Wairarapa) can no longer be considered an index of Castlecliffian and early Haweran time. A specimen from a borehole in post-glacial sediments at Gisborne has been dated by the radiocarbon method at about 9000 years BP, and three modern specimens have been seen, from the Bay of Islands and from Waiwera, near Auckland.

We have not attempted to illustrate a high proportion of the Castlecliffian and Haweran molluscan fauna. Powell (1979) has described and illustrated nearly all of the modern New Zealand molluscs that had been named prior to about 1975, so most of the common species at Castlecliffian and Haweran fossil localities will be found in his book. We have tried to include (a) a range of the more abundant species, (b) a few spectacular but less common species of interest to taxonomists and collectors, and (c) most species that are restricted to Castlecliffian-Haweran rocks, or are otherwise useful in biostratigraphy and paleoecology.

REPRESENTATIVE MID-LATE PLEISTOCENE MOLLUSCA

Pl. 43 a,c,e. *Leptochiton finlayi* (Ashby, 1929) [*Lepidopleurus finlayi* Ashby 1929b, p. 372; *Terenochiton finlayi*] (Lepidopleuridae.)

Very small (whole live animal to only 10 mm long, median valves to 3 mm wide), very thin and fragile, with evenly convex dorsum (i.e., no dorsal angle or jugum), without insertion plates but with small, triangular sutural laminae on fronts of valves 2-8. Sculpture coarse for genus, of widely spaced rows of relatively large granules on pleural areas and end valves, but random granules on lateral areas; unique peg-like spines (only partly preserved on figured specimen) project from posterior edge of valves 1-7.

Mangapanian-Recent; Recent, 110 m, off Otago Heads, eastern South Island (type).

Leptochiton finlayi has been included as the only available figures of a large group of small, primitive chitons lacking insertion plates and having even granules all over the tegmentum. It is similar to the more common *L. inquinatus* (Altonian-Recent) but much smaller (*L. inquinatus* reaches 25 mm long) and more coarsely sculptured, with fewer than half as many rows of more widely spaced granules, and with posterior spines on valves 1-7 that are absent from *L. inquinatus*. *L. inquinatus* occurs commonly today all around New

Zealand on hard substrates from the intertidal zone to about 60 m, whereas *L. finlayi* occurs moderately commonly on hard substrates all around New Zealand in about 50-300 m. Both are fairly common in washings from Castlecliff shellbeds, and *L. finlayi* occurs also in deep-water siltstone in southern Wairarapa (Mangapanian); *L. inquinatus* occurs also at Ohope Beach, Whakatane (Castlecliffian), Te Piki, Cape Runaway (Haweran, oxygen isotope stage 7) and at many Miocene and Pliocene localities. The opportunity is taken to illustrate the three remaining valves of the Recent holotype of *L. finlayi*, and to point out Fleming's (1966b, p. 86) confusion of the type locality, stated wrongly as Castlecliff, Castlecliffian; Ashby (1929b, p. 373) recorded the holotype from 110 m off Otago Heads, eastern South Island. We agree with Kaas and Van Belle (1985a) that all named New Zealand Lepidopleuridae (except *Parachiton textilis* Powell, 1937, Recent, Three Kings Is.) belong in *Leptochiton* Gray, 1847 (= *Terenochiton* Iredale, 1914).

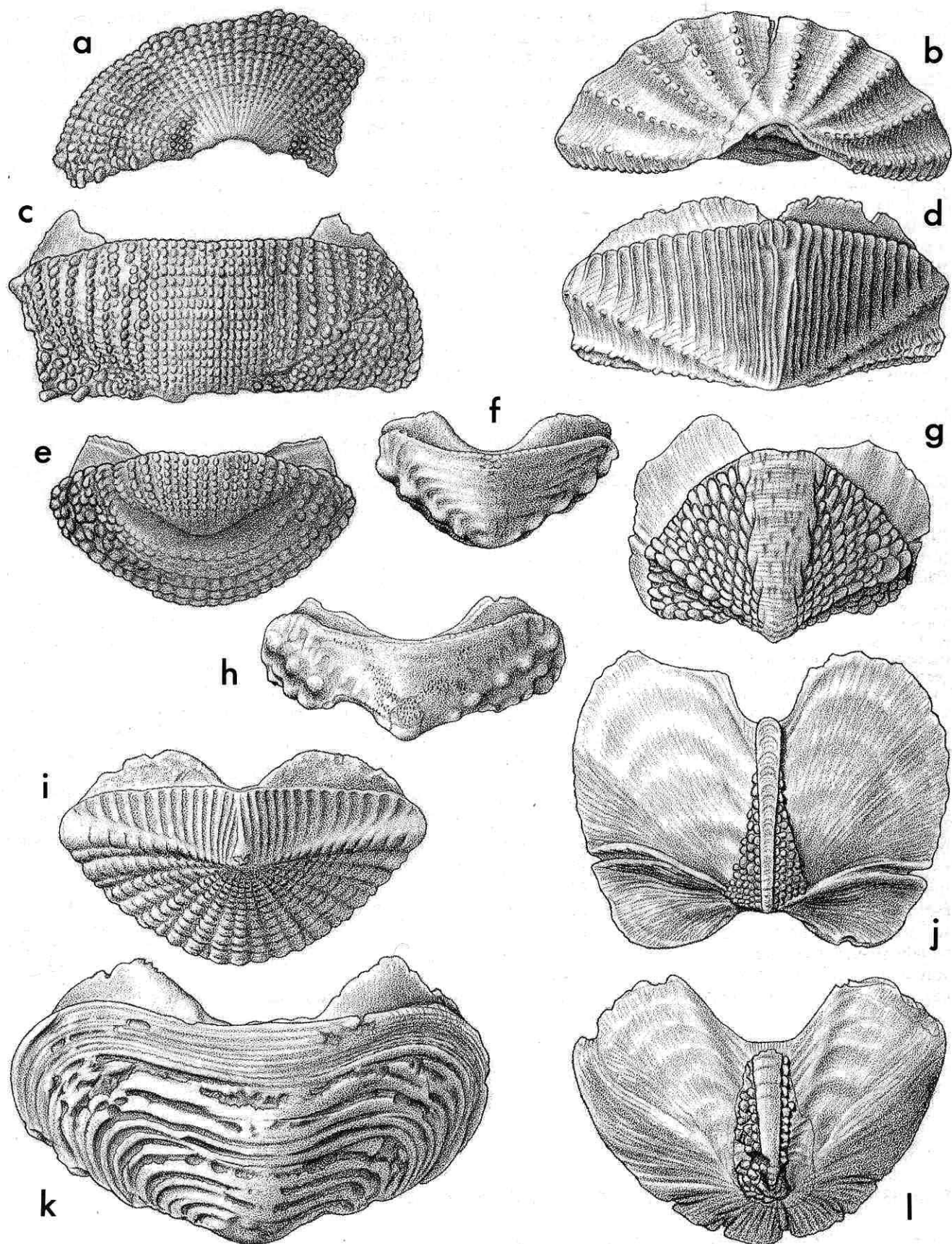
Figured specimen (Pl. 43a, c, e): holotype, 110 m, off Otago Heads, eastern South Island, Recent (Australian Museum, Sydney, C95165; apparently the only 3 valves remaining) x 33.

Pl. 43 f,h,k. *Onithochiton neglectus neglectus* Rochebrune, 1881 [*Chiton undulatus* Quoy and Gaimard 1835, p. 393 (not of Wood, 1828); *Tonicia lineolata* "Frembly" of Hutton 1880, p. 114 (not of Frembly, 1828); *Onithochiton neglectus* Rochebrune 1881, p. 120; *Onithochiton astrolabei* Rochebrune 1881, p. 120; *Onithochiton filholi* Rochebrune 1881, p. 120; *Onithochiton decipiens* Rochebrune 1882, p. 196; *Onithochiton semisculptus* Pilsbry 1894, p. 425; *Onithochiton marmoratus* Wissel 1904, p. 658; *Onithochiton nodosus* Suter 1907c, p. 297; *Onithochiton opiniosus* Iredale and Hull 1932, p. 159; *Icoplax chathamensis* Dell 1960, p. 153; *Onithochiton undulatus*; *Tonicia undulata*; *Anthochiton* (*Nodioplax*) *chathamensis*; *Rhyssoplax* (*Nodioplax*) *chathamensis*]. Type species of *Onithochiton* Gray, 1847, and of *Nodioplax* Beu, 1967 (= *Onithochiton* Gray, 1847) (Chitonidae).

Small to moderate-sized (fossil median plates to 12 mm wide and 7.3 mm long), second valve markedly longer than valves 3-8; tegmentum uniformly pink in juvenile forms (smooth and structureless in fossils), brightly striped with commarginal alternate cream and dark green bands in most modern adults (remaining brown and white in some fossils, and white bands eroding away differentially, so it seems likely that green bands are calcite and cream bands are aragonite). Anterior valve

Plate 43 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (1).

- a,c,e. *Leptochiton finlayi* (Ashby), x 33.
- b,d. *Lorica haurakiensis* Mestayer, x 10.5(b) and x 6.3(d).
- f,h,k. *Onithochiton neglectus neglectus* (Rochebrune), x 10.5(f,h) and x 5.3(k).
- g. *Acanthochitona* (*Acanthochitona*) *zelandica* (Quoy and Gaimard), x 10.5.
- i. *Rhyssoplax canaliculata* (Quoy and Gaimard), x 10.5.
- j,l. *Cryptoconchus marwicki* Bucknill, x 8.6.



semicircular, with 8 slits, insertion plates short and thick, finely denticulate. Median valves very short and wide, with 1 slit in each edge. Posterior valve small, triangular, with terminal mucro; posterior edge thick, callused, smooth, without slits. Sculpture of radial rows of low, rounded nodules on anterior valve and on lateral areas of valves 2-7, highly variable in prominence, commonly seen on polished, pink juvenile form (= *O. marmoratus*, *O. nodosus*, *I. chathamensis*) but absent from most adult shells.

Mangapanian-Recent; Recent, New Zealand (types of all names in the above synonymy). A common chiton under boulders on exposed rocky shores throughout New Zealand, and in the Subantarctic Islands (where adults are uniformly brown, so recognised as the subspecies *O. neglectus subantarcticus* Suter, 1906) and dredged in a few metres of water, but a most uncommon fossil. Specimens have been seen from T23/f6565, OU8122, Te Ekaou Stream, Pohangina, eastern Wanganui basin (Mangapanian; Otago University Geology Dept), from Ohope Beach, Whakatane (Castlecliffian; juv. *marmoratus* form, illustrated; National Museum of N.Z.), and from GS158, high "raised beach", Amuri Bluff, Marlborough, coll. A. McKay (20 large valves; early Haweran).

The uniform pink, nodulous juvenile form of *Onithochiton neglectus* (Pl. 43f, h) has often been placed in a different genus and family from the smooth cream and green adult, but O'Neill (1984, 1985) studied growth series and revised the taxonomy of New Zealand *Onithochiton*, confirming that the sculptured pink juvenile grows up to become the smooth cream and green adult.

Figured specimens (Pl. 43f, h, k): Ohope Beach, Whakatane, Castlecliffian (National Museum of N.Z.; small median and posterior valves, form *marmoratus*) x 10.5 (Pl. 43f, h); GS158, O32/f9038, Pleistocene terrace remnant at 170 m altitude, north end of Amuri Bluff, Marlborough, Haweran (NZGS; large median valve) x 5.3 (Pl. 43k).

Pl. 43 i. *Rhyssoplax canaliculata* (Quoy and Gaimard, 1835) [*Chiton canaliculatus* Quoy and Gaimard 1835, p. 394; *Chiton insculptus* A. Adams 1854, p. 91; *Lepidopleurus canaliculatus*; *Anthochiton canaliculatus*] (Chitonidae).

Valves small (median valves to about 11 mm wide, 3.5 mm long), much wider than long, highly arched, with prominently angled dorsum; sutural laminae short and wide, insertion plates thick and very short, square-edged, very finely and complexly denticulate. Anterior valve semicircular, with 8 slits in anterior edge, and about 30-40 moderately prominent wide, low closely spaced, weakly nodulous radial costae. Median valves with 1 slit in each side, almost smooth but obscurely defined jugal area, pleural areas dissected by 10-15 wide, shallow grooves (producing the same number of smooth-topped, low, narrow longitudinal costae), lateral areas with 3 or 4 prominent, low, wide, weakly nodulous radial costae (as on anterior valve). Posterior valve semicircular, with 10-12 slits around posterior edge, much lower than anterior valve of same specimen; mucro slightly in front of centre, narrow pleural areas sculptured as on valves 2-7; jugal area longitudinally costate on most specimens, i.e., not as well defined and smooth as on valves 2-7; posterior half of valve bears 24-30 low, close, weakly nodulous radial costae, as on anterior valve and lateral areas of median valves.

Nukumaruan-Recent; Recent, New Zealand (types of both *Chiton canaliculatus* and *C. insculptus*). *R. canaliculata* is abundant today throughout New Zealand, dredged with *Acanthochitona* (*Notoplax*) *rubiginosa* (but not quite as common as *A. rubiginosa*) on hard substrates (usually on shells) in about five to 100 m. It is an

uncommon fossil, however; specimens have been seen from Hawke's Bay blue-grey siltstone (Nukumaruan), from several shellbeds at Castlecliff, Wanganui (Castlecliffian), from Te Piki, Cape Runaway (Haweran, oxygen isotope stage 7), from Ohope Beach and Matata, Bay of Plenty (Castlecliffian; National Museum of N.Z.), and from the shellbed on Hauriri Terrace, Waverley Beach, west of Wanganui (oxygen isotope stage 5a, 80 000 years BP).

Rhyssoplax canaliculata is much more steeply arched and with pleural areas much more subdivided into costae than on the intertidal to shallow subtidal *R. aerea* (Reeve, 1847) (= *clavata* Suter, 1907; = *oliveri* Mestayer, 1921; = *suteri* Iredale, 1910; ? = *stangeri* Reeve, 1847; = *huttoni* Suter, 1906); also, in modern specimens, *R. aerea* is usually glaucous green but varies to yellow or speckled brown, and some specimens have pink dorsal areas, whereas *R. canaliculata* is consistently brownish pink, with a dark grey stripe on each side of the pink jugum on median valves. Fossils that could be identified as *R. aerea* rather than *R. canaliculata* have not been recognised with certainty. The only other chiton with which this could be confused is *Lorica haurakiensis* (below) but *R. canaliculata* differs from *L. haurakiensis* in its much smaller size, lower dorsal (jugal) angle, lower and wider pleural costae, and very much lower and wider lateral radial costae lacking the small, sharp nodules of *Lorica*; the anterior valve is deeply concave and coarsely costate and the posterior valve has a posterior mucro in *Lorica*.

Figured specimen (Pl. 43i): GS4013, R22/f6353, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS), a posterior valve, x 10.5.

Pl. 43 b,d. *Lorica haurakiensis* Mestayer, 1921 [*Lorica volvox* of Suter 1907c, p. 297 (not of Reeve, 1847); *Lorica haurakiensis* Mestayer 1921, p. 177; *Aulocochiton haurakiensis*]. Type species of *Zelorica* Finlay, 1926 (= *Lorica* H. and A. Adams, 1852) (Schizochitonidae).

Very large for fossil chiton plates (median valves up to 20 mm wide, 10 mm high, 8 mm long; valve 2 up to 11 mm long); short and very wide, highly arched, with sharply angled dorsum; sutural laminae wide and very short, insertion plates thick, very short, weakly pectinate. Colour pattern of alternate broad bands of reddish brown and white remains on many fossils. Anterior valve (rare as a fossil) short and widely arcuate, very steeply arched, with concave anterior silhouette and embayed posterior edge, bearing about 10 very prominent, narrowly crested radial costae, each with a row of nodules down its crest. Median valves (common) very wide and short, with many high, narrow, almost smooth longitudinal costae on pleural areas and dorsum and 2 or 3 narrow-crested, widely spaced, nodulous costae on lateral areas; without jugum; valve 2 narrowly triangular, markedly longer at dorsum than valves 3-7. Posterior valve (not seen fossil) very small, essentially like median valves, with posterior mucro, longitudinally costate pleural areas and dorsum, and 1 coarsely nodulous costa along each side of posterior margin.

Waipipian-Recent; Recent, Hauraki Gulf, east of Auckland (type). Although uncommon in the living fauna (specimens are known from hard substrates throughout New Zealand, from the intertidal zone down to about 50 m) this is one of the largest and more common of fossil chitons; specimens have been examined from the Waipipi shellbeds, Waverley Beach (Waipipian), Waihi Beach, Hawera (Waipipian), Hawke's Bay Nukumaruan siltstone (several localities), Ohope Beach, Whakatane (Castlecliffian), and are common in the shellbed on Hauriri Terrace (oxygen isotope stage 5a, 80 000 years BP) at Waverley Beach (12 valves).

Lorica haurakiensis is easily recognised by its large size, its prominent costae, the prickly nodules on the costal crests, the strongly concave anterior slope of the anterior valve, the long, triangular second valve, and the small posterior valve with a terminal mucro.

Figured specimens (Pl. 43b, d): Ohope Beach, Whakatane, Castlecliffian (National Museum of N.Z.), anterior valve, x 10.5 (Pl. 43b); coast west of Waipipi Point, Waverley Beach, west of Wanganui, Waipipian (NZGS, ex F. D. Chambers colln.), median valve, x 6.3 (Pl. 43d).

Pl. 43 g. *Acanthochitona* (*Acanthochitona*) *zelandica* (Quoy and Gaimard, 1835) [*Chiton zelandicus* Quoy and Gaimard 1835, p. 400; *Acanthochoetes hookeri* Gray 1843, p. 262; *Acanthochiton zelandicus doubtlessensis* Ashby 1926, p. 12; *Acanthochiton brookesi* Ashby 1926, p. 14; *Acanthochiton zelandicus amplificatus* Iredale and Hull 1930, p. 166; *Chitonellus zelandicus*; *Acanthochites zelandicus*] (Acanthochitonidae).

Small (median plates rarely more than 5 mm wide and 4 mm long), thin. Very similar in most characters to valves of *A. (Notoplax) mariae* (Pl. 44a, d, h), and many fossils are difficult to identify with certainty, even to subgenus; finely sculptured, markedly triangular, relatively wide median valves associated with anterior valves with 5 prominent radial ribs can be identified as *A. mariae* with some confidence; whereas markedly smaller, slightly more rounded and more antero-posteriorly elongate median valves with coarser tegmental granules, wider jugal areas, and more prominent radial ridges between lateral and pleural areas, associated with a relatively long anterior valve lacking radial ridges, are identified as *A. zelandica* (at least, in Castlecliffian and younger rocks). Such specimens are, however, among the least common of fossil chiton plates, presumably reflecting the intertidal rocky shore habitat of living *A. zelandica* and the scarcity of preservation of this environment in the fossil record.

Castlecliffian-Recent; Recent, New Zealand (types of all names listed in the synonymy). The only fossil specimens certainly referred here are a few from Tainui Shellbed at Castlecliff, Wanganui (Castlecliffian) in Auckland University Geology Department, and a few from Ohope Beach, Whakatane (Castlecliffian) in the National Museum of N.Z.

Figured specimen (Pl. 43g): R22/f6353, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (Auckland University Geology Department) x 10.5.

Pl. 44 a,d,h. *Acanthochitona* (*Notoplax*) *mariae* (Webster, 1908) [*Acanthochites* (*Loboplax*) *mariae* Webster 1908, p. 254; *Loboplax stewartiana* Thiele 1909, p. 37; *Notoplax* (*Amblyplax*) *mariae haurakiensis* Ashby 1926, p. 26; *Notoplax brookesi* Ashby 1929b, p. 370; *Notoplax brookesi fortior* Iredale and Hull 1931, p. 66; *Notoplax mariae*] (Acanthochitonidae).

Small (median plates to 9 mm wide, 5 mm long), moderately thin. Median valves with triangular tegmentum, almost smooth, narrowly triangular jugum, flat, oval pleural granules, a narrow radial ridge on each side, and moderately large sutural laminae with a single deep slit on each side. Anterior valve semicircular, with 5 deep slits in insertion plate, and lobate tegmentum with 5 prominent radial costae. Posterior valve with oval to subcircular tegmentum, central mucro, 2 long sutural laminae, and 5 slits around posterior.

Nukumaruan-Recent; Recent, New Zealand (types of all names listed in the synonymy). Modern specimens are found on hard substrates from the intertidal zone to outer shelf depths; specimens from deeper water have a more steeply angled dorsum than those from shallow water.

The second-most common of New Zealand Plio-Pleistocene fossil chitons, occurring fairly commonly at many localities of near-shore and shelf facies (the most common species is *A. (Notoplax) rubiginosa*, Pl. 38a-c). *A. mariae* is common in Nukumaruan and Castlecliffian formations of Wanganui basin, Nukumaruan blue-grey siltstone widespread in central and southern Hawke's Bay, Castlecliffian outcrops of the Ohope Beach-Ohiwa Harbour area and the Matata coast, Bay of Plenty, and the late Haweran Te Piki bed, Cape Runaway.

Acanthochitona mariae is smaller, narrower, more finely sculptured, and occurs to greater depths than the common intertidal living *A. violacea* (Quoy and Gaimard, 1835), so it is not surprising that undoubted valves of *A. violacea* have not been found fossil. Modern specimens of *A. mariae* have a relatively narrow, finely spiculous girdle, and this is one of the least specialised species referred to *A. (Notoplax)*. The only apparent difference between *Acanthochitona* and the generalised *Notoplax* species is the prominent radial costae on the anterior valve of species referred to *Notoplax*, so it seems best to treat *Notoplax* as a subgenus of *Acanthochitona*.

Figured specimens (Pl. 44a, d, h): to complete illustrations of this species (used here as the example of a "typical" acanthochitonid), an anterior valve from a Recent specimen, Point Chevalier, Auckland, intertidal (Pl. 44 a; NZGS) x 10.5; median and posterior valves: Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7; Pl. 44 d,h; National Museum of N.Z.) x 10.5.

Pl. 43 j,l. *Cryptoconchus marwicki* Bucknill, 1928 [p. 163] (Acanthochitonidae).

Moderately large, nearly equidimensional valves, each to about 12.0 mm wide and 9.7 mm long (dimensions of holotype). Articulamentum enormously expanded into wide, smooth, antero-laterally extended, strongly convex laminae; in median valves each side deeply cut by single slit at posterior quarter of length; in posterior valve, 5 closely spaced, deep slits around posterior end, dividing off 4 thick, square-sided, peg-like insertion plates; anterior valve not seen. Tegmentum very limited in area, forming narrowly triangular, finely sculptured pleural area on each side of long, narrow, smooth, very narrowly triangular jugum.

Castlecliffian; Castlecliff, Wanganui (type), probably from Tainui Shellbed (provenance of all of the few recently collected valves); uncommon.

Cryptoconchus marwicki is very similar to *C. porosus* (Recent; and Haweran, Te Piki, Cape Runaway = *C. mucronatus* Grant-Mackie and Chapman-Smith, 1971), but has a wider and longer jugum and slightly larger pleural areas; presumably *C. marwicki* was ancestral to *C. porosus*. *C. porosus* is the common living intertidal to shallow subtidal "butterfly chiton", a curious yellow-green to dark brown, slug-like animal up to 80 mm long, with only a smooth "skin" (the girdle) showing exteriorly, and with large knobs at each of the girdle spicule-tufts, but with a row of small slits along the dorsal mid-line revealing the tiny tegmental areas. We may assume, then, that *C. marwicki* was a similar large, slug-like chiton living in shallow water on rocky substrates. No earlier species are known in New Zealand, but it seems very likely that *Cryptoconchus* is the ultimate development of the common evolutionary trend in *Acanthochitona* (*Notoplax*) towards mantle expansion and consequent reduction of the tegmentum and expansion of the

articulamentum. In *C. porosus*, the tegmentum has been lost almost completely; the final step of complete tegmentum loss and completely internal valves has been taken by the huge western North American and North Pacific chiton *Cryptochiton stelleri* (Middendorf) (reaching 250 mm in length). *Cryptoconchus* appears to be an endemic New Zealand development from *Acanthochitona* (*Notoplax*), and not closely related to *Cryptochiton*.

Figured specimens (Pl. 43j, l): holotype, Castlecliff, Wanganui (Tainui Shellbed ?), Castlecliffian (TM4903, NZGS; a seventh valve) (Pl. 43j); posterior valve, Tainui Shellbed, Castlecliff, Castlecliffian (NZGS; coll. Mrs E. Wolffe) (Pl. 43l), both x 8.6.

Pl. 44 c,f. *Barbatia novaezelandiae* (Smith, 1915) [*Arca decussata* (not of Sowerby) of Suter 1913c, p. 848; *Arca* (*Barbatia*) *novae-zelandiae* E. A. Smith 1915, p. 88] (Arcidae: Arcinae).

Moderate-sized for family (to 75 mm long), elongate, weakly inflated, with low umbones and subparallel dorsal and ventral margins; anterior margin rounded, posterior margin weakly subrectangular, in most specimens weakly inclined backward towards venter. Sculpture of many low, narrow, closely spaced radial costae, raised into many small, scaly nodules where crossed by many low, narrow, commarginal ridges. Hinge long, straight, narrow, with many similar teeth; teeth are short ridges, vertical in centre of hinge but radially diverging at ends. Ligamental area between umbo and hinge narrow, with a few prominent ligamental grooves. Interior of ventral margin finely denticulate except around shallow, smooth, byssal gape that occupies central 0.2-0.3 of shell length. Pallial line simple; interior finely striate inside pallial line, except for small, subcircular, roughly equal anterior and posterior adductor scars.

Waipipian-Recent; Recent, New Zealand (type). Not uncommon in many Pliocene and Pleistocene shellbeds—Waipipi Shellbeds, Waverley Beach, west of Wanganui; particularly common in Tainui Shellbed, Castlecliff; common in some Haweran terrace faunules and at Te Piki, Cape Runaway. Common today byssally attached in crevices and under boulders, at and below low tide on exposed rocky shores, and attached to hard substrates (boulders, shells) dredged on the shelf, down to about 200 m. Consequently, most Pliocene and Pleistocene localities where *B. novaezelandiae* occurs are in shallow-water, high-energy facies. Tainui Shellbed, Castlecliff (Castlecliffian), where it is particularly common, is a shellbed formed by bypassing of fine sediment in a current-swept mid-shelf environment (oysters, brachiopods, carnivorous epifaunal gastropods, and epifaunal, byssally attached bivalves such as *Modiolus aerolatus*, *Limaria orientalis*, and *Chlamys gemmulata* are also common).

Barbatia awamoana (Altonian) differs from *B. novaezelandiae* only in its slightly more elongate shape and more rounded posterior end; but similar specimens are virtually unknown from Middle Miocene to early Pliocene rocks.

Figured specimen (Pl. 44c, f): Te Piki, Cape Runaway, near East Cape, Haweran (Oxygen isotope stage 7; NZGS, from an early collection) x 2.

Pl. 44 b,e. *Anadara trapezia* (Deshayes, 1839) [*Arca trapezia* Deshayes 1839, p. 358; *Arca lobata* Reeve 1844 (in 1843-1844), pl. 3, fig. 19; *Diluvarca trapezia*] (Arcidae: Anadarinae).

Moderately large for genus (to at least 80 mm long), thick and solid,

strongly inflated, coarsely ribbed. Hinge line long and straight, with umbo protruding strongly above it at anterior 0.2-0.3 of shell length; anterior margin evenly rounded; posterior margin sloping backward; dorsal and ventral margins nearly straight but diverging posteriorly, producing an oblique rhomboidal, postero-ventral extension of shell shape. Exterior sculptured with 25-27 prominent, wide, widely spaced, radial costae of almost square section, smooth except for weak commarginal growth ridges. Interior of ventral margin coarsely crenulated by radial costae. Hinge a long row of similar teeth; short, straight, vertical ridges over central area but shallowly V-shaped at each end. Wide, shallowly triangular ligamental area between umbo and hinge grows downwards as shell grows, obliterating central hinge teeth of old shells; bearing few, widely spaced, shallow ligamental grooves, shallowly V-shaped in young shells but straight in older ones, and obliterated by many shallow vertical grooves in old individuals. Interior with an obvious, simple pallial line; coarsely striate inside the pallial line except for small, circular, anterior adductor scar and markedly larger, circular, posterior one.

Castlecliffian-late Haweran in New Zealand (living in south-eastern Australia); Recent, Australia (types of *Arca trapezia* and *A. lobata*). Extinct in New Zealand (probably since late in the last glaciation, 37 000 years ago) but the "Sydney mud cockle" of New South Wales today, living abundantly, shallowly buried in sand or mud "eel-grass" (*Zostera*) flats in estuaries and enclosed bays, with salinity markedly lower than oceanic; dead, evidently recently (geologically) extinct colonies occur in Port Phillip, Victoria, and in South Australia. Almost all New Zealand localities are beyond the range of conventional C14 dating (greater than 40 000 yrs), and range from late Castlecliffian (oxygen isotope stage 11; Wanganui basin) to late Haweran (oxygen isotope stage 5, probably 5c or 5a; youngest high terrace on Mahia Peninsula), an age range from about 400 000 to 80 000 years ago, so this provides one of few molluscan biostratigraphic guides over this young period (one lot, from Rangitoto Island, Auckland, has recently been dated by C14 (tandem accelerator) at 37,600 ± 1800 years; pers. comm. Prof. J. A. Grant-Mackie, Univ. Auckland). Superabundant in the high terrace cover on Kaiti Hill, Gisborne (oxygen isotope stage 9 or 7 ?); common in dredgings from Rangitoto Channel, Auckland (37 000 years old?), in drillholes at Marsden Pt, Whangarei (beyond the range of conventional C14; Fleming and Powell 1974), in a fossil mud-flat community at at least two localities in Hokianga Harbour (beyond the range of conventional C14 dating), and still washing ashore (very abraded) on Spirits Bay and other northern beaches, Northland.

Anadara trapezia is the sole *Anadara* species we are aware of in New Zealand, and is easily recognised by its very large size for a New Zealand arcid, its trapezoidal shape, and its prominent radial costae.

Figured specimen (Pl. 44b, e): GS11475, R11/f7743, dredged in Rangitoto Channel, Auckland Harbour, Haweran (37 000 years?), a small left valve (large valves are longer and narrower) x 1.

Pl. 45 i. *Pecten benedictus marwicki* (Finlay, 1930) [*Notovola marwicki* Finlay 1930b, p. 52; *Pecten benedictus tepungai* Fleming 1957, p. 33] (Pectinidae).

Very large for genus, to about 130 mm high and 180 mm long, i.e., markedly longer than high in large individuals; left valve slightly and evenly concave, right valve moderately convex, with anterior and posterior ends compressed into relatively weakly convex extensions of disc. Ears almost equal. Right valve with about 15 to 18 low, wide radial costae of evenly convex section, blending into their shallow, evenly concave interspaces, each interspace only slightly narrower than 1 costa.

Left valve with narrow, very low, flat-topped radial costae. Commarginal lamellae largely absent from right valve, prominent on some left valves, particularly in intercostal spaces.

Late Castlecliffian only; Castlecliff, Wanganui, horizon not specified (type of *Notovola marwicki*; probably from Upper Castlecliff Shellbed—Fleming 1957, p. 30); Rangitawa “fossil beds” (Te Punga 1962), Rangitawa Stream, Rangitikei Valley (type of *Pecten benedictus tepungai*). Abundant in beds of low-energy, shallow-water facies of the late Castlecliffian (oxygen isotope stages 15 to 11 and possibly 9) in the Castlecliff and Rangitikei River sections, Wanganui basin. The extinction of *Pecten benedictus marwicki* (last appearance in Putiki Shellbed at Wanganui) now defines the top of the Castlecliffian Stage (Beu et al. 1987). The relationship to *P. tainui* is discussed below.

Pecten benedictus marwicki is almost indistinguishable from the Mediterranean Miocene and Pliocene *P. benedictus* (Lamarck), and Fleming’s (1957, p. 30) suggestion of a close genetic relationship between these populations appears realistic, and implies a Pleistocene range extension from the North Atlantic-Mediterranean Sea area as planktonic larvae. *P. tainui* (below) has flat-topped radial costae with prominent, vertical (or even undercut) edges, contrasting strongly with the low, gently rounded costae of *P. benedictus marwicki*.

Figured specimen (Pl. 45i): GS4033, R22/f6371, Lower Castlecliff Shellbed, Castlecliff, Wanganui, Castlecliffian (oxygen isotope stage 11) (NZGS) x 0.67.

Pl. 45 j. *Pecten tainui* (Finlay, 1930) [*Notovola tainui* Finlay 1930b, p. 51; *Pecten tainui aotea* Fleming 1953, p. 344; *Pecten novaezelandiae tainui*; *Pecten novaezelandiae aotea*] (Pectinidae).

Moderately large for genus (to about 110 mm high and 130 mm long), i.e., slightly longer than high when adult; left valve flat to weakly concave, concavity most marked near umbo; right valve moderately and evenly convex. Ears almost equal. Right valve with 20 to 22 extremely prominent, flat-topped, well raised radial costae with squarely raised or even slightly undercut edges, separated by deep, flat-bottomed interspaces, each about 0.2 width of 1 costa; interspaces bear many fine commarginal lamellae on most specimens. Left valve with about 20 high radial costae of almost square section, or in some specimens with slightly undercut edges, varying from 0.7 interspace width to equal in width to 1 interspace.

Late Castlecliffian-Haweran; Tainui Shellbed, Castlecliff, Wanganui, late Castlecliffian (type of *Notovola tainui*); Landguard Formation, Landguard Bluff, east of Wanganui River, early Haweran (type of *Pecten tainui aotea*). Most common in beds where it occurs alone: Tainui Shellbed, Castlecliff (mid-oxygen isotope stage 11); Landguard Bluff, east of mouth of Wanganui River (oxygen isotope stage 9); Mingaroa, Rangitikei Valley (oxygen isotope stage 7); but a few specimens are now known with *P. benedictus marwicki* in several beds at Castlecliff and in the Rangitikei Valley, as low as Kupe Formation; the population at Te Piki, near East Cape (oxygen isotope stage 7) seems also to fall in *P. tainui*.

Several discoveries since the publication of Fleming’s (1957) revision of New Zealand *Pecten* necessitate a rethinking of *Pecten* taxonomy and biostratigraphy:

- (1) A large collection of *Pecten* from the mouth of Ohinekoao Stream, east of Matata, Bay of Plenty, is indistinguishable from

P. novaezelandiae (occurs with the calcareous nannofossil *Pseudoemiliania lacunosa*, so certainly deposited during oxygen isotope 13 or older (pers. comm. A. R. Edwards, NZGS), i.e. older than all *Pecten* in Wanganui basin, except *P. kupei* and the Upper Westmere Siltstone zone of *P. benedictus marwicki*); specimens from Ohope Beach and Rurima Rocks, Bay of Plenty, also seem most similar to *P. novaezelandiae*.

- (2) Specimens nearer to *P. novaezelandiae* than to any other taxon are also known from (a) Upper Kai-Iwi Siltstone at Castlecliff (one valve only); (b) Waiomio Shellbed, Rangitikei Valley (lowest *Pecten* record in the Rangitikei sequence); (c) some Putiki Shellbed outcrops in Whangaehu and Turakina Valleys, east of Wanganui (with more common *P. benedictus marwicki*); (d) two thin shellbeds underlying Mingaroa Shellbed in Rangitikei Valley; and (e) Brunswick Pebbly Sand in a quarry on Brunswick Road, west of Wanganui (*P. benedictus zeehananae* Fleming, from this horizon at Mt Jowett, Wanganui, is therefore regarded as a synonym of *P. novaezelandiae*).
- (3) Specimens of *P. tainui* are known
 - (a) with *P. benedictus marwicki*:
 - (i) in Seafeld Sand equivalent, in Shell Creek, Rangitikei Valley;
 - (ii) in Lower Castlecliff Shellbed, in Kaukatea Valley, east of Wanganui (the three typical *P. tainui* valves are from a gravel tongue in otherwise typical fine brown sand; the sand contains abundant *P. benedictus marwicki*);
 - (iii) in the Onepuhi Shellbeds (Tainui Shellbed lateral equivalent) in Rangitikei Valley, where the two taxa occur together in approximately equal numbers in several outcrops;
 - (b) with *P. kupei*: a left valve with characteristic very high ribs, in Fleming’s original Kupe Formation collection from the *Pecten* layer in the Castlecliff coastal section;
 - (c) in a thick valley-side sequence exposed off No. 2 Line, near Warrengate, Fordell (the most extreme coarsely sculptured collection known to us, but from Landguard Formation; so *P. tainui aotea* is regarded as a synonym of *P. tainui*).
- (4) *P. benedictus tepungai* is within the range of variation of the Lower Castlecliff Shellbed population of *P. benedictus marwicki*, and in our opinion these two names are synonyms.
- (5) Typical populations of *P. kupei* (small, highly inflated shells, to only about 90 mm high, with prominent, evenly rounded ribs and many subdividing grooves and riblets) are known from only three localities in Wanganui basin, all at the same stratigraphic horizon:
 - (a) the coastal outcrop of Kupe Formation;
 - (b) a road cut off the end of Whangaehu Valley Road; and
 - (c) mudstone beneath Tom’s Conglomerate in Shell Creek, Rangitikei Valley.
 Other Kupe Formation localities in Wanganui basin have yielded only *P. benedictus marwicki*. A possible implication is that *P. kupei* is merely an ecomorph of *P. benedictus marwicki*. Outside Wanganui basin, a few specimens are known from
 - (a) Leader River on “Mendip Hills”, near Parnassus, North Canterbury;
 - (b) a small but undoubted fragment from basal Maraetotara Sand in Maraetotara River, inland from Clifton, Cape Kidnappers, Hawke’s Bay (more than one million years old, from magnetostratigraphy; pers. comm. Dr P. Kamp, University of Waikato).
- (6) All late Castlecliffian formations in Rangitikei Valley (Seafeld Sand equivalent to Rangitawa “fossil beds”) contain *P. benedictus marwicki*, in some formations with common *P. tainui* as well.

The following reinterpretations of the *Pecten* record in New Zealand therefore seem necessary:

- (1) the earliest *Pecten* record is at Cape Kidnappers, where *P. kupei* is more than one million years old, more than twice the age of the earliest record in Wanganui basin.
- (2) *P. novaezelandiae* has lived in New Zealand since at least oxygen isotope stage 13 (probably equivalent to Upper Kai-Iwi Siltstone at Castlecliff; Beu and Edwards 1984), and did not evolve from *P. tainui*; possibly it was unable to compete with *P. tainui* and *P. benedictus marwicki* in Wanganui basin, although it may have occupied a deeper zone outside their range.
- (3) *P. aotea* is part of the variation of *P. tainui*; *P. benedictus*

zeehanae is part of the variation of *P. novaezelandiae*; and *P. benedictus tepungai* is part of the variation of *P. benedictus marwicki*.

- (4) *P. tainui* and *P. benedictus marwicki* existed side-by-side in Wanganui basin from at least oxygen isotope stage 13 until about the end of oxygen isotope stage 11, and seem to have behaved as distinct but closely related species, occupying different environments. *P. tainui* seems to have occupied the high-energy and *P. benedictus marwicki* the low-energy environments, until *P. benedictus marwicki* became extinct (top of Putiki Shellbed) and its place seems to have been taken by *P. novaezelandiae*. The final extinction of *P. tainui* (at about the end of oxygen isotope stage 7) left *P. novaezelandiae* as the sole New Zealand species. "*P. jacobus to*" is interpreted as a hybrid population, preserved at the one horizon where the boundary between *P. benedictus marwicki* and *P. tainui* crossed the deposition site (topmost one metre of Pinnacle Sand, conformably and gradationally overlain by Tainui Shellbed).

The *Pecten* sequence in Wanganui basin is therefore much more complex (in fine detail) than Fleming (1957) was aware of, and its major features appear to have been controlled by the ecology of the deposition site, rather than (as was suggested by Fleming 1957) by wider-scale migrations caused by temperature changes. *P. kupei* occurs in only some outcrops of Kupe Formation near Wanganui; further afield, it is at least one million years old near Cape Kidnappers (so correlation of the North Canterbury "Mendip Hills" locality by this criterion is not possible). *P. benedictus marwicki* is recorded from all formations from Upper Westmere Siltstone to Putiki Shellbed, but is replaced by *P. kupei* in some outcrops of Kupe Formation, and by *P. tainui* in all western outcrops of Tainui Shellbed (*P. tainui* occurs in almost equal numbers with *P. benedictus marwicki* in the two Onepuhi Shellbeds, lateral equivalents of Tainui Shellbed in Rangitikei Valley). *P. tainui* is common in only Tainui Shellbed (specially in the western part of the basin), Landguard Formation, and Mingaroa Shellbed, but occurs rarely in most other formations. *P. novaezelandiae* occurs from at least Upper Kai-Iwi Siltstone (oxygen isotope stage 13) to Recent, but was rare before late oxygen isotope stage 9 (Brunswick Terrace cover beds).

Pecten lives today on intertidal sand flats in large bays, and on the shelf down to about 30 m (rarely to about 120 m), lying on the convex (right) valve with the flat valve at about the sediment-water interface, and swims when necessary to avoid predators (mainly starfish); so *Pecten* occurs fossil in shallow-water beds only. The absence of

Pecten from beds older than Upper Westmere Siltstone (oxygen isotope stage 15) in Wanganui basin therefore conceivably results from their deposition in water too deep to be inhabited by *Pecten*. However, the lack of even a single valve from older Castlecliffian formations after more than 100 years of collecting strongly suggests that *Pecten* arrived in north-eastern New Zealand more than half a million years before it arrived in Wanganui basin, possibly as a result of the East Australian current extending further southwards than previously.

Figured specimen (Pl. 45j): GS4013, R22/f6353, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (TM2015, NZGS) x 0.67.

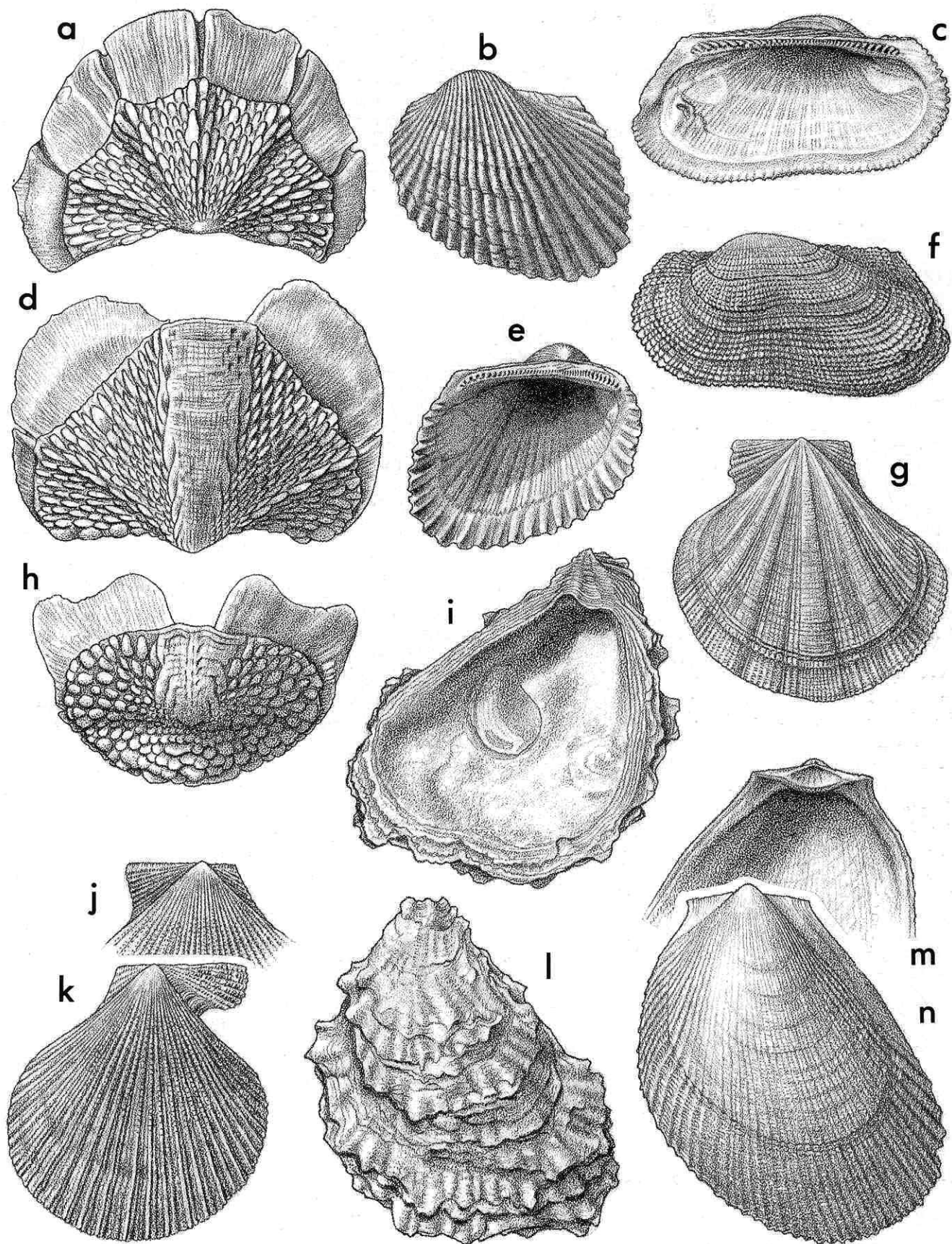
Pl. 44 j.k. *Chlamys* (sensu lato) *gemma* (Reeve, 1853) [*Pecten gemmulatus* Reeve 1853 (in 1852-1853), pl. 27, fig. 111; *Pecten radiatus* Hutton 1873a, p. 82 (secondary homonym of *Ostrea radiata* Gmelin, 1791, = *Pecten radiatus* of Bosc 1802); *Pecten* (*Chlamys*) *suteri* Hertlein 1933, p. 63 (new name for *Pecten radiatus* Hutton, preoccupied); *Chlamys* (*Mimachlamys*) *gemma*; *Chlamys gemmulata radiata*; *Chlamys gemmulata suteri*] (Pectinidae).

Small for genus (to about 50 mm high, 65 mm in the *suteri* form), thin and brittle, very little-inflated (left valve more inflated than right), finely sculptured. About 25 low, narrow, closely spaced costellae on shells up to 10 mm high divide to form 35 or more major costae and many secondary and tertiary costellae over outer third of disc of adults, tending to be arranged in groups of 3 or more costae in increasing and then decreasing sizes, so that each primary costa is of low triangular section, with several orders of costellae on its flanks; all costal crests finely scaly or spinous; costal interspaces crowded with fine *Camptonectes* diverging microsculpture. Disc higher than long, extended slightly obliquely postero-ventrally; anterior ears much larger than posterior ones, anterior ear of right valve with deep, wide byssal notch and long, finely toothed ctenolium; simple pallial line and circular adductor scar visible in some specimens.

Tongaporutuan-Kapitean?; Opoitian-Recent. Recent, New Zealand (types of *Pecten gemmulatus* and *P. radiatus* (non Bosc) = *P. suteri*). Common today all around New Zealand, byssally attached to hard substrates (canyon walls, worm tubes, boulders, other shells) from not far below low tide to the upper bathyal zone; abundant and ubiquitous in all New Zealand Pliocene and Pleistocene rocks, other than very shallow, near-shore deposits (e.g., terrace deposits). Specimens from Stewart Island (e.g., living in Paterson Inlet) are larger and less inflated than

Plate 44 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (2).

- a,d,h. *Acanthochitona* (*Notoplax*) *mariae* (Webster), x 10.5.
b,e. *Anadara trapezia* (Deshayes), x 1.
c,f. *Barbatia novaezelandiae* (Smith), x 2.
g. *Mesopeplum* (*Mesopeplum*) *convexum* (Quoy and Gaimard), x 1.
i,l. *Tiostrea chilensis lutaria* Hutton, x 1.
j,k. *Chlamys* (sensu lato) *gemma* (Reeve), x 1.5.
m,n. *Limaria orientalis* (A. Adams and Reeve), x 3.



those from most of the rest of New Zealand, and the name *suteri* is available for the Stewart Island form, but most taxonomists now consider it to be an infrasubspecific variety of only ecological significance (e.g., Powell 1979, p. 378).

Chlamys gemmulata is a member of a group of very finely costate species recorded also in Landon to Taranaki Series rocks, but early forms are of uncertain status; *C. araroensis* (Kapitean, East Cape) may be part of the variation of *C. gemmulata*. The similar, highly varied species *C. zelandiae* (= *dieffenbachi* Reeve, 1853; = *zealandona* Hertlein, 1931; = *suprasilis* Finlay, 1928) (Mangapanian-Recent) has fewer, wider, more prominent, and more coarsely scaly radial costae, and varies according to its ecological station; fossils are much less common than those of the ubiquitous *C. gemmulata*, and most are from moderately near-shore, high-energy environments (e.g., Tainui Shellbed, Castlecliff).

Figured specimens (Pl. 44j, k): GS4061, R22/f6392, Lower Kai Iwi Siltstone, Castlecliff, Wanganui, Castlecliffian (NZGS), x 1.5 (right valve exterior, and left valve exterior of umbonal area and ears).

Pl. 44 g. *Mesopeplum (Mesopeplum) convexum* (Quoy and Gaimard, 1835) [*Pecten convexus* Quoy and Gaimard 1835, p. 443; ? = *Pecten burnetti* Zittel 1864, p. 51; *Pecten kapitensis* Mestayer 1929, p. 249; *Pallium convexum*; *Pallium (Mesopeplum) convexum*; *Pallium (Felpes) convexum*] (Pectinidae).

Small for family (to 60 mm high), thick and solid, well inflated, *exceedingly* variable in sculpture. All specimens have 4 or 5 (6 in a few specimens) prominent radial folds in disc; superimposed on and between folds are about 35 to 50 closely spaced, narrow radial costae, varying from many scarcely discernible fine threads (so shell appears almost smooth) to fewer, coarser, well raised costae of square cross-section. Two valves almost equally inflated; anterior ear of each valve much larger than posterior one; right valve with small but obvious byssal notch and short, finely toothed ctenolium. No cardinal crura or other obvious internal characters other than simple pallial line and large, circular adductor scar.

(Kaiatan?-) Duntroonian-Recent. Recent, New Zealand (types of *Pecten convexus* and *Pecten kapitensis*); "Motupipi, Massacre Bay, Province of Nelson", i.e., Tarakohe Limestone, Tarakohe, Takaka, west of Nelson, Waitakian (type of *Pecten burnetti*).

The range of variation of fossil taxa is in need of further study, and the number of valid species, and their time

ranges, are unclear; the above synonymy assumes that at least the most common early-mid Cenozoic form (*Mesopeplum burnetti*) is part of the variation of *M. convexum*, but early-mid Cenozoic populations seem consistently to be relatively coarsely sculptured and could be distinct from Late Miocene-Recent populations. Modern specimens are *exceedingly* variable in the number and size of radial folds, the number and prominence of radial costae, the inflation and growth steps of the disc, and the shape of the disc; it seems possible that named extreme forms such as *M. syagrus* and *M. waikohuense* are also part of the variation of *M. convexum*.

Despite the apparently functional byssal notch, adults lie unattached on clean, firm sand or gravel, offshore in about 20 to 80 m (and rarely deeper), and are the most actively swimming of modern New Zealand pectens, leaping about and "clapping" their valves actively when dredged. Fossils are common to abundant in sandstone and, particularly, coquina limestone (e.g., Castlepoint, Wairarapa, Nukumaruan; Patutahi Limestone, Gisborne, Tongaporutuan; Takaka Limestone, Tarakohe, northwest Nelson, Waitakian), rocks that formed in high-energy environments on the middle shelf. The earliest specimen of this type we are aware of is from Point Elizabeth-Rapahoe Beach, north of Greymouth (Kaiata Mudstone, Kaiatan) and specimens are locally common in high-energy facies throughout New Zealand at all ages after Late Eocene time. Some similar but smaller and more finely ribbed species occur in northern New Zealand Early Miocene rocks (*M. costatostriatum*, *M. kaiparaense*, both Otaian-Altonian of Kaipara Harbour); the larger *M. dendyi* (early Pliocene, Chatham Islands; Pl. 32b, g) is figured above.

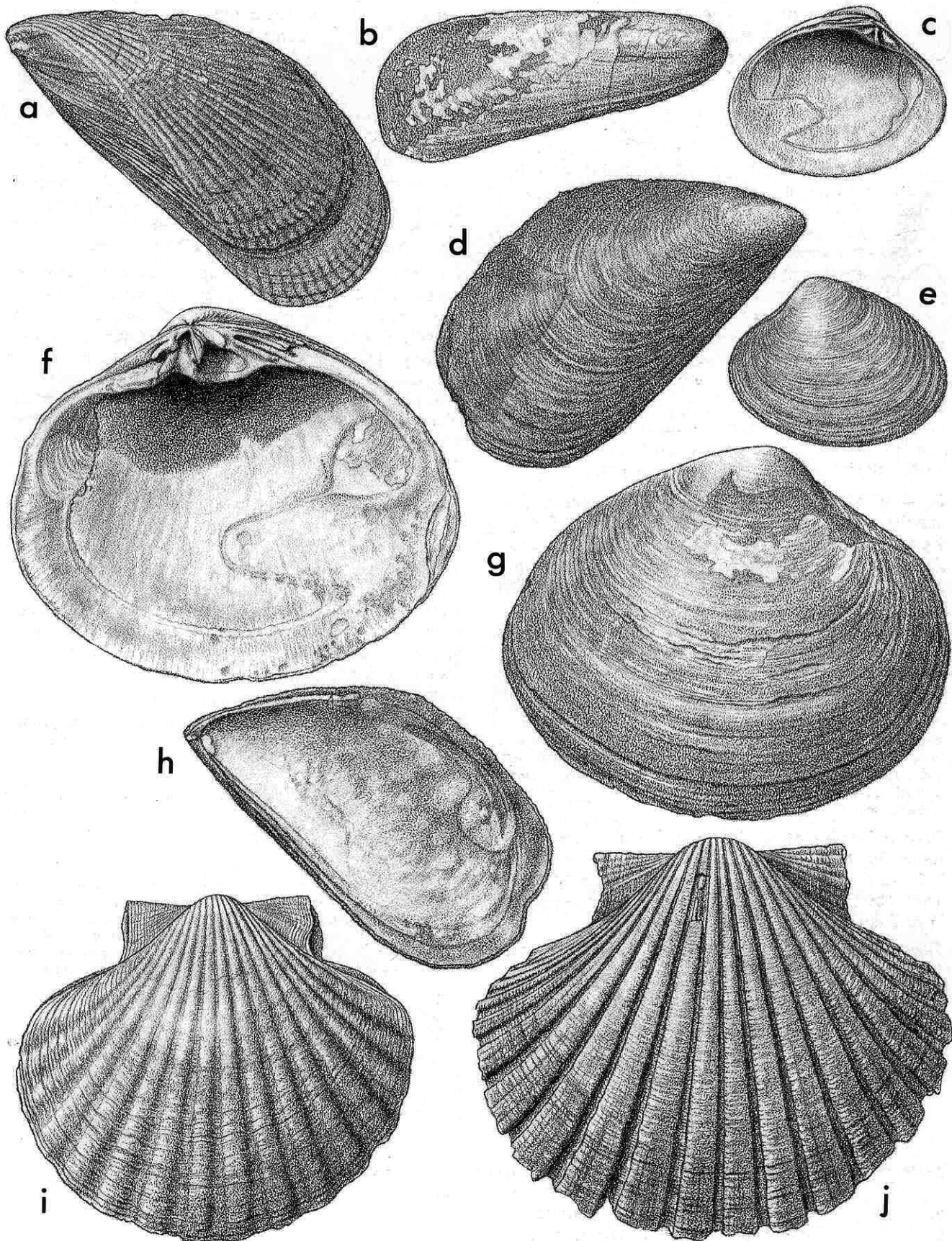
Figured specimen (Pl. 44g): Castlecliff, Wanganui, Castlecliffian (NZGS, from old collection), left valve with tip of left ear broken, x 1.

Pl. 45 b. *Amygdalum striatum* (Hutton, 1873) [*Lithodomus striatus* Hutton 1873b, p. 26; ? = *Modiolus dolichus* Suter 1917, p. 67; *Lithophaga striata*] (Mytilidae: Modiolinae).

Moderate-sized for family; an exceedingly fragile, thin-shelled, smooth "mussel", up to about 80 mm long. Anterior end almost evenly hemispherical, umbones low but obvious, almost at anterior end; dorsal and ventral margins diverging at low angle; posterior end slightly compressed laterally and weakly truncated. The only sculpture is weak growth ridges on antero-ventral area. Interior highly nacreous, with

Plate 45 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (3).

- a. *Aulacomya ater maoriana* (Iredale), x 1.
- b. *Amygdalum striatum* (Hutton), x 1.
- c,e. *Notocallista (Striacallista) multistriata* (Sowerby), x 1.5.
- d,h. *Mytilus edulis aoteanus* Powell, x 1.
- f,g. *Cyclomactra ovata* (Gray), x 1.
- i. *Pecten benedictus marwicki* (Finlay), x 0.67.
- j. *Pecten tainui* (Finlay), x 0.67.



no discernible teeth or muscle scars. Most specimens appearing nacreous on exterior also, or found as internal moulds.

Duntroonian-Castlecliffian ? (*A. dolichum*: Duntroonian-Altonian; *A. striatum*: Kapitean-Castlecliffian). "Shakespeare Cliff", Wanganui, Castlecliffian ? (type of *Lithodomus striatus*; Weka Pass, North Canterbury (Altonian?; Waiauian?) (type of *Modiolus dolichus*). Most of the more recently collected specimens of *Amygdalum striatum* are from either the Kai-Iwi siltstone beds or the Tainui Shellbed at Castlecliff, and Tainui Shellbed seems likely to be the type horizon. It is also relatively common at a few localities in Tokomaru Sandstone (Kapitean) near Tokomaru Bay, Gisborne district.

Little additional material of *Amygdalum* has come to light since Fleming (1959, p. 169) reviewed known localities and, under a heading for both *A. striatum* and *A. dolichum*, noted that "Material and data are as yet inadequate to decide the status of these nominal species". The relatively few specimens known from the Wanganui Series reach a larger size than Oligocene and Miocene *A. dolichum*, but there appear to be no other consistent differences, and it seems likely that these belong in one species.

Amygdalum lives now in tropical and warm-temperate waters, byssally attached to hard substrates (boulders, logs, shells) well below the intertidal zone, and mostly in outer shelf to bathyal depths. Dell (1987) recently recorded the similar genera *Adipicola* Dautzenberg, 1927, *Idasola* Iredale, 1915 and *Benthomodiolus* Dell, 1987 living attached to logs in the bathyal zone around New Zealand, but there are no records of Recent *Amygdalum* from New Zealand. Common mytilids from the "Modiolus limestone" facies of northern Wairarapa to near East Cape (see above, in introduction to Middle Miocene Mollusca) appear to be a large species of a genus similar to *Idasola* (to 100 mm long) differing from *Amygdalum* in having a more marked umbonal-ventral ridge, and in having more prominent umbones further behind the anterior end.

Figured specimen (Pl. 45b): GS2665, T24/f7403, left bank of Manawatu River five km northeast of Kumeroa, southern Hawke's Bay, Nukumaruan (TM2137, NZGS) x 1.

Pl. 45 d,h. *Mytilus edulis aoteanus* Powell, 1958 [*Mytilus edulis* (not of Linné) of Suter 1913c, p. 862; *M. planulatus* (not of Lamarck) of Oliver 1923, p. 181; *M. aoteanus* Powell 1958, p. 87] (Mytilidae: Mytilinae).

Moderate-sized for family (to 100 mm long; a few specimens to 150 mm), with narrowly pointed anterior, terminal umbones, straight ventral margin, strongly convex dorsal margin, and evenly rounded posterior; smooth except for weak growth ridges. White (aragonitic) internal layer ending at obvious pallial line; adductor scar postero-dorsal, long, narrow; white ligamental scar along anterior third of dorsal margin; weak, short teeth and grooves below umbo. Calcitic outer shell layer thick, remaining deep, bright blue in young fossils, black in older fossils.

Haweran (Brunswick Terrace cover, oxygen isotope stage 9)—Recent; Recent, New Zealand (type). *M. edulis* is almost cosmopolitan in cool and temperate seas, occurring as several geographic subspecies; it apparently arrived in New Zealand only about 300,000 years ago, presumably as a neoaustrian immigrant from the Atlantic. *Mytilus edulis aoteanus* (the common "blue mussel") lives

now in dense mats byssally attached to intertidal rocks only, and so occurs fossil only in the shallow-water faunules of late Pleistocene terraces ("raised beaches").

Figured specimen (Pl. 45d, h): GS12290, E38/f15, Teer Creek fauna (oxygen isotope stage 7 or 5e?), beneath Cascade Moraine, north side of Cascade Point, South Westland, Haweran (NZGS) x 1.

Pl. 45 a. *Aulacomya ater maoriana* (Iredale, 1915) [*Mytilus magellanicus* (not of Lamarck) of Suter 1913c, p. 865; *Mytilus maorianus* Iredale 1915, p. 484; *Aulacomya maoriana*] (Mytilidae: Mytilinae).

Moderate-sized for family (to 120 mm long), a coarsely ribbed "mussel". Radiating, weakly anastomosing costae cover most of exterior, costae extremely variable in number and prominence; the narrow antero-ventral area bears much lower, narrower, closer costellae than remainder of shell, or is almost smooth in some specimens. Beak narrowly pointed and umbo anterior, as in *Mytilus*; a prominent ridge extends from umbo along junction of antero-ventral area with remainder of shell. Pallial line prominent, but single large adductor scar very little impressed, not visible in most fossils; a low, short tooth and groove below umbo of each valve is eroded from some specimens.

Waipipian-Recent; Recent, New Zealand (type). Widespread but uncommon in New Zealand before Nukumaruan time, but abundant in shallow-water shellbeds of Nukumaruan age, and younger; particularly common in near-shore shellbeds at Wanganui (Castlecliffian) and in the many Haweran terrace faunas around New Zealand.

Aulacomya ater maoriana is much more coarsely ribbed than the superficially similar Early Miocene *Trichomya* species; it is larger and much more coarsely ribbed than Miocene *Septifer* species, which also differ in having a shelf inside the umbo; also, it is much larger than the Paleocene *Hormomya(?) willetsi* (Marwick). In the modern fauna, *A. ater maoriana* lives byssally attached to hard substrates in the intertidal zone, and down to about 50 m. It is considered to be a geographic subspecies of the circum-subantarctic *A. ater* (Molina) (Dell 1964b, p. 176). It appeared suddenly in New Zealand during Waipipian time, and occurs mostly in cool faunas, so is presumably a neoaustrian immigrant from South America, or from the southern islands of New Zealand.

Figured specimen (Pl. 45a): GS6665, Q29/f8504, concretions trawled off Cape Campbell, Cook Strait, late Haweran (C14 age: 19 000 years) (TM4179, NZGS; specimen illustrated by Boreham and Fleming in Pantin 1957, fig. 4) x 1.

Pl. 44 i,l. *Tiostrea chilensis lutaria* (Hutton, 1873) [*Ostrea lutaria* Hutton 1873a, p. 84; *O. virginica* (not of Lamarck) of Hutton 1873a, p. 84; *O. corrugata* Hutton 1873b, p. 35 (not of Brocchi, 1814); *O. discoidea* (not of Gould) of Hutton 1880, p. 175; *O. edulis* (not of Linné) of Hutton 1880, p. 175; *O. angasi* (not of Sowerby), *O. hyotis* (not of Linné), and *O. reniformis* (not of Sowerby) of Suter 1913c, p. 888-892; *Ostrea tatei* Suter 1913c, p. 889, in part (Suter's type is an Australian Eocene fossil, the holotype of *O. hippopus* Tate, 1886, not of Lamarck); *O. sinuata* of Finlay 1928b, p. 264 (not of Lamarck); *O. fococarens* Finlay 1928b, p. 264 (footnote) (new name for *O. corrugata* Hutton, preoccupied); *O. heffordi* Finlay 1928b, p. 265; *O. charlottae* Finlay 1928b, p. 265; *O. huttoni* Lamy 1929, p. 166 (new name for *O. corrugata* Hutton, preoccupied)]. Type species of *Tiostrea* Chanley and Dinamani, 1980 (Ostreidae: Ostreinae).

Small to medium-sized for family (to c. 120 mm high), oval and (in most specimens) weakly inflated, but extremely variable in shape, depth, colour, and sculpture, according to environment; calcitic. Right valve almost flat, the only sculpture of wide, brittle lamellae; left valve shallowly to moderately cupped, with weak radial costae or no regular sculpture, bearing lamellate frills in some specimens. Cemented by left valve to substrate (as are all oysters) when young, but the substrate can be either low-tidal to subtidal rocks (in which case the adult remains attached, and grows into the *heffordi* form, or "Dunedin rock oyster"), or can be merely a shell-fragment on softer substrate on the inner shelf, in which case the adult is free-lying, and in current-swept situations grows into the relatively smooth "dredge" or "Bluff" oyster, or in quiet environments into the *charlottae* form with elaborate frills, specially on the lower (left) valve (illustrated). Chomata very small, limited to margins near hinge, obliterated in old specimens. Hinge a large, irregularly triangular resilifer, with shallow, triangular central pit bordered by anterior and posterior ridges. No pallial line; large, weakly reniform adductor muscle scar slightly in front of middle of valve.

Kapitean-Recent; Recent, New Zealand (types of *O. lutaria*, *O. heffordi*, *O. charlottae*); Te Araroa-East Cape coast, Kapitean (Beu 1981a; type of *O. corrugata* Hutton, not of Brocchi, = *O. fococarens*, = *O. huttoni*). Exceedingly abundant and widespread in Pliocene and Pleistocene rocks deposited in high-energy, shallow-water environments throughout New Zealand; the earliest known specimens are in Kapitean rocks between Te Araroa and East Cape.

In a new classification of living oysters, Harry (1985) appears to have assumed that there is only one species of Ostreidae Ostreinae living now around southern South America. He regarded *Ostrea puelchana* d'Orbigny, 1841 (Argentina; type species of *Eostrea* Ihering, 1907) as the same taxon as *Ostrea chilensis* Philippi, 1845 (Chile; regarded by Buroker et al. (1983) as the valid name for the species including *Ostrea lutaria* Hutton (New Zealand), type species of *Tiostrea* Chanley and Dinamani, 1980). Harry therefore thought that (a) there is only one species of *Ostrea* (*Eostrea*) in the circum-Southern Ocean, including such named taxa as *O. lutaria*, *O. chilensis*, *O. angasi* Sowerby, and *O. algoensis* Sowerby; and (b) *Eostrea* Ihering, 1907 and *Anodontostrea* Suter, 1917 (type species: *O. angasi* Sowerby, southern Australia) are earlier names for *Tiostrea* Chanley and Dinamani, 1980.

However, it is now clear that two different species groups of oysters have been confused in Harry's concept of *Ostrea* (*Eostrea*) *puelchana*. Chanley and Dinamani (1980) proposed the, in our opinion, justified genus *Tiostrea* (type species: *O. lutaria* Hutton, New Zealand) for *T. lutaria* and *T. chilensis* because of their highly distinctive larval shells, differing from those of all other described Ostreidae and Gryphaeidae in lacking (1) the posterior dorsal sulcus, (2) umbones, and (3) all hinge structures.

In contrast, Castro and Lucas (1987) pointed out that the Argentinian *O. puelchana* has small neotenous males attached to some large female shells (an apparently unique character), and later (Castro and le Pennec 1988) showed that *O. puelchana* has a normal *Ostrea* larva with a posterior dorsal sulcus, umbones, and hinge teeth. Dix (1976) had earlier demonstrated the normal *Ostrea* larva of the southern Australian *O. angasi*.

We conclude that

- (1) there are no differences between *Eostrea* (= *Anodontostrea*) and *Ostrea* sensu stricto;
- (2) *O. puelchana*, *O. angasi* and the recently named *O. aupouria* Dinamani (1981, p. 110; subtidal hard

substrates in northern New Zealand) are Southern Ocean species of *Ostrea* sensu stricto;

- (3) *Tiostrea chilensis* is highly distinct from *O. puelchana*, and the genus *Tiostrea* is abundantly justified; and
- (4) the minor genetic and developmental differences between the populations of *O. chilensis* in Chile and New Zealand, reported by Buroker et al. (1983), show that they are worth recognising as geographic subspecies; the New Zealand form is best identified as *Tiostrea chilensis lutaria* (Hutton).

Tiostrea chilensis lutaria is the well known "Bluff" or "dredge" oyster, fished commercially in Foveaux Strait, and is abundant in many intertidal and shallow subtidal environments throughout New Zealand at present. Specimens have been collected at depths down to about 150 m, although living specimens are generally found from the intertidal zone down to about 60 m. It is an almost ubiquitous fossil throughout New Zealand Kapitean to Castlecliffian rocks of shallow-water facies, most commonly found as the broadly frilled "charlottae" form (the form occupying offshore, relatively quiet environments at present). Its occurrence as a fossil indicates either the presence of a hard substrate, allowing shell attachment, or at least strong current by-passing of sediment to allow shells to lie on a nearly sediment-free sea floor (as occurs now in the Foveaux Strait oyster beds). The apparently abrupt appearance of *Tiostrea chilensis lutaria* in New Zealand during Kapitean time presumably implies that it extended its range to here from South America at that time, so it is probably a member of the neoaustal biogeographic element.

Figured specimen (Pl. 44i, l): GS208, R22/f7379, Castlecliff, Wanganui, Castlecliffian (almost certainly from Tainui Shellbed) (NZGS) x 1.

Pl. 44 m,n. *Limaria orientalis* (A. Adams and Reeve, 1850) [*Lima orientalis* A. Adams and Reeve 1850, Mollusca p. 75; *Lima* (*Mantellum*) *marwicki* Powell 1926c, p. 48; *Promantellum marwicki*] (Limidae).

Small for family (20-28 mm high), very thin and brittle, weakly inflated, elongated obliquely postero-ventrally, with straight hingeline, umbones projecting weakly above centre of hinge. Anterior outline moderately convex except for shallow embayment marking off small anterior ear; ventral margin strongly convex; postero-dorsal margin long, straight except for very slight embayment below hinge line. External sculpture of many very narrow, relatively widely spaced radial costae, most prominent on postero-dorsal slope, but absent from postero-dorsal area and anterior ear; rendered finely scaly by commarginal growth lamellae. Hinge narrow, smooth except for wide, shallow, central triangular resilial pit. Interior apparently smooth and shiny, without visible characters.

Duntroonian(?)—Recent, but possibly discontinuously; Recent, "Philippine Archipelago" (type of *Limaria orientalis*); Castlecliff, Wanganui, Castlecliffian (almost certainly from Tainui Shellbed) (type of *Lima* (*Mantellum*) *marwicki*). Common in some offshore to nearshore mudstone beds at Castlecliff, Wanganui (Castlecliffian) and in central Hawke's Bay (Nukumaruian); Duntroonian to Pliocene records were listed by Beu (1977c).

Limaria orientalis is easily recognised by its trigonal shape and its very thin, finely sculptured shell. It occurs in the modern fauna from Japan, throughout the western Pacific to New South Wales, Victoria and South Australia, and Willan (1973), Grange (1974) and Powell

(1974) discussed its abrupt appearance in the north-eastern North Island during 1972. Since then it has become a normal, common member of the fauna, most commonly found nestling in algae or under boulders in the intertidal zone of the muddy outer parts of large estuaries, but also dredged commonly in 10-30 m on the inner shelf and locally in up to about 80 m, and as far south as East Cape, on coarse substrates; Hayward et al. (1986) found very high densities of specimens (up to 400 per square metre) in depths of 10-20 m off the Broken Islands, on the west side of Great Barrier Island, east of Auckland. The many occurrences since its Duntroonian (Oligocene) appearance in New Zealand were discussed by Beu (1977c); most occurrences probably reflect a continuous presence in New Zealand, but its apparent absence from New Zealand between mid-Castlecliffian time and 1972 suggests that it has arrived here again as planktonic larvae after becoming extinct during several of the many Pleistocene glaciations.

Figured specimen (Pl. 44m, n): holotype of *Lima marwicki* Powell, Castlecliff, Wanganui (almost certainly from Tainui Shellbed), Castlecliffian (TM4276, NZGS) x 3.

Pl. 46 b. *Divaricella (Divalucina) huttoniana* (Vanatta, 1901) [*Lucina divaricata* of Gray 1843, p. 257, not of Lamarck; *Lucina dentata* of Hutton 1884b, p. 525, not of Wood; *Divaricella huttoniana* Vanatta 1901, p. 184; *Divaricella cumingii* of Hutton 1904, p. 92, not *Lucina cumingii* A. Adams and Angas, 1863; *Divaricella notocenica* King 1933, p. 353; *Divalucina huttoniana*] (Lucinidae).

Moderately large for family (26-47 mm long), almost circular, well inflated, with low, central umbones. Margins smooth. External sculpture of many prominent, low, wide, bevelled costae crossing faint commarginal growth lines at about 45°; costae bevelled ("terraced"), with narrow, sharply raised dorsal edges and wide, gradually descending ventral slopes, divaricating at a radial line slightly in front of centre of disc. Long, narrow, weakly defined lunule in front of umbo. Hinge narrow, dominated by long, wide ligamental nymph and groove, with central socket and 1 bifid cardinal tooth in each valve, and 1 or 2 low, short lateral teeth at anterior end of hinge. Anterior adductor scar long and narrow, descending parallel to pallial line; posterior adductor scar oval; pallial line wide, without sinus.

Bortonian-Recent; Recent, New Zealand (type of *D. huttoniana*); "Otekaike, Oamaru" (Otekaike Limestone near Otekaike, possibly Trig Z, Otiake, Waitaki Valley, North Otago; Waitakian) (type of *D. notocenica*). Common in many near-shore shellbeds and in sandstone throughout the Cenozoic rocks of New Zealand, from Middle Eocene to Recent.

Analysis of rib widths and frequencies by Wakefield (1976) demonstrated that all New Zealand Eocene to Recent specimens of *Divaricella* belong in one species. *Divaricella huttoniana* lives now all around New Zealand, deeply buried in sand or mud, from the outer edge of the intertidal zone to the bathyal zone, but most commonly in less than 10 m off sandy beaches, in anoxic black sediment (Luckens 1972b); the bevelled, divaricating ribs are used in burrowing into the sediment.

Figured specimen (Pl. 46b): Castlecliff, Wanganui, Castlecliffian (NZGS, old collection) x 1.

Pl. 45 f,g. *Cyclomactra ovata* (Gray, 1843) [*Spisula ovata* Gray 1843, p. 251; ? = *Mactra tristis* Deshayes in Reeve

1854, pl. 14, fig. 69; ? = *Mactra inflata* Hutton 1873b, p. 18; ? = *Mactra rudis* Hutton 1873b, p. 19; *Standella aequalis* Webster 1905, p. 280; *Mactra ovata*]. Type species of *Cyclomactra* Dall, 1895 (Mactridae: Mactrinae).

Large for family (60-75 mm long), oval to subtriangular, strongly inflated, thin and fragile, most shells with thin hinge; exterior smooth apart from weak commarginal growth ridges. Hinge plate very thin, with deep, widely triangular resilifer in each valve, separated from external ligament by a thin plate; prominent, thin, anterior and posterior lateral teeth in each valve; a prominent, solid, relatively small, deeply bifid cardinal tooth in left valve and matching pair of widely spread, thin cardinal teeth in right valve. Both adductor scars moderately large, equidimensional; pallial sinus deep, with rounded anterior end.

Waipipian(?) - Recent; Recent, New Zealand (types of *Spisula ovata*, *Mactra tristis*, and *Standella aequalis*); Haweran terrace cover beds at Motunau Beach, North Canterbury (lectotype of *Mactra inflata*); "upper beds" at Castlecliff, Wanganui, Castlecliffian (lectotype of *Mactra rudis*). *Cyclomactra ovata* lives deeply buried in the mud of estuaries, and less commonly off sheltered sand beaches, and occurs commonly as a very young fossil in estuarine faunas, with *Austrovenus*.

The taxonomy of *Cyclomactra* is very poorly understood, and probably cannot be resolved without the use of sophisticated biochemical or genetic techniques. Some large shells (including the figured one) develop a thicker hinge and thicker, shorter, more ventrally directed lateral teeth than smaller shells, and the outline is highly variable, but it seems likely that the named younger forms are all one species, varying with environment. Boreham (1965) illustrated the lectotypes of *Mactra inflata* and *M. rudis*, considering them to be the same species as the Recent *C. ovata* and *C. tristis*, respectively. However, the shape separation is nowhere near as clear-cut in the modern fauna as this suggests, and circular shells similar to the lectotype of *M. rudis* have not been seen in the modern fauna. Much more study is needed of the variation and ecology of the genus. The Waipipian *C. williamsi* (Otahuhu Brewery well) is smaller and more inflated than the younger *C. ovata/tristis* forms. Although we suggest a conservative alternative here, the other alternative (all nominal species are valid) is adopted in the checklist.

Although no really typical species of *Cyclomactra* are known earlier than Waipipian, "*Eumarcia*" *altihunula* proves to be a member of a species group (other known members are unnamed) in Oligocene to Late Miocene fully marine faunas that has a very thin shell and very thin hinge similar to that of *Cyclomactra*, but differs in its more nearly trigonal shell shape and its weaker inflation. This group is possibly ancestral to younger species included in *Cyclomactra*, but needs further study.

The figured specimen is a topotype of *Mactra inflata*, but apparently not a syntype; the lectotype was collected from the "upper beds" (i.e., Haweran terrace cover) at Motunau Beach by Buchanan in 1867 (Boreham 1965, p. 66) whereas the figured specimen still bears its original label stating that it was collected from the "upper beds" at Motunau Beach by Sir James Hector in 1873. Interestingly, the figured shell is the *rudis* (= *tristis* ?) form, not the *inflata* (= *ovata*) form.

Figured specimen (Pl. 45f, g): "upper beds", Motunau Beach, North Canterbury, Haweran (NZGS; coll. by Sir J. Hector, 1873), x 1.

Pl. 46 k. *Nemocardium (Pratulium) pulchellum* (Gray, 1843) [*Cardium pulchellum* Gray 1843, p. 252; *Protocardia pulchella*; *Nemocardium pulchellum*] (Cardiidae: Protocardiinae).

Very small for family (25-30 mm long), very thin and fragile, strongly inflated, slightly longer than high, very finely sculptured. Umbones low, slightly in front of centre. Flanks and anterior sculptured with low, wide radial costae with almost smooth, lightly polished, convex surfaces, interspaces half width of 1 costa; about 3 per mm at 10 mm from umbo; crossed by very thin, low, widely spaced commarginal lamellae over distal third of shell. Posterior area about a quarter of length, demarcated from flank by narrow groove and 1 very narrow radial costa, remainder of posterior sculptured with narrower, more widely spaced radial costae than on flanks, each costa bearing a row of small, sharp nodules on well preserved specimens; on some specimens, nodules of each fourth or fifth costa are more prominent than on their neighbours. Lunule a very narrow, smooth area above anterior hinge, not otherwise demarcated; escutcheon similar to lunule, almost smooth, elevated in right valve but depressed in left valve. Ventral margin crenulate. Hinge very thin and narrow, with a small, peg-like cardinal tooth and corresponding socket in each valve, a very small second, anterior cardinal tooth in right valve, a thin lateral tooth on each hinge extremity in left valve, and a corresponding socket and thin lateral tooth on each hinge extremity in right valve. Adductor muscle scars small, oval, weakly impressed; pallial line a broad, weakly impressed band with 2 very shallow inflexions below posterior adductor scar.

Mangapanian-Recent. Recent, New Zealand (type).

Nemocardium pulchellum lives commonly today in soft, fine-grained sediments in a wide range of habitats and depths, from small bays within large harbours to the outer shelf, and from about 5 m to at least 200 m, and empty valves are commonly dredged in up to 500 m and more. It is not surprising, then, that it is one of the most ubiquitous fossil molluscs in offshore siltstone of Pleistocene and late Pliocene age throughout New Zealand. As with the possibly ancestral *N. quinarium* (Pl. 34c; Tongaporutuan (?) -Waipipian), it seems to be an indicator of fine-grained, unconsolidated substrates rather than any particular depth range. The earlier Pliocene *Nemocardium (Pratulium)* species are compared with *N. pulchellum* under *N. quinarium* (Pl. 34c). The species group has inhabited New Zealand since at least Early Paleocene time (*N. modicum*, Wangaloan) and the extinction of the last of the large, spectacular mid-Cenozoic Cardiidae (*Maoricardium spatiosum* and *Trachycardium rossi*, both during Magapanian time) left *N. pulchellum* as the sole cardiid remaining in New Zealand (with the possible exception of the minute *Corculum inexpectatum* Crozier, 1966, from the Three Kings Islands).

Figured specimen (Pl. 46k): Castlecliff, Wanganui, Castlecliffian (NZGS, from an old collection) x 2.

Pl. 45 c,e. *Notocallista (Striacallista) multistriata* (Sowerby, 1851) [*Cytherea (Callista) multistriata* G. B. Sowerby II 1851 (in 1842-1887), p. 628; *Cytherea (Callista) planatella* of von Martens 1873, p. 44, not of Lamarck; *Notocallista (Striacallista) multistriata ovalina* Marwick 1938, p. 70; *Callista multistriata*; *Paradione (Notocallista) multistriata*]. Type species of *Striacallista* Marwick, 1938 (Veneridae: Pitarinae).

Small for family (25-35 mm long), thin and fragile, elongate-oval, with umbones at anterior 0.2-0.33 of length. Anterior and posterior margins narrowly rounded; ventral margin evenly curved; antero-dorsal margin straight; postero-dorsal margin straight (in narrow, subtriangular specimens) to quite strongly convex (in rounded, inflated specimens, form *ovalina*, illustrated). Lunule long and narrow, flat, bounded by shallow groove. Sculpture of very many fine, closely spaced commarginal ridges, producing a silky sheen on fresh shells. Hinge narrow and thin;

in left valve, with thin posterior cardinal tooth partly fused to ligamental ridge (nymph) above it, 2 other thin, widely separated cardinal teeth, and a prominent, narrow anterior lateral tooth; in right valve, with relatively thick, grooved, posterior cardinal, 2 other solid, protruding, upright, very closely spaced cardinal teeth (their orientation is characteristic of Pitarinae), and deep anterior lateral socket flanked by low ridges. Adductor scars approximately equal; pallial sinus wide, shallow, truncated by forward-sloping anterior edge.

Waipipian-Recent; Recent, New Zealand (type of *Cytherea multistriata*); "bed 3c", Castlecliff, Wanganui (apparently basal shellbed(?) of the Shakespeare Cliff Sand), Castlecliffian (type of *Notocallista multistriata ovalina*). Common in late Pliocene to Pleistocene shallow, offshore, soft-bottom facies and shellbeds throughout New Zealand, but particularly in Nukumaruan siltstone of Hawke's Bay and Wairarapa, and Castlecliffian siltstone of Wanganui basin. *N. multistriata* is a common species in the soft-bottom infauna of the continental shelf around New Zealand today, below about 10 m; Recent specimens have a bright red-brown chequerboard pattern.

Marwick (1938) distinguished four shape variants of *Notocallista multistriata* in the Castlecliff beds, but named only one (*ovalina*) as a "subspecies"; these individual variants occur also in the modern fauna, and in our opinion are of no taxonomic significance. Older species placed in the subgenus *Notocallista (Fossacallista)* Marwick, 1938 differ mainly in their smaller size and subtly different muscle scars. The Tongaporutuan-Opoitian *N. (Striacallista) makoensis* is more elongate and the Kapitean *N. (Striacallista) kapitea* is shorter and more trigonal than *N. multistriata*.

Figured specimen (Pl. 45c, e): Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.5.

Pl. 46 d,f. *Dosinia (Asa ?) lambata* (Gould, 1850) [*Arthemis lambata* Gould 1850 (in 1846-1850), p. 277; *Dosinia (Dosinia) lambata*] (Veneridae: Dosiniinae).

Small for genus (24-33 mm long), well inflated, circular apart from weakly protruding umbones, thin and fragile, with smooth margins. External sculpture of exceedingly fine, closely spaced, commarginal ridges, about 50 per cm, giving freshly preserved shells a silky sheen; ridges are low and wide over most of disc, but raised into thin lamellae over anterior and posterior ends; crossed by a few very narrow, faint, radial grooves. Lunule small, narrow, deeply impressed. Hinge thin and narrow, teeth much as in *D. subrosea* (below) but much shorter and thinner, and anterior cardinal tooth in each valve curved. Adductor scars narrow, very weakly impressed; pallial sinus very deep, more than half shell length, V-shaped with narrowly rounded apex, directed at top of anterior adductor scar.

Duntroonian-Recent; Recent, New Zealand (type). Common today deeply buried in fine soft sediment (commonly black anoxic mud) in bays and on the continental shelf, in about five to 50 m; apparently identical fossils are not uncommon in shallow soft-bottom facies as old as Duntroonian (Oligocene) (e.g., Chatton and Wendon Valley, near Gore) although it is difficult to be certain that such fragile shells have identical hinges to Recent ones; uncommon in Nukumaruan and Castlecliffian siltstone in Wanganui, Hawke's Bay, and Wairarapa, and in the Haweran Te Piki bed near Cape Runaway, East Cape.

Dosinia lambata is smaller and has a much thinner shell, very much finer sculpture, and a much narrower hinge than all other New Zealand Neogene to Recent *Dosinia* species, and its subgeneric position is uncertain. The only

other named species that is so nearly circular is *D. (Phacosoma) maoriana*, which differs in its very much thicker shell, wider hinge, and much wider commarginal ridges.

Figured specimen (Pl. 46d, f): GS5833, Y14/f7505, Te Piki, Cape Runaway, Haweran (oxygen isotope stage 7) (NZGS) x 2.

Pl. 46 j,l. *Dosinia (Phacosoma) subrosea* (Gray, 1835) [*Arthemis subrosea* Gray 1835, p. 309; *Dosinia (Phacosoma) wanganuiensis* Marwick 1927, p. 586; *D. (Austrodosinia) subrosea*] (Veneridae: Dosiniinae).

Moderately large for genus (45-63 mm long), almost circular, weakly inflated, thick and solid, with smooth margins. Umbo strongly anterior; dorsal margin only weakly curved, producing a weak postero-dorsal wing; remainder of margin regularly curved. External sculpture of about 20 low, wide, closely spaced commarginal ridges per cm, weakly anastomosing and narrower over posterior wing than elsewhere; lunule small, wide, deeply impressed, steeply angled. Hinge of right valve with long narrow posterior cardinal tooth separated widely from the closely spaced, wide, triangular, median cardinal and narrow anterior cardinal teeth, and with a short anterior lateral socket with raised edges; hinge of left valve with long, low, very thin posterior cardinal tooth, thick, bevelled median cardinal tooth, widely separated high, thin anterior cardinal tooth, and low, wide, anterior lateral knob. Adductor scars narrow, weakly impressed; pallial sinus deep, V-shaped, apex at centre of shell length, directed at centre of anterior adductor scar.

Waipipian-Recent; Recent, New Zealand (type of *Arthemis subrosea*); Castlecliff, Wanganui (the preservation and yellow-brown colour suggest a Shakespeare Cliff Sand provenance), Castlecliffian (type of *Dosinia wanganuiensis*). *D. subrosea* lives commonly at low tide off sand beaches, both in enclosed bays and on open coasts, and so is a common fossil in a variety of soft-bottom facies.

We agree with Powell (1979, p. 423) that *Dosinia wanganuiensis* is identical to *D. subrosea*; Marwick evidently had not seen large modern specimens of *D. subrosea*. Unnamed Waipipian to Nukumaruan species of *D. (Phacosoma)* from Wanganui basin and Hawke's Bay differ from *D. subrosea* in their thinner shells and finer sculpture. The subgenus appears to have arrived in New Zealand (presumably from the tropical Pacific) during Opoitian or Waipipian time. The larger *D. (Austrodosinia) anus* (Nukumaruan-Recent) has much coarser sculpture, lamellose on the posterior wing, and is an obligate open-ocean sand beach species.

Figured specimen (Pl. 46j, l): holotype of *D. wanganuiensis* Marwick, Castlecliff, Wanganui (Shakespeare Cliff Sand?), Castlecliffian (TM4685, NZGS) x 1.

Pl. 46 a,c. *Protothaca crassica* (Deshayes, 1835) [*Venus costata* Quoy and Gaimard 1835, p. 521 (not of Dillwyn, 1817); *Venus crassica* Deshayes 1835, p. 373; *Chione costata*; *Tapes crassica*; *Paphia (Protothaca) crassica*; *Protothaca (Tuangia) crassica*]. Type species of *Tuangia* Marwick, 1927 (here synonymised with *Protothaca* Dall, 1902) (Veneridae: Chioninae).

Small for genus (35-45 mm long), elongate-ovate to subrectangular, solid, with finely serrate interior ventral margin. Dorsal and ventral margins weakly to quite strongly curved, subparallel; anterior and posterior margins lightly curved, converging towards dorsum; umbo at anterior quarter of length. External sculpture of many wide, closely spaced, prominent radial costae, wider over posterior third than elsewhere, crossed by many narrow commarginal ridges that are regular and moderately prominent over anterior third but weaker further back. Lunule very small, narrow, marked off by shallow groove. Hinge with 3 narrow cardinal teeth, only, in each valve; left posterior cardinal lamellar, fused to nymph; left median and right median and posterior teeth grooved. Adductor muscle scars moderately large, shallowly impressed; pallial sinus small, very narrow, slightly ascending.

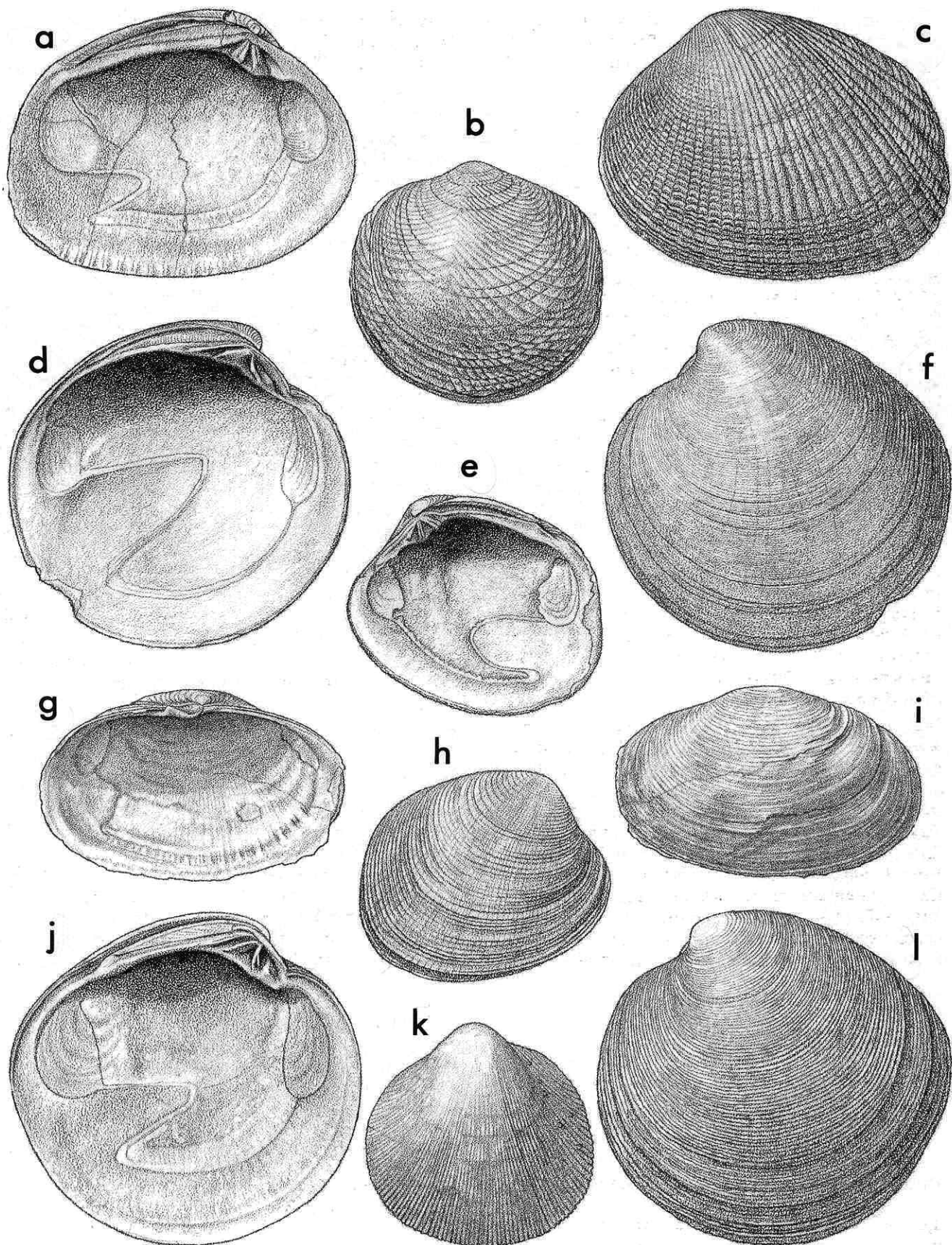
Castlecliffian-Recent; Recent, New Zealand (types of *Venus costata* and of *Venus crassica*); common in the modern fauna buried in sand and gravel in crevices on exposed rocky shores, low in the intertidal zone and just below, and so rare as a fossil. We know of one record from the early Castlecliffian of Cape Kidnappers (figured) and several from Haweran raised terrace faunules. The characters used by Marwick (1927) to separate the subgenus *Tuangia* appear to us to be merely of specific rank.

Figured specimen (Pl. 46a, c): GS13734, W21/f49, basal shellbed of Maraetotara Sand, Cape Kidnappers, Hawke's Bay, Castlecliffian (NZGS) x 1.5.

Pl. 46 e,h. *Ruditapes largillierti* (Philippi, 1847) [*Venus intermedia* Quoy and Gaimard 1835, p. 526, not of de Serres, 1829; *Venus largillierti* Philippi 1847, p. 87; *Tapes intermedia*; *Tapes (Amygdala) intermedia*; *Paphia (Ruditapes) intermedia*; *Paphirus largillierti*; *Pullastra (Paphirus) largillierti*; *Venerupis (Paphirus) largillierti*]. Type species of *Paphirus* Finlay, 1926 (= *Ruditapes* Chiamanti, 1900) (Veneridae: Tapetinae).

Plate 46 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (4).

- a,c *Protothaca crassica* (Deshayes), x 1.5.
- b. *Divaricella (Divalucina) huttoniana* Vanatta, x 1.
- d,f. *Dosinia (Asa?) lambata* (Gould), x 2.
- e,h. *Ruditapes largillierti* (Philippi), x 1.
- g,i. "*Parilimya*" *neozelanica* (Suter), x 1.5.
- j,l. *Dosinia (Phacosoma) subrosea* (Gray), x 1.
- k. *Nemocardium (Pratulium) pulchellum* (Gray), x 2.



Moderately large for genus (45-65 mm long), elongate and subrectangular, thick and solid, with smooth ventral margin. Umbones at anterior fifth of length; dorsal and ventral margins curved, subparallel; anterior and posterior margins nearly straight to lightly convex, converging towards dorsum. External sculpture of many low, wide, almost smooth, rather irregular, weakly anastomosing, commarginal costae, the postero-dorsal slope with about half the number of costae that are more prominent than on remainder of disc; all crossed by very fine, close, irregular commarginal ridges, and by rather stronger and more regular grooves on posterior area. Lunule concave, almost smooth, long and narrow, large for shell, weakly differentiated. Hinge with 3 narrow, cardinal teeth, only, in each valve; left posterior one lamellar, broken off most specimens; right anterior one low, lamellar; the other 2 in each valve medially grooved. Pallial sinus deep, oval.

Waipipian-Recent; Recent, New Zealand (types of *Venus intermedia* and of *V. largillierti*). Abundant today in about 5 to 20 m, burrowing in muddy and sandy substrates in large, enclosed bays (i.e., in slightly lower than oceanic salinity, never in open-ocean situations) and so a rare fossil other than in some shallow-water beds at Castlecliff and in Haweran raised terrace faunas.

We agree with Fischer-Piette and Métivier (1971, p. 37) that *Ruditapes largillierti* belongs in *Ruditapes* Chiamenti, 1900; Suter (1913c, p. 995) also referred it to *Ruditapes*, as a subgenus of *Paphia*. Marwick (1927, p. 633) listed *Tapes fabagella* Deshayes, 1853 as a synonym of *R. largillierti*, and has been followed by all subsequent New Zealand authors, but Fischer-Piette and Métivier (1971, p. 9) listed it as a synonym of *Venerupis anomala* (Lamarck).

Figured specimen (Pl. 46e, h): GS4104, R22/f6518, basal shellbed member of Shakespeare Cliff Sand, Castlecliff, Wanganui, Castlecliffian (NZGS) x 1.

Pl. 46 g,i. "*Parilimya*" *neozelanica* Suter, 1914 [*Thracia granulosa* Hutton 1973b, p. 19 (not of A. Adams and Reeve, 1850); *Thracia neozelanica* Suter 1914, p. 54 (new name for *Thracia granulosa* Hutton, preoccupied)] (?New genus of Parilimyidae).

Small for family (43-48 mm long), thin and fragile, evenly elongate-oval and very inflated, except for slight anterior rostration on some specimens; umbo central, only slightly elevated; both anterior and posterior ends gape slightly. Exterior sculptured with many weak, irregular, commarginal growth sulci; entire surface closely and microscopically granulous; granules of posterior end tend to be disposed in radial rows. Hinge plate thin and smooth, apart from a low nymph just behind umbo, separated from hinge plate by deep, narrow groove. Anterior adductor scar small, narrowly oval; posterior one wider. Pallial line irregular, with transverse ridges; shallow, almost rectangular pallial sinus below posterior adductor scar. Siphonal retractor (taenoid) muscle scar small but obvious, at anterior third of shell length.

Castlecliffian-Recent; "Wanganui (upper beds)", i.e., upper part of the section at Castlecliff, Wanganui, Castlecliffian (type). A rare but interesting species known fossil as only three or four valves, all from the late Castlecliffian of Castlecliff, Wanganui; recently collected specimens are from Pinnacle Sand (Boreham 1965, pl. 20, fig. 2, 3) and Upper Castlecliff Shellbed. Modern specimens in the National Museum of N.Z. are from 40-180 m on the shelf around much of New Zealand, but are very rare.

The taxonomic position of "*Thracia*" *neozelanica* has been in doubt; it certainly does not belong in the Thraciidae, and a position in Parilimyidae seems appropriate. The position of several New Zealand "*Pholadomya*" species in *Parilimya* was discussed above (under *Pholadomya neozelanica*); the present species differs from *Parilimya*

species in its longer and lower shape, with almost equal anterior and posterior ends, and in its relatively thick shell lacking radial sculpture, and appears to belong in an unnamed genus. The siphonal retractor muscle scar characteristic of Parilimyidae is prominent. The relatively coarsely granulous surface makes "*Parilimya*" *neozelanica* easily recognised.

Figured specimen (Pl. 46g, i): holotype, "upper beds, Wanganui", Castlecliffian (TM4863, NZGS) x 1.5.

Pl. 47 a,e. *Barnea (Anchomasa) similis* (Gray, 1835). [*Pholas similis* Gray 1835, p. 309; *Anchomasa similis*] (Pholadidae: Pholadinae).

Large for family (68-100 mm long), long and narrow, subcylindrical, tapering slightly to posterior; thick and relatively solid. Anterior end deeply embayed for foot protrusion at all stages; posterior end evenly oval; no groove between anterior and posterior areas. External sculpture of thin, raised, lamellar, commarginal ridges, smooth on posterior but over anterior area raised into many low spinous flutes by low, narrow, widely spaced radial costellae. Antero-dorsal margins raised into sharply recurved edge, smooth and bearing anterior adductor scar in front of umbo, adductor muscle protected in living specimens by large, narrow, relatively thick, medially grooved mesoplax (rarely preserved in fossils). Posterior adductor scar large, elongate-oval, near centre of shell length just below dorsal margin; pallial sinus very deep. Long, thick, curved apophysis beneath each umbo, preserved in some fossils.

Opoitian(?) - Recent; Recent, New Zealand (type). Typical specimens are known from Mangapanian-Recent; Opoitian-Waipipian specimens are more narrowly cylindrical, with a shorter anterior end, and probably represent an unnamed species.

Barnea similis is moderately common around much of New Zealand today (and particularly around Auckland), boring vertically into Cenozoic mudstone outcrops or, less commonly, into weathered older rocks (e.g., siltstone of Mesozoic flysch beds near Wellington, at Day's Bay and in Pauatahanui Inlet). It is a common fossil in situ, boring in the many disconformity surfaces in the Castlecliff section, and in the marine-planed surfaces at the bases of many Haweran terrace deposits, but is otherwise uncommon (i.e., dislodged shells are not often found in shellbeds). It is very much larger and thicker-shelled than *Pholadidea* species (and so more often encountered fossil, although usually less common than *P. suteri* in the living fauna) and is easily distinguished from them by the lack of an umbonal-ventral groove and by retaining the anterior pedal gape in adults.

We follow Turner (in Moore 1969, p. N708) in ranking *Anchomasa* as a subgenus of *Barnea*.

Figured specimen (Pl. 47a, e): Castlecliff, Wanganui, Castlecliffian (NZGS, from old collection; apparently removed from a bore-hole in a disconformity plane), x 1.

Pl. 47 b,d. *Pholadidea suteri* Lamy, 1926 [*Pholas spathulata* G. B. Sowerby II 1850 (in 1842-1887), p. 162, not of Deshayes, 1843; *Pholadidea suteri* Lamy 1926, p. 141 (new name for *Pholas spathulata* Sowerby, 1850, preoccupied)] (Pholadidae: Martesiinae).

Rather small for family (25-50 mm long), narrowly elongate, gradually tapered toward posterior; circular in cross-section (of articulated shell). A single prominent, narrow, diagonal, umbonal-ventral groove present. Anterior end with low umbo, gaping widely for foot protrusion when immature, hemispherical and with ventral gape filled by smooth callum in adult. Posterior end elongate, oval in immature specimens, truncated by base of siphonoplax in adults (siphonoplax chitinous, not found in fossils). Anterior umbonal area protected by thin, fragile, oval accessory

plate (mesoplax), preserved in some fossils. Exterior of anterior area sculptured with many moderately widely to very closely spaced, low, narrow, finely crenulate commarginal ridges; posterior area sculptured with low, fine, smooth, widely spaced commarginal ridges. Interior with no hinge teeth, but small, thin apophysis present below umbo (although rarely found in fossils). Pallial sinus very deep; posterior adductor muscle scar narrowly oval, near dorsal margin; anterior adductor scar on dorsally raised shell edge in front of umbo.

Castlecliffian-Recent; Recent, New Zealand (type). The most common rock-boring pholad in the intertidal zone around New Zealand at present, boring in Cenozoic mudstone (and, less commonly, other soft rock) and an important indicator in the fossil record of hiatuses in deposition (as neither this nor *Barnea similis* survive in any location where sediment accumulates). Not uncommon as a fossil, particularly as loose valves in Haweran near-shore faunules.

The less common living *Pholadidea tridens* (Gray) is stouter than *P. suteri*, with more prominent sculpture and a calcified siphonoplax (not recorded fossil). The Kaawa Creek Opoitian species *P. finlayi* is similar to *P. tridens*.

Figured specimen (Pl. 47b, d): GS13937, W21/f58, in situ in large boulders in low terrace in front of shelter huts, between Black Reef and Cape Kidnappers, Hawke's Bay, Holocene (2,300 years old; in NZGS) x 1.5.

Pl. 47 c. *Haliotis (Sulculus) powelli* Fleming, 1952 [p. 231] (Haliotidae).

Small for genus (47 mm long), very weakly inflated, with clearly spiral, very low apex but extremely large, depressed last whorl and very large aperture, passing its exhalent current out 4 tremata near the columellar lip; formerly open tremata form a spiral row of low nodes. Sculpture of 20 prominent, narrow, rounded spiral costae, each interspace with several finer costellae, all crossed by irregular, weak to prominent growth ridges.

Castlecliffian, Ohope Beach, Whakatane (type), not uncommon; ? Nukumaruan, Pohangina Valley, eastern Wanganui basin (Carter 1972, fig. 22, p. 316). A rare fossil, known with certainty only from Ohope Beach but representative of a reasonably good fossil history of Eocene-Pleistocene *Haliotis* in New Zealand (most records unpublished; see also *Haliotis* n. sp., Pl. 13g, k; Lee et al. 1983, fig. 2, 3, p. 124).

Haliotis flemingi is much flatter and more prominently sculptured than the Haweran to Recent *H. (Sulculus) australis* and *H. (Sulculus) virginea*; and much smaller, flatter, more coarsely sculptured, and with a narrower columellar lip than the well-known "paua", *H. (Paua) iris* (Opoitian-Recent).

Figured specimen (Pl. 47c): holotype, GS3893, W15/f7501, Ohope Beach, Whakatane, Castlecliffian (TM4908, NZGS) x 1.

Pl. 47 h,i. *Tugali pliocenica* (Finlay, 1926b) [p. 227] (Fissurellidae).

Moderate-sized for genus (18-21 mm long), a narrow boat-shaped "limpet" with hooked, backward-directed apex 0.1-0.25 of total length from posterior end, relatively tall so posterior lateral outline is weakly concave, anterior strongly convex. A high, narrow costa extending down anterior crest from apex divides into 3 lower costellae, leading down to shallow sulcus in anterior margin; other sculpture of many low, relatively wide, closely spaced radial costellae, crossed by considerably narrower, well raised, commarginal ridges. Margin finely crenulate.

Nukumaruan-Castlecliffian; "Castlecliff blue clays (Castlecliffian)", type; common in offshore, current-swept

facies (notably Tainui Shellbed) at Castlecliff, Wanganui (Castlecliffian), less common in Hawke's Bay in blue-grey siltstone (Nukumaruan).

Tugali pliocenica is smaller, higher and narrower, and more closely sculptured than the Haweran and living *T. elegans* but, like *T. elegans*, has only a low median anterior costa. Most other fossil species are smaller and have a more prominent, more intricately subdivided anterior median costa than *T. pliocenica*. The other living species, *T. suteri* Thiele, is smaller and markedly shorter and more inflated than *T. pliocenica*.

Figured specimen (Pl. 47h, i): GS4013, R22/f6353, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS) x 2.

Pl. 47 l,p. *Zethalia zelandica* (Hombron and Jacquinot, 1854) [*Globulus anguliferus* Philippi, 1853 [in 1842-1855], p. 51 (not of J. de C. Sowerby, 1840); *Rotella zelandica* Hombron and Jacquinot 1854, p. 53; *Umbonium zelandicum* A. Adams 1855b, p. 189; *Ethaliopsis zelandica* of Cossmann 1918, p. 223; *Umbonium anguliferum*; *Umbonium (Zethalia) zelandicum*]. Type species of *Ethaliopsis* Cossmann, 1918 (not of Schepmann, 1908), and of *Zethalia* Finlay, 1926 (Trochidae: Umboniinae).

Large for genus (15 to 23 mm in diameter), with very low, conic spire, narrowly biangled periphery, wide almost flat base, smooth dorsal surface, and completely filled, almost smooth umbilical plug. Subsutural nodules and circumumbilical sculpture described above under *Z. russelli* (Opoitian; Pl. 36e, h) and (under same heading) *Z. coronata* (Waipipian-Mangapanian; early Nukumaruan ?) almost completely lost, the only remnant being weak radial grooves on and shallow margining groove around umbilical plug. Base bearing many very fine spiral grooves; the only other sculpture is 2 narrow, smooth, peripheral spiral cords and weak growth ridges. Modern specimens have a bright colour pattern of red to purple radial streaks, running forward to cross growth lines at a low angle over outer 0.6 of each whorl (except the last, where streaks tend to become narrow, closely spaced, and strictly radial), on a cream or pale pink ground; base pink or cream, with wide purple spiral band outside outer edge of umbilical plug. Colour pattern remains on most fossils, particularly Castlecliffian and Haweran specimens.

Nukumaruan-Recent; Recent, New Zealand (types of names listed in synonymy). A very abundant fossil in late Nukumaruan, Castlecliffian and Haweran sandstone deposited near shore, just off sandy ocean beaches (it lives now in huge numbers in about three to five metres, in the wave zone off slightly protected sand beaches) and a very useful and precise indicator (along with the clypeasteroid echinoid *Fellaster zelandiae* Gray) of this near-shore, sandy beach environment.

As described above under *Zethalia russelli* (Opoitian; Pl. 36e, h), the immediately ancestral *Z. coronata* is slightly smaller than *Z. zelandica*, has a slightly less filling umbilical plug, and has more sculpture, with a spiral row of low, rounded nodules below the suture. *Z. coronata* is common in Waipipian and Mangapanian near-shore sandstone, but its upper limit is uncertain as some weakly nodulous specimens persist in early Nukumaruan populations.

The species name has most frequently been attributed to A. Adams (following Finlay 1926c) but according to Sclater (1893) Adams's paper was not published until 16 May 1855, and so the name was introduced earlier by Hombron and Jacquinot (1854, p. 53).

Figured specimen (Pl. 47l, p): GS4186, R22/f6469, Shakespeare Cliff Sand, Castlecliff, Wanganui, Castlecliffian (NZGS) x 2.

Pl. 47 k. *Opalia* n. sp. (Epitoniidae).

Moderately large for family (30-35 mm high), tall and narrow, with moderately well inflated whorls, simple oval aperture with a continuous thickened peristome, and almost smooth base bordered by a prominent, rounded, smooth cord that runs around suture of whole shell. Sculpture of prominent but wide, rounded, curved, indistinctly edged, slightly irregular axial costae, crossed by many very low, wide, closely spaced, rather indistinct spiral cords. No varices present. Entire surface microscopically pitted in regular spiral rows; pits are large and obvious on some costal surfaces on the last whorl. Protoconch not seen.

Castlecliffian; Castlecliff, Wanganui, only; most specimens are from the Ototoka Siltstone Tongue member of Butler's Shell Conglomerate, but a few have been seen from as high as Pinnacle Sand.

The new species is unusual among New Zealand Epitoniidae, most of which have sculpture of high, thin, axial lamellae only (*Epitonium*) or with the addition of many narrow spiral cords (*Cirsotrema*). It is an uncommon and interesting addition to the New Zealand Castlecliffian fauna, and was apparently a Castlecliffian arrival. The regular microscopic pitting and low, wide axial costae leave little doubt that this is a species of *Opalia* (Kilburn 1985, p.241, 266). It is not unlike the living southern Australian *O. australis* (Lamarck), but we have been unable to match the relatively low, wide, very closely spaced axial costae and weak spiral cords with those of any Australian living species. The most closely similar species appears to be *Opalia* (?*Pliciscala*) *aglaia* (Bartsch) (Kilburn 1985, p. 271, fig. 51, 52) from South Africa.

Figured specimen (Pl. 47k): "The Pinnacles" gully, between Kai Iwi and Castlecliff, Wanganui (from Pinnacle Sand?), Castlecliffian (NZGS, from a private collection) x 2.

Pl. 47 j,n. *Capulus uncinatus* (Hutton, 1873) [*Pilaeopsis uncinatus* Hutton 1873b, p. 14; *Capulus australis* (Lamarck) of Suter 1914, p. 19 (not of Lamarck); *Hipponyx uncinatus*] (Capulidae).

Large for genus (20-30 mm in diameter), low and limpet-shaped, with protoconch of 1.3 smooth planspiral whorls, followed by a simple, cap-shaped, rapidly expanding teleoconch of less than 1 whorl, smooth inside except for a large horseshoe-shaped muscle scar. Apex overhangs posterior end; posterior slope concave, anterior slope strongly convex. Exterior bears many very fine, close radial costellae, crossed by prominent, irregular growth ridges; most specimens with large anterior sulcus in margin, generating a high, wide, rounded radial fold occupying a third of shell width, and with several narrow, deep, posterior sulci in margin that generate prominent narrow radial folds.

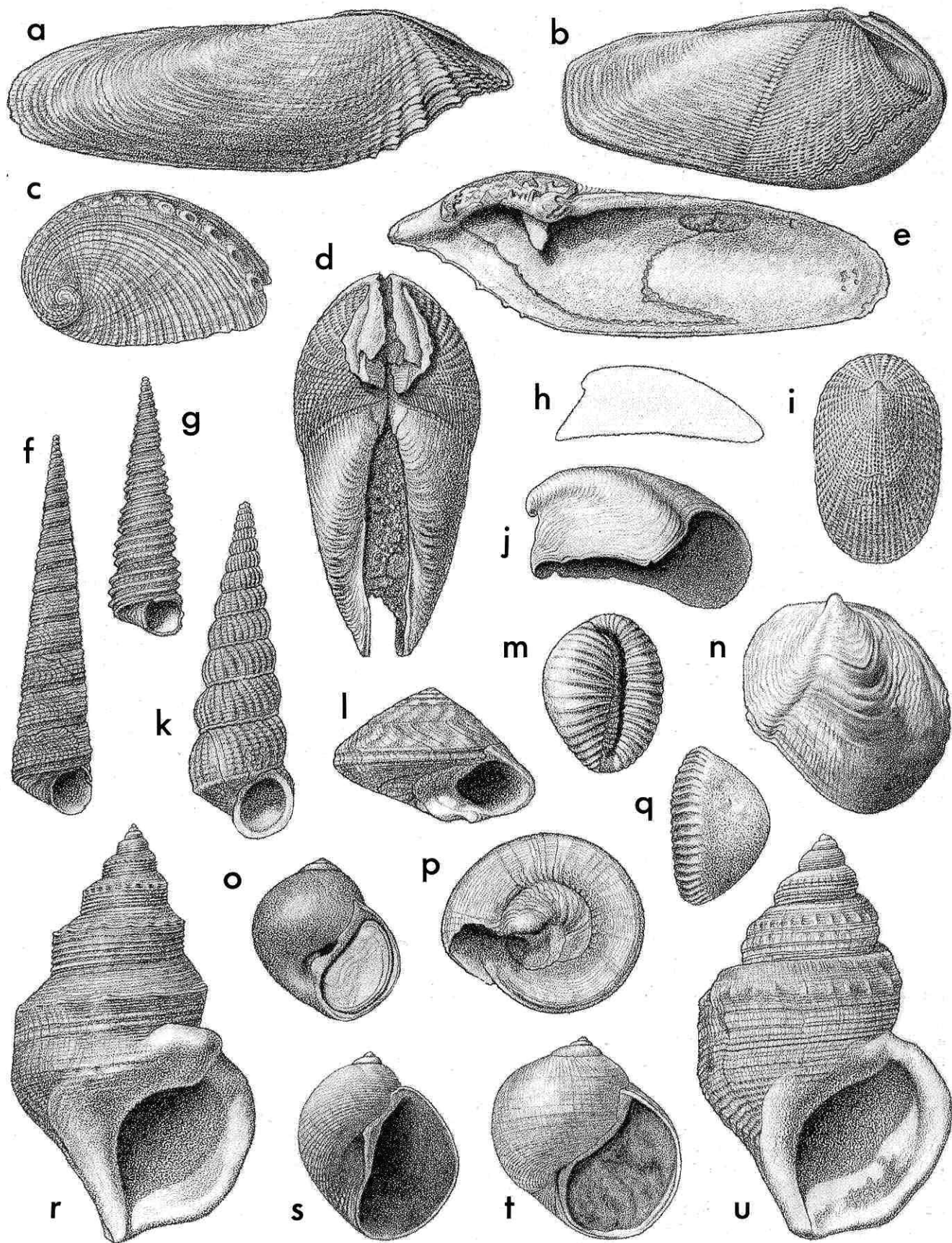
Haweran; Landguard Sand, Landguard Bluff, east of mouth of Wanganui River (type), very rare (oxygen isotope stage 9); Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7), not uncommon.

Capulus uncinatus lived attached to *Pecten tainui* shells at the junction of an ear with the umbo, on the right (inflated) valve (Dell 1964) and shows xenomorphic sculpture (reflecting that of its host) in the form of a wide, deep sulcus in the margin (fitting the *Pecten* ear) that generates a prominent, low, wide radial fold, between its narrow anterior projection and the shell apex; several smaller sulci and projections around the posterior end (below the protoconch) of most specimens fit the interspaces between the *Pecten* costae. In most specimens, the wide sulcus is on the right side of the anterior margin (the shell lived on the anterior *Pecten* ear) but it is on the left side of a few (the *Capulus* lived on the posterior *Pecten* ear).

Suter (1914, p. 19) thought *Capulus uncinatus* the same species as the living southern Australian *C. australis* (Lamarck), and a new comparison of shells has shown no differences from specimens in Suter's collection labelled as such. However, this name applies to a southern Australian species of *Sabia* (Hipponicidae); Suter's specimens are wrongly identified (pers. comm. W.F. Ponder, Australian Museum). *Capulus uncinatus* may be the valid name for a species of *Capulus* living now in southern Australia. Certainly *C. uncinatus* is not closely related to the living southern deep-water species *C.*

Plate 47 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (5).

- a,e. *Barnea (Anchomasa) similis* (Gray), x 1.
- b,d. *Pholadidea suteri* Lamy, x 1.5.
- c. *Haliotis (Sulculus) powelli* Fleming, x 1.
- f. *Zeacolpus (Zeacolpus) vittatus* (Hutton), x 1.
- g. *Stiracolpus delli murchisoni* Marwick, x 2.
- h,i. *Tugali pliocenica* Finlay, x 2.
- j,n. *Capulus uncinatus* (Hutton), x 1.5.
- k. *Opalia* n.sp., x 2.
- l,p. *Zethalia zelandica* (Hombrón and Jacquinot), x 2.
- m,q. *Trivia zelandica* Kirk, x 3.
- o. *Tanea zelandica* (Quoy and Gaimard), x 1.
- r. *Struthiolaria (Struthiolaria) papulosa* (Martyn), x 1.
- s. *Eunaticina linnaeana* (Récluz), x 2.
- t. *Globisium drewi* (Murdoch), x 1.
- u. *Pellicaria vermis vermis* (Martyn), x 1.5.



novaezelandiae Dell (1978, p. 164), and it appears that *C. uncinatus* could be based on chance spatfalls of an Australian species in New Zealand.

Figured specimen (Pl. 47j, n): Landguard Sand, Landguard Bluff, Wanganui, Haweran (oxygen isotope stage 9) (NZGS, ex Suter Collection) x 1.5.

Pl. 47 g. *Stiracolpus delli murchisoni* (Marwick, 1957) [*Zeacolpus* (*Stiracolpus*) *delli murchisoni* Marwick 1957b, p. 32; probably = *Z. delli* Marwick 1957b, p. 31; *Z. delli granti* Marwick 1957b, p. 33; *Z. shepherdii* Marwick 1957b, p. 44] (Turritellidae).

Small for family (20-25 mm high), tall and narrow, with only weakly convex whorls, flat base, and marked peribasal angulation on last whorl. Sculpture greatly dominated by 3 prominent, wide, widely spaced spiral cords of rounded cross-section (cords A, B and C); secondary and tertiary threads weak; no axial sculpture other than growth lines. On early spire whorls, cord B begins first, and A and C are weak; A and C strengthen after fifth whorl, and rival B on last 7-8 whorls. Outer lip thin, with wide, relatively shallow, V-shaped sinus with medial apex. Protoconch of about 1 smooth whorl, with large, rounded apex.

Castlecliffian; Recent? Recent, New Zealand (type of *Z. delli delli*); Castlecliff, Wanganui, Castlecliffian (types of *Z. delli murchisoni*, *Z. delli granti*, *Z. shepherdii*). Abundant in siltstone beds along the Castlecliff-Kai-Iwi coast, Wanganui (Castlecliffian); *Z. delli* is common in large bays and off ocean beaches in a few metres of water around central New Zealand at present.

The taxonomy of *Stiracolpus* is poorly understood. Many of Marwick's (1957b) nominal species and subspecies appear to be part of the variation of more widespread, more long-lived species (see particularly Marwick's table 2, where many Castlecliff intergrades are identified as "hybrids"). The many Castlecliff forms are particularly in need of revision; we illustrate *S. delli murchisoni* as an example of the abundant Castlecliffian strongly tricostate type of shell, differing from the Recent, southern, cold-water *S. symmetricus* only in its slightly narrower spire angle and slightly flatter whorl outlines (*S. symmetricus* possibly includes *S. delli vellai* and *S. quennelli*, from the early Nukumaruan and Mangapanian, respectively). The abundant Hawke's Bay Nukumaruan species *S. waikopiroensis* (almost certainly the same taxon as *S. uttleyi*, based on the more coarsely sculptured variants in the population) has more numerous, lower, more closely spaced spiral cords than the *S. symmetricus* group, and is close to the living, northern, warm-water *S. maorius* (Powell, 1940) and *S. mixtus* Finlay, 1930. *S. waikopiroensis* occurs also in the Kupe Formation, at Wanganui (Castlecliffian). In Haweran beds of Wanganui, *S. vigilax* is a small species with prominently single-keeled whorls (cord B predominates), apparently related to the living, northern, warm-water *S. pagoda* (Reeve). Earlier species of the genus are *S. huttoni* (Opoitian-Nukumaruan; Pl. 36), with only two prominent cords; *S. procellosus* (Opoitian) with one prominent cord low on the whorls and a weaker one high on the whorls; and *S. propagoda* (Mangapanian) with many low primary, secondary and tertiary cords.

Figured specimen (Pl. 47g): holotype of *S. delli murchisoni*, GS4055, R22/f6386, Upper Kai-Iwi Siltstone, Castlecliff, Wanganui, Castlecliffian (TM1656, NZGS) x 2.

Pl. 47 f. *Zeacolpus* (*Zeacolpus*) *vittatus* (Hutton, 1873) [*Turritella* (*Haustator*) *vittata* Hutton 1873a, p. 29;

Turritella carlottae Watson 1881, p. 222]. Type species of *Zeacolpus* Finlay, 1926 (Turritellidae).

Moderate-sized for family (60-80 mm high), tall and slender, with 15-18 almost flat-sided whorls and very little-indented suture, a prominent peribasal angulation, and a subquadrate aperture with thin lips. Protoconch of 1 unusually tall whorl, partly uncoiled, with exert apex. First 2-3 teleoconch whorls strongly convex, gradually developing primary spiral cords in order B, then C, then A; A is low and narrow, and is rivalled in prominence by gradually developing intermediate cords. Lower down the shell, B descends the whorl, so B-C interspace is narrower than A-B, and intermediate cords strengthen. On last 4-5 whorls, many fine spiral cords are subequal in prominence, producing a slightly outward-sloping subsutural zone with even, weak sculpture, wide, very slightly concave, mid-whorl zone with 6 subequal cords, and a narrow basal zone that contracts again slightly to suture. All main cords bright tan on cream ground on modern shells; colour pattern remains on some shells from Castlecliff. Outer lip with deep, wide, V-shaped sinus; wide, shallow sinus occupies base.

Opoitian-Recent; Recent, New Zealand (types of *T. vittata* and *T. carlottae*). Extremely widespread and abundant in a variety of shallow-water, soft-bottom facies throughout New Zealand.

Zeacolpus vittatus has a markedly narrower spire angle, slightly more prominent spiral cords, and a smaller protoconch of fewer whorls than the even more abundant, partly sympatric *Maoricolpus roseus*. *M. roseus* is much more common than *Z. vittatus* today in very shallow water (e.g., *M. roseus* is intertidal in Manukau Harbour, Auckland) and *Z. vittatus* is the more common on the shelf, in depths of about five to 50 m. Only typical *Z. vittatus* occurs in Mangapanian-Recent faunas. Ancestral forms in Opoitian and Waipipian rocks vary greatly in the prominence of the spiral cords; some were included by Marwick (1971a, p. 18) in *Z. vittatus*, whereas forms with more prominent cords were included in *Z. opoitius opoitius* (Opoitian) and *Z. opoitius takapauensis* (Waipipian). The species group apparently descended from the very coarsely sculptured *Z. kanieriensis* (Kapitean-Waipipian?, Westland; Pl. 36n).

Fleming (in Marwick 1971b, p. 67, footnote) recorded an ovoviviparous modern specimen of *Maoricolpus roseus*, and Marwick (1971b) recorded an ovoviviparous fossil specimen of *Zeacolpus taranakiensis*, so it seems likely that most or all New Zealand turritellids of at least Miocene to Recent age are ovoviviparous. The lack of a dispersive larval stage should be expected to produce highly variable species.

Figured specimen (Pl. 47f): Landguard Sand, Landguard Bluff, east of mouth of Wanganui River, Castlecliffian (NZGS, from old collection) x 1.

Pl. 47 r. *Struthiolaria* (*Struthiolaria*) *papulosa* (Martyn, 1784) [*Buccinum papulosum* Martyn 1784, fig. 54 (valid, ICZN Opin. 479); *Buccinum coronarium* Lightfoot 1786, p. 160 (nomen nudum); *Murex stramineus* Gmelin 1791, p. 3542; *Struthiolaria nodulosa* Lamarck 1816, *Liste* p. 7, pl. 431, fig. 1a,b; *Struthiolaria nodosa* Gray 1835, p. 308; *Struthiolaria sulcata* Jonas 1839, p. 342; *Struthiolaria gigas* Sowerby 1842 (in 1842-1887), pl. 5, fig. 17; *Struthiolaria tasmani* King 1933, p. 340]. Type species of *Struthiolaria* Lamarck, 1816 (Struthiolariidae).

Large for family (70-90 mm high, i.e., much larger than *P. vermis*), with tall, stepped spire, short last whorl without anterior canal, nearly circular aperture with thick, reflected lips, outer lip strongly sinuous; particularly thickly callused at top of aperture. Sutural ramp gently sloping, straight in outline, above an obvious angle that bear low nodules

to large, spine-like nodes; a second rounded, peribasal angulation low on last whorl. Sculpture of many low, close spiral cords, variable from fine threads to relatively coarse cords (form *tasmani*), but coarse and prominent on early spire whorls of almost all specimens; crossed by faint growth lines only. Protoconch small, conical, of 2 smooth whorls.

(Waipipian?-) Nukumaruan-Recent. Recent, New Zealand (types of *Buccinum papulosum*, *Murex stramineus*, *Struthiolaria nodulosa*, *S. nodosa*, *S. sulcata*, and *S. gigas*); upper *Struthiolaria* bed of two (the lower has only *S. frazeri*) in Okauawa Stream, Kereru Road, central Hawke's Bay, Nukumaruan (type of *S. tasmani*). Common throughout New Zealand at present and in shallow-water, soft-bottom facies of Nukumaruan-Haweran age.

The identity and time ranges of the much less common Pliocene (Waipipian and Mangapanian) forms of *Struthiolaria* (sensu stricto) is unclear; *S. errata* (age uncertain, Opoitian-Mangapanian?) is possibly a distinct species (with finer spiral sculpture than *S. papulosa*). The origin of *S. papulosa* is uncertain, but *S. errata* is one possible ancestor. Southern New Zealand shells at present are large, tall, and weakly nodulous (form *gigas*, common at Stewart Island), and this form occurs fossil in the Kai-Iwi beds (early Castlecliffian) (suggesting temperatures were lower at the time of deposition than they are at Wanganui now), whereas northern shells at present are relatively small, short, and bear large, pointed nodules; there is a complete geographic cline between these extreme forms.

Figured specimen (Pl. 47r): GS4068, R22/f6399, Kaimatira Pumice Sand, Kai-Iwi, west of Wanganui, Castlecliffian (NZGS) x 1.

Pl. 47 u. *Pellicaria vermis* (Martyn, 1784) [*Buccinum vermis* Martyn 1784, fig. 53 (valid, ICZN Opin. 479); *Murex australis* Gmelin 1791, p. 3542; *Struthiolaria crenulata* Lamarck 1822, p. 148; *Struthiolaria tricarinata* Lesson 1841, p. 256; *Struthiolaria inermis* Sowerby 1842 (in 1842-1887), p. 23]. Type species of *Pellicaria* Gray, 1857 (Struthiolariidae).

Moderate-sized for genus (40-55 mm high), with moderately tall spire, short last whorl without anterior canal, and narrow, flat or, in some forms, deeply channelled subsutural ramp. Sculpture of many fine spiral threads and weak growth ridges; most specimens with 2 (or, in a few specimens, 3) low, wide, rounded, weakly nodulous cords on spire whorls, fading out before last whorl of many specimens. Aperture nearly circular, lips thickened and reflected but much less so than in *S. papulosa*; outer lip weakly sinuous. Outer lip meets columella at shallow anterior notch. Protoconch a low, wide, smooth, irregular dome of 1 whorl, reflecting direct development.

Castlecliffian-Recent; Recent, New Zealand (types of all nominal species in the synonymy). A common fossil in Castlecliffian shallow-water siltstone at Wanganui, and in the Haweran Te Piki bed, Cape Runaway; known also from Castlecliffian rocks in the Bay of Plenty, at Cape Kidnappers, and near Parnassus, North Canterbury, but very rare in Haweran terrace cover deposits.

Five well-marked geographic subspecies of *Pellicaria vermis* occur around New Zealand at present (Neef 1970): *P. vermis vermis* (= *tricarinata* Lesson, 1841), solid, short, and weakly sculptured, but many specimens have shoulder nodules (much like the figure), occurring in the north-eastern North Island; *P. vermis flemingi* Neef, large, smooth and inflated, occurring in the Bay of Plenty; *P. vermis powelli* Neef, tall and weakly

sculptured, occurring along the Wellington west coast; *P. vermis bradleyi* Neef, short, biangled and with a deeply channelled suture, occurring in the Marlborough Sounds to west Nelson; and *P. vermis grahami* Neef, large, tall, inflated, and with many prominent spiral cords, occurring in relatively deep water (mid-outer shelf) off the east coast from Castlepoint to Otago. Fossils in the offshore siltstone facies of the lower Castlecliffian near Kai-Iwi are close to *P. vermis grahami* (with many strong spiral cords) but have a shorter spire than modern specimens, whereas those in higher beds of shallower facies (e.g., the figured shell) are more like *P. vermis vermis* and *P. vermis powelli*. *P. vermis flemingi* occurs at Cape Kidnappers (Castlecliffian), in Bay of Plenty Castlecliffian localities (Ohope and Matata), in the Kupe Formation at Wanganui (Castlecliffian), and at Te Piki, Cape Runaway (Haweran). As was pointed out by Neef (1970), occurrences of *Pellicaria* at Wanganui appear to reflect varying temperature regimes: *P. vermis* aff. *grahami* in the Kai-Iwi siltstone beds presumably indicates both offshore deposition and a relatively cool temperature, the occurrence of *P. vermis vermis* and *P. vermis powelli* populations in most higher beds indicates temperatures much like those near Wanganui at present, and the occurrence of *P. vermis flemingi* (together with the return of the otherwise Nukumaruan *Stiracolpus waikopiroensis*) in the Kupe Formation indicates a temperature markedly higher than that near Wanganui now. *P. vermis* has direct development (Morton 1950) and so the segregation of regional forms into local populations that are recognised as geographic subspecies is to be expected.

Figured specimen (Pl. 47u): Castlecliff, Wanganui (apparently from Tainui Shellbed), Castlecliffian (NZGS, from an early collection) x 1.5.

Pl. 47 m,q. *Trivia zealandica* Kirk, 1882 [*Trivia zealandica* Kirk 1882, p. 409; *Trivia neozelanica* of Hutton 1893, p. 58 (error); *Triviella zealandica*; *Ellatrivia zealandica*] (Triviidae: Triviinae).

Moderate-sized for family (10-15 mm high), widely and almost evenly oval, with only slightly protruding apertural extremities, strongly thickened, protruding ridges along sides of base, and smooth, polished dorsum with high-arched, slightly pointed summit. Aperture long and narrow, almost parallel-sided, curved to left at posterior end, with 18 or 19 teeth on outer lip and 18 on inner lip. A few other ridges intercalated between tooth-ridges near outer edges of base; ridges extend only a short way up sides of dorsum, but significantly above callus ridges along the central half of each side. Area between sculptural ridges densely covered with small, distinct pustules; pustules are not seen on dorsum of many specimens, but on well preserved specimens extend over summit of dorsum in a narrow band corresponding to the zone between the mantle lobes of living specimens. Fossula prominent, deeply concave. Spire visibly protruding but thickly callused.

Nukumaruan-Castlecliffian; "near Petane", Hawke's Bay, i.e., hillside north of Petane Pa, north of mouth of Esk River, north of Napier, Nukumaruan (type). Not uncommon in Nukumaruan blue-grey siltstone and coquina limestone in central Hawke's Bay (particularly in siltstone at Roro-o-kuri and Watchman Hill, Ahuriri Lagoon, Napier); rare in Wanganui basin and at Castlepoint, Wairarapa (Nukumaruan); rare in Castlecliffian mudstone at Ohope Beach, Bay of Plenty, and Leader River on "Mendip Hills" station, near Parnassus, North Canterbury (figured).

The wide, flattened base, the prominent latero-basal

ridges similar to those of Cypraeidae, the presence of sculptural ridges on only the base and lateral callus ridges of mature shells (i.e., their absence from the dorsum), and the presence of pustules between the sculptural ridges and in a band over the dorsum make *Trivia zealandica* a distinctive species. The living northern North Island *Trivia merces* occurs rarely in Hawke's Bay Nukumaruan siltstone with *T. zealandica*, but is easily distinguished by its narrower shape and by having ridges over the whole dorsum. *T. flora* (Pitt Island, Waipipian) and *T. aequiflora* (Pakaurangi Point, Northland, Otaian) closely resemble *T. zealandica* in having the dorsum almost completely devoid of transverse ridges. The few available specimens of *T. flora* are smaller than *T. zealandica* (height 8-10 mm), and have a somewhat narrower aperture; they may represent a distinct taxon, possibly ancestral to *T. zealandica*. The holotype of *T. aequiflora*—the only specimen seen—is much smaller than either *T. zealandica* or *T. flora* (height only 3.7 mm) and has fewer transverse ridges (11 on inner lip, 15 on outer lip) (possibly a reflection of its smaller size)—it is likely to be different in view of its considerably greater age. All other New Zealand fossil Triviinae differ in having more uniformly ridged surfaces.

Figured specimen (Pl. 47m, q): O32/f8875, Leader River, "Mendip Hills" Station, near Parnassus, North Canterbury, Castlecliffian (NZGS) x 3.

Pl. 47 s. *Eunaticina linnaeana* (Récluz, 1843) [*Sigaretus linnaeanus* Récluz 1843, p. 8; *Sigaretus lamarckianus* Récluz 1843, p. 7; *Sigaretus (Naticina) cinctus* Hutton 1885b, p. 318; *Eunaticina cincta*; *Pervisinum dingeldeii* Iredale 1931, p. 216] (Naticidae: Poliniceinae).

Small for family (18-20 mm high), regularly oval, with small, pointed spire and large, long last whorl with evenly rounded anterior; thin and fragile. Inner lip only lightly thickened; umbilicus deep, widely open to relatively narrow, conical, without funicle. Sculpture of many low, wide, square-edged, widely spaced spiral cords, cord surfaces and interspaces equally crowded with fine spiral threads; all crossed by relatively prominent, narrow axial ridges, serrating edges of spiral cords, and raised into prominent axial ridges and folds over last half-whorl of large specimens. Protoconch very low, of about 2 polished, apparently smooth whorls, not clearly differentiated from the teleoconch.

Haweran (-Recent?); Landguard Sand, Landguard Bluff, east of Wanganui River mouth, Haweran (oxygen isotope stage 9) (type of *S. cinctus*); very rare in the Landguard Sand at Wanganui (only the type known?), uncommon (about eight specimens seen) in the Te Piki bed, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7); also one stained Recent(?) specimen recorded from the Bay of Islands (Powell 1979, p. 158) but its status in the Recent fauna is unknown.

No close relationship has been recorded previously between *Eunaticina cincta* and any modern Indo-West Pacific species. Finlay and Marwick (1937, p. 55) pointed out that "*Pervisinum*" *dingeldeii* Iredale, 1931 (Recent, eastern Australia) appears to belong in *Eunaticina*, and comparison of specimens of the New Zealand fossil and Australian living populations (with B.A. Marshall, National Museum of N.Z.) showed that they have identical protoconchs, teleoconch and umbilicus shape, and range of variation in teleoconch sculpture. Kilburn (1976, p. 870) has shown that the earliest name for this species is *Eunaticina linnaeana* (Récluz, 1843), and we adopt this name for the New Zealand species. Modern

specimens occur from Japan and Fiji to Natal and Mozambique. Other Australian (or other warm-water) species that apparently extended their ranges briefly to include New Zealand during Castlecliffian or Haweran times include *Anadara trapezia* (Pl. 44b, e), *Bankivia fasciata*, *Bembicium* of the group of *B. melanostoma*, *Capulus uncinatus* (Pl. 47j, n) and *Opalia* n. sp. (Pl. 47k). Figured specimen (Pl. 47s): GS5833, Y14/f7505, Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7) (NZGS) x 2.

Pl. 47 t. *Globisium drewi* (Murdoch, 1899) [*Sigaretus undulatus* Hutton 1885b, p. 318 (not of Lischke, 1872); *Natica (Ampullina) laevis* Hutton 1885b, p. 317 (not of Weerth, 1884); *Sigaretus drewi* Murdoch 1899, p. 320; *Euspira venusta* Suter 1907b, p. 215; *Globisium wollastoni* Finlay 1927b, p. 500 (new name for *Sigaretus undulatus* Hutton, preoccupied); *Globisium mucronatum* Marwick 1928, p. 481; *Globisium flemingi* Powell 1931a, p. 98]. Type species of *Globisium* Marwick, 1924 (Naticidae: Globisininae).

Moderately large for family (20-45 mm high), almost spherical, with large aperture, very low spire and very thin, fragile shell. Last whorl very large, enclosing almost all of previously formed shell; anterior evenly rounded, without siphonal canal. Inner lip weakly thickened, regularly curved below parietal area; umbilicus closed or at most a very narrow slit. Sculpture of many regular, exceedingly fine, close spiral threads crossed by weak, irregular growth ridges. Protoconch small, of 2.5 whorls, smooth and polished except for weak spiral cords on last quarter-whorl, sharply marked off from teleoconch.

Opoitian-Recent; "Wanganui and Petane" (i.e., Castlecliffian, Wanganui city area, and Nukumaruan, hillside north of Petane Pa, north of Napier, Hawke's Bay, both localities stated for types of both *Sigaretus undulatus* and *Natica laevis*); "Pliocene, sand and blue clay: Wanganui", i.e., type Castlecliffian section west of Wanganui (type of *Sigaretus drewi*); Recent, New Zealand (type of *Euspira venusta*); Tarawhenua Peninsula, Pitt Island, Chatham Islands, Whenuataru Tuff, Waipipian (type of *Globisium mucronatum*); Waipipi shellbeds, Waverley Beach, west of Wanganui, Waipipian (type of *G. flemingi*). *Globisium drewi* is not uncommon today, dredged in 30 m and more on the mid-outer shelf on soft substrates; it is moderately common in the Kai-Iwi siltstone beds (Castlecliffian) west of Wanganui, uncommon at some localities in blue-grey siltstone in Hawke's Bay (Nukumaruan), and rare throughout New Zealand in offshore facies of Pliocene age.

Globisium drewi is easily recognised by its large size, its almost spherical shape, its very thin, fragile shell lacking the prominently thickened inner lip of other Naticidae, and its fine, even spiral sculpture. The surprisingly many synonyms have been based on minor differences in umbilical diameter and sculptural prominence, but all names refer to a single, moderately variable species.

Figured specimen (Pl. 47t): holotype of *Sigaretus drewi* Murdoch, Castlecliff, Wanganui, Castlecliffian (TM6794, NZGS) x 1.

Pl. 47 o. *Tanea zelandica* (Quoy and Gaimard, 1832). [*Natica zelandica* Quoy and Gaimard 1832, p. 237, pl. 66, fig. 11, 12; *Cochlis zelandica*; *Tanea zelandica*]. Type species of *Tanea* Marwick, 1931 (Naticidae: Naticinae).

Moderate-sized for family (25 to 33 mm high), smooth and oval to

subspherical, with low spire, well impressed sutures, and inflated spire whorls. Aperture large, D-shaped, with evenly rounded anterior. The only sculpture is of weak growth lines, weakly retracted to suture. Umbilicus about 0.6-0.8 filled by a large, rounded funicular ridge, ending in a smooth semicircular funicle, leaving a narrow but deep umbilical chink above funicle but only a narrow groove lower down, around ridge; inner lip otherwise weakly callused. Operculum (remaining inside the aperture of a small proportion of Castlecliff fossils, but otherwise rarely found fossil) semicircular, thin, smooth except for weak growth lines and 2 narrow, shallow grooves close to and parallel to outer-lip margin. Protoconch small, low-conical, of 2.5 low, narrow, smooth whorls.

Nukumaruan-Recent; Recent, New Zealand (type). Common throughout New Zealand on sand in shallow water (commonly cast ashore alive on ocean beaches), and an abundant fossil in all shallow-water, soft-bottom facies of Nukumaruan and Castlecliffian age.

Tanea is a typical shell-boring naticid carnivore, drilling bevel-edged holes in a wide variety of bivalves and gastropods, but most commonly in small venerids such as *Tawera*. Evidence of their carnivory is seen in the drill holes in many fossils in the same beds as the *Tanea* shells (not to be confused with the more nearly cylindrical holes drilled by many Muricidae). *Tanea zelandica* is the Pliocene to modern New Zealand representative of a widespread Pacific genus or subgenus, closely related to *Natica* (sensu stricto), differing from *Natica* principally by its distinctive radula and by the two narrow opercular grooves (two much more prominent grooves occur on *Natica* opercula, many prominent ones on *Naticarius*, and most other naticine genera have almost smooth opercula). Modern specimens have a colour pattern of four rows of crescentic or chevron-shaped, dark brown spots on a pale fawn ground, and the spots remain on most Castlecliff fossils. The Miocene *T. consortis* (Pl. 20i) and other pre-Nukumaruan species have lower spires and wider shells than *T. zelandica*, whereas the Pliocene to earliest Castlecliffian *Taniella planisuturalis* (Pl. 41n) differs in its markedly smaller size, its larger funicle, and its somewhat taller spire, with much more weakly impressed sutures and so almost straight spire outlines.

Figured specimen (Pl. 47o): GS1163, R22/f6498, Kai-Iwi siltstone beds, west of Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.

Pl. 48 b. *Galeodea (Galeocorys)* n. sp. (Cassidae: Cassinae).

Moderately large for genus (55 mm high), evenly oval, with low, conic spire, short, straight, open, weakly twisted anterior canal, and no fasciole. Sculpture of many prominent spiral cords, 5 on weakly convex sutural ramp, 1 more prominent than the others around the weak shoulder angle, 2-3 below shoulder on spire, and about 35 below shoulder on last whorl; the upper 4 interspaces below the shoulder each bear 1 intermediate weaker cord; cord at shoulder angle rendered finely nodulous by indistinct growth ridges which are otherwise smooth. Aperture large, oval, wide at anterior, more constricted above; outer lip weakly flared, lightly callused inside, with many low, indistinct, transverse ridges; inner lip rather thin, smooth except for sculpture showing through parietal glaze, narrowly spread over narrow umbilical chink. Protoconch small, mamillate, of 1.5 smooth whorls.

Castlecliffian, Castlecliff, Wanganui (rare, three specimens known, all from Upper Westmere Siltstone); Recent, outer shelf around New Zealand (rare, three or four specimens known).

Galeodea (Galeocorys) n.sp. is not certainly distinct from *G. (Galeocorys) sulcata* (Kapitean-Opoitian, Westland; Waipipian, South Taranaki coast). Westland Kapitean-

Opoitian specimens have a thicker outer lip, slightly wider spiral cords, and nodules continuing further below the periphery (present on four or five cords) than in Castlecliffian-Recent shells, but the single South Taranaki Waipipian shell seen (Ohawe Beach, Hawera, in colln. F. D. Chambers) is more like Castlecliffian than older specimens.

Figured specimen (Pl. 48b): Upper Westmere Siltstone, Kai-Iwi, west of Wanganui, Castlecliffian (NZGS; from a private collection) x 1.

Pl. 48 a. *Semicassis pyrum pyrum* (Lamarck, 1822) [*Cassis pyrum* Lamarck 1822, p. 226; *Cassis nivea* Brazier 1872, p. 616; *Cassis striatus* Hutton 1873b, p. 8 (not of Sowerby, 1812); *Cassis tumida* Petterd 1886, p. 321; *Cassidea turgida* "Reeve" of Hedley 1903, p. 340; *Cassidea stadialis* Hedley 1914, p. 72; *Cassidea multisecta* Finlay 1924a, p. 101 (new name for *C. striatus* Hutton, preoccupied); *Xenogalea finlayi* Iredale 1927, p. 342; *Xenogalea powelli* Finlay 1928b, p. 247; *Xenophalium wanganuiense* Powell 1928b, p. 637; *Xenophalium hamiltoni* Powell 1928b, p. 639; *Xenophalium ericanum* Powell 1928b, p. 639; *Xenophalium harrissonae* Powell 1928b, p. 640; *Xenogalea denda* Cotton 1945, p. 168; *Xenophalium (Xenogalea) matai* Powell 1952, p. 178; *Xenogalea halli* Cotton 1954, p. 2; *Xenophalium (Xenogalea) abernethyi* Dell 1956c, p. 87; *Xenogalea pyrum*; *Xenophalium pyrum*; *Phalium pyrum*]. Type species of *Xenogalea* Iredale, 1927 (= *Semicassis* Mörch, 1852) (Cassidae: Phaliinae).

Large for subfamily (60-100 mm high), evenly oval and inflated, superficially almost smooth, with low spire and short, very strongly twisted anterior canal separated from previous whorl by deep, wide, concave groove, forming a prominent, ridge-margined fasciole. Sculpture of a few shallow grooves on spire in a narrow subsutural zone, and on base; many specimens have nodules around the shoulder angle, and a lower row of nodules is present on a few specimens. Aperture large, oval. Outer lip strongly curved, thick, reflected, with or without low nodules on inner edge; inner lip thick, raised over neck into thick, smooth, free-standing collar; with or without wrinkles and low transverse ridges on lower columellar area. Protoconch moderately large, conical, of 2.5 smooth, inflated whorls.

Nukumaruan-Recent; Recent, Australia (types of *Cassis pyrum*, *C. nivea*, *C. tumida*, *Cassidea stadialis*, *Xenogalea denda*, *Xenogalea halli*); Recent, New Zealand (types of *Xenogalea finlayi*, *X. powelli*, *Xenophalium harrissonae*, *X. hamiltoni*, *X. ericanum*, *X. matai*, *X. abernethyi*); "Wanganui (U); Shakespeare Cliff; Puku-tapu(?)" (Hutton 1873b, p. 8), i.e., upper beds at Castlecliff, Wanganui, and Shakespeare Cliff (in Wanganui city), Castlecliffian (type of *Cassis striatus*, not of Sowerby, = *Cassidea multisecta*) [the "Puku-tapu" locality is unknown to us]; "Wanganui (Upper Pliocene), Castlecliff", i.e., Castlecliff, Wanganui (unspecified horizon), Castlecliffian (type of *Xenophalium wanganuiense*).

Semicassis pyrum pyrum is common around New Zealand today, from shallow water off oceanic sand beach and in large bays, to the outer shelf on soft substrates, and from rises and banks near the Three Kings Islands to the Snares in the south. It also occurs commonly in southern Australia, and weakly differentiated geographic subspecies occur in South Africa and South America. The shell varies markedly in size, shell thickness, colour pattern, spire height, the presence or absence of ridges

inside the outer lip, and the presence or absence of one or two rows of nodules around the shoulder, and the many subtly different, intergrading ecological forms have received many "species" names, but are of no biological significance. It is an uncommon fossil in the Castlecliffian beds near Wanganui, and very rare in Nukumaruan siltstone in central Hawke's Bay and southern Wairarapa. The Castlecliffian fossil *multisecta* form was based on immature specimens with a strongly dentate outer lip and relatively prominent spiral grooves over the entire last whorl, but these are identical to characters of immature modern specimens.

Beu (1976c) showed that some specimens of the Stewart Island cool-water, thick-shelled *harrisonae* form of *S. pyrum pyrum* have intricately wrinkled inner lips as in typical *Semicassis* species. The species arrived abruptly in New Zealand during early Nukumaruan (latest Pliocene) time from the northern hemisphere, and probably from a stock related to the European fossil *S. laevigata* (Serres), and "*Xenophalium*" species are simply weakly sculptured species of *Semicassis*. In our opinion *Semicassis* is a genus distinct from *Phalium*, as it lacks the multiple varices (in all but a few unusual individuals) and complex sculpture, in most species axial or coarsely cancellate, of *Phalium*.

The closely similar *S. labiata labiata* (Te Piki bed, Cape Runaway, Haweran, oxygen isotope stage 7; and living in the north-eastern North Island and south-eastern Australia; again, with weakly differentiated geographic subspecies in South America and South Africa) is smaller, taller and narrower, and more weakly sculptured than *S. pyrum*, with a much narrower groove between the canal and last whorl, and the inner lip is plastered smoothly to the shell rather than raised into a free collar as in *S. pyrum*.

Figured specimen (Pl. 48a): GS4068, R22/f6399, Kaimatira Pumice Sand, Kai-Iwi Beach, west of Castlecliff, Wanganui, Castlecliffian (NZGS) x 1.

Pl. 48 f. *Sassia* (*Sassia*) *parkinsonia* (Perry, 1811) [*Septa parkinsonia* Perry 1811, pl. 14, fig. 1; *Triton fusiformis* Kiener 1842, p. 36; *Cymatium parkinsonianum*; *Austrosassia parkinsoniana*; *Austrotriton parkinsonia*]. Type species of *Austrosassia* Finlay, 1931 (= *Sassia* Bellardi, 1873) (Ranellidae: Cymatiinae).

Small for subgenus (35-55 mm high), finely sculptured, with moderately tall spire and short, open, weakly twisted anterior canal. Whorls inflated, evenly rounded except for a weak shoulder angle. Low, rounded varices each 0.67 whorl. Sculpture of narrow, widely spaced spiral cords and low, narrow, widely spaced axial costae, forming low, rounded nodules at their intersections; whole surface closely covered with narrow, finely gemmate spiral threads. Aperture almost circular, with widely flared lips, bearing a parietal tubercle, and 5 low nodules inside the outer lip. Protoconch moderately large, solid, conical, of 3.5 smooth, inflated whorls.

Haweran-Recent; Recent, unlocalised, probably from south-eastern Australia (type of *Septa parkinsonia*); Recent, "New Holland" (type of *Triton fusiformis*). Uncommon to moderately common on hard substrates from the intertidal zone (rarely) to outer shelf depths around north-eastern North Island today (particularly at the Poor Knight's Islands); also at the Kermadec Islands, Lord Howe Island, Norfolk Island, and in south-eastern Australia (common intertidally on rocks near Sydney);

the single known fossil locality is Te Piki, Cape Runaway, near East Cape (Haweran, oxygen isotope stage 7) where it is the most common ranellid (about 15 specimens seen).

The Pliocene (Opoitian-Nukumaruan) *Sassia pusulosa* differs from *S. parkinsonia* in having much more coarsely gemmate sculpture; the Middle-Late Miocene *S. pahaoensis* (Clifdenian-Tongaporutuan) has more angled whorls, and higher varices that clasp the previous whorl; the Oligocene-Early Miocene *S. maoria* (Pl. 20 o) (Duntroonian-Altonian) has coarser spiral cords, more inflated whorls, and a longer anterior canal. These species have in recent years been included in an endemic Australasian "genus" *Austrosassia*, but there are no significant characters distinguishing them from the very large, cosmopolitan, Late Cretaceous-Recent genus *Sassia*. European fossil species such as *S. formosa* (Deshayes) (Eocene, Paris Basin) are extremely similar to *S. parkinsonia* in size, shape, sculpture (including the many fine surface gemmae), aperture, and protoconch characters.

Figured specimen (Pl. 48f): GS5833, Y14/f7505, Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7, 200 000 years; NZGS) x 1.5.

Pl. 48 d. *Cabestana tabulata* (Menke, 1843) [*Tritonium tabulatum* Menke 1843, p. 25; *Triton waterhousei* A. Adams and Angas 1864, p. 35; *Cabestana debiliior* Finlay 1930b, p. 59; *Cabestana waterhousei segregata* Powell 1933a, p. 156; *Cabestana otagoensis* Powell 1954, p. 236; *Cabestana waterhousei*; *Cymatilesta waterhousei*; *Cymatium waterhousei*] (Ranellidae: Cymatiinae).

Moderately large for genus (65-95 mm high), with moderately tall spire and short to moderately long, open anterior canal; whorls evenly rounded except for a weak shoulder angle, with high, thin varices every 0.67 whorl. Sculpture of low, wide, widely spaced spiral cords, each clearly subdivided by a median groove, with several secondary and tertiary threads in each interspace, crossed by prominent, narrowly crested, widely spaced axial costae on spire whorls, fading to low, rounded nodules on periphery of last whorl; whole surface crossed by obvious, low, closely spaced axial costellae. Aperture oval, with almost smooth lips; outer lip not flared over varix; inner lip with a few nodules on base of columella. Protoconch as in *S. parkinsonia*.

Nukumaruan-Recent; Recent, southern Western Australia (type of *Tritonium tabulatum*); Recent, south-eastern Australia (type of *Triton waterhousei*); Recent, New Zealand (types of *Cabestana waterhousei segregata* and *C. otagoensis*); Castlecliff, Wanganui, Castlecliffian (type of *C. debiliior*). Not uncommon today in the intertidal zone of rocky shores and dredged on hard to soft substrates on the shelf around all of southern Australia (quite common on beaches along the southern coast of Western Australia) and at the Kermadec Islands, Lord Howe Island, and Norfolk Island, but one of the rarest of living Ranellidae around New Zealand (the largest number of specimens has been brought up by the Foveaux Strait oyster dredges). A rare fossil in Nukumaruan blue-grey siltstone in central Hawke's Bay, and in Castlecliffian shellbeds (particularly Pinnacle Sand) near Wanganui; quite common as Castlecliffian fossils eroded from submarine outcrops and cast up on Wellington west coast beaches.

As in all Ranellidae, Recent specimens of *Cabestana tabulata* become taller and narrower with increasing depth of water, and Castlecliff fossils (type locality of *C. debiliior*) can be matched with offshore Recent shells; the

type of *C. otagoensis* is a very elongate specimen dredged in 80 m. *C. manawatuana* is doubtfully distinct; Tongaporutuan-early Nukumaruan specimens reach a larger size and have narrower and more prominent spiral cords and axial costae than *C. tabulata*, but mid-late Nukumaruan shells intergrade. The Castlecliffian-Recent *C. spengleri* is larger, thicker-shelled, shorter, with a shorter siphonal canal, and with lower, wider spiral cords than *C. tabulata*. In Australia, *C. spengleri* occurs only in the south-east, whereas *C. tabulata* occurs in Western Australia as well as in the east.

Many authors have included *Cabestana* Röding, 1798 (type species: *C. cutacea* (Linné, 1758), Recent, Mediterranean and eastern Atlantic) in *Cymatium* Röding, 1798, but *Cymatium* species consistently have a tall, narrow, horny protoconch (reflecting a long-lived planktonic larval life) and a wide, low, central radular tooth, whereas *Cabestana* species resemble *Sassia* in having a short, solid, turbiniform protoconch (reflecting a relatively short larval life) and an equidimensional central radular tooth. In our opinion, *Cabestana* is a valid genus, more nearly related to *Sassia* than to *Cymatium*. Figured specimen (Pl. 48d): GS2189, R22/f6314, Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.

Pl. 48 g. *Cymatium* (*Monoplex*) *parthenopeum parthenopeum* (Salis, 1793) [*Murex costatus* Born 1778, p. 295 (not of Pennant, 1777); *Murex parthenopeus* von Salis 1793, p. 370; *Monoplex australasiae* Perry 1811, pl. 3, fig. 3; *Triton succinctum* Lamarck 1816, "Liste" p. 5; *Triton acclivis* Hutton 1873a, p. 13; see Beu 1970f, p. 229 for full list of the many synonyms]. Type species of *Monoplex* Perry, 1811 (Ranellidae: Cymatiinae).

Large for genus (80-130 mm high), ovate-fusiform, with strongly inflated whorls, moderately tall spire (equal to or slightly shorter than aperture and canal), and moderately long, straight to slightly recurved anterior canal. Whorls weakly angled (at upper third on spire whorls) by uppermost spiral cord. External sculpture dominated by very prominent, rounded, widely spaced spiral cords, 2 major ones on spire whorls and 5 (and a weak sixth) on last whorl; many weak cords on canal and sutural ramp; fine spiral threads cover much of surface, particularly in interspaces of major cords; crossing many low, widely spaced, narrow axial costae that produce weak angles in whorl coiling. Aperture large; outer lip reflected, strongly thickened to form varix, interior bearing 6 pairs of large, short ridges; inner lip coarsely ridged, with 2 ridges on parietal callus and many on columella and left edge of canal. Only a terminal varix present on most specimens, but some have 1 other on last whorl, and a few specimens have varices at each 0.67 whorl. Protoconch small, very fragile (largely horny in life), tall and narrow, of 3.5 smooth, weakly inflated whorls.

Castlecliffian-Recent (New Zealand), Early Miocene to Recent (Northern Hemisphere); several scores of synonyms have been proposed for variants of this almost cosmopolitan species in the Recent fauna, only a few of which are listed here (Mediterranean, types of *Murex costatus* and *M. parthenopeus*; Australia, type of *Triton succinctum*; New Zealand, type of *Triton acclivis*). One fossil specimen from Wellington west coast beaches (NZGS) is assumed to be Castlecliffian, but there are no other Castlecliffian records; fairly common in the Te Piki bed near Cape Runaway (Haweran, oxygen isotope stage 7, 200 000 years B.P.).

Cymatium parthenopeum is common in sheltered rocky environments and on harbour sand flats (in the intertidal zone in early summer, laying eggs) and dredged on the

shelf throughout northern and western New Zealand today. It is very widely distributed in the Mediterranean Sea, the eastern and western Atlantic, South Africa, and Australia. Two very weakly differentiated geographic subspecies extend the range still more widely: *C. parthenopeum echo* (Kuroda and Habe in Kira, 1961) from Oman to southern Japan and Hawaii, and *C. parthenopeum keenae* (Beu, 1970) in tropical western America and the Galapagos Islands. *C. parthenopeum* is easily distinguished from other *Cymatium* (*Monoplex*) species by its small protoconch, its large size, its strongly inflated whorls, its few prominent, widely spaced spiral cords, its heavily armed aperture, and by most specimens having only a terminal varix.

Figured specimen (Pl. 48g): GS5833, Y14/f7505, Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7; NZGS) x 0.67.

Pl. 48 c. *Linatella caudata* (Gmelin, 1791) [*Buccinum caudatum* Gmelin 1791, p. 3471; *Fusus cutaceus* Lamarck 1816, "Liste" p. 6; *Cassidaria cingulata* Lamarck 1822, p. 216; *Fusus voigtii* Anton 1838, p. 77; *Triton undosum* Kiener 1842, p. 44; *Ranularia* (*Lagena*) *rostratus* Mörch 1852, p. 110; *Triton* (*Linatella*) *poulsenii* Mörch 1877, p. 33; *Linatella neptunia* Garrard 1963, p. 43; see Beu and Cernohorsky 1986 for full synonymy]. Type species of *Linatella* Gray, 1857 (Ranellidae: Cymatiinae).

Moderate-sized to large for family (34 to 96 mm high), with moderately tall, weakly stepped spire (0.5-0.66 aperture and canal), strongly inflated whorls, and moderately long, widely open, straight to strongly recurved anterior canal with weak fasciole. Whorls weakly angled (at upper third of whorl height on spire) and with few small nodules around shoulder angle on some specimens; axial sculpture otherwise of faint growth ridges only. Sculpture of many prominent, wide, convex-topped spiral cords, of even width and height and with narrow, flat-bottomed interspaces in most specimens, but variable; some have regularly alternating narrow and wide cords, whereas others have wide cords with only linear interspaces. No varices present; outer lip strongly reflected and only lightly thickened, strongly fluted by spiral cords; inner lip thick, smooth or with low ridges over lower half. Protoconch tall and narrow, of 5.5 weakly convex whorls, smooth, fragile (not seen on fossils).

Castlecliffian-Recent; Recent, unlocalised, or tropical Indo-West Pacific (types of most names listed above); Recent, Caribbean Sea (type of *Triton poulsenii*); Recent, eastern Australia (type of *Linatella neptunia*). This unusual *Tonna*-like ranellid is very widespread (but uncommon) today throughout the Red Sea, the entire Indo-West Pacific province as far north as southern Japan, as far east as Hawaii, and as far south as northern New Zealand, in the western Atlantic from South Carolina to Brazil, and at the Canary and Cape Verde Islands off West Africa. A single Recent specimen has recently been collected in central eastern Northland, New Zealand, washed ashore after severe storms. It seems to live only on soft substrates on the shelf in about 20 to 100 m. This distribution makes it somewhat surprising to find that *L. caudata* is one of the more common Ranellidae (nine specimens examined) at Te Piki, Cape Runaway (Haweran); it occurs also at Ohope Beach, Whakatane (Castlecliffian). These localities are outside its present range and point to the warm climate of the eastern Bay of Plenty at the times when the Ohope and Te Piki faunules lived. It also occurs in Pliocene rocks of the tropical Pacific (Taiwan, Java, Sumatra) and in Zanzibar, East Africa, and in Miocene and Pliocene rocks of the central western Atlantic.

Linatella caudata is easily distinguished from other Ranellidae by its simple spiral sculpture and its lack of varices, and from *Tonna* by its much taller and narrower protoconch, its less inflated shell, its taller spire, and its long anterior canal. Beu and Cernohorsky (1986) discussed the variation, range, synonymy and fossil record of *Linatella* species.

Figured specimen (Pl. 48c): Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7; M49096, National Museum of N.Z.) x 1.

Pl. 49 h. *Coluzea spiralis* (A. Adams, 1856) [*Fusus spiralis* A. Adams 1856a, p. 221; *Fusus pensum* Hutton 1873a, p. 8; *Columbarium suteri* E. A. Smith 1915, p. 87; *Coluzea espinosa* Finlay 1930e, p. 268; *Columbarium (Coluzea) spiralis*] (Turbinellidae: Columbariinae).

Moderately large for subfamily (60-110 mm high), very tall and narrow, with tall spire and very long, narrow, straight anterior canal (equal to height of aperture and spire). Whorls strongly angled at mid-height, with narrow, nodulous keel around shoulder angle, and a few low, narrow, widely spaced spiral cords above and below angle, including several down anterior canal; whole surface crossed by fine axial ridges. Aperture small, quadrate, with simple, unthickened inner and outer lips. Protoconch large and obvious, of 2 smooth whorls, the first low, wide and protruding laterally, the second taller, with a weak median angle.

Nukumaruan-Recent; Recent, New Zealand (types of *Fusus spiralis*, *F. pensum*, *Columbarium suteri*); "Petane, blue clays", i.e., hillside north of Petane Pa, north of Napier, Hawke's Bay, Nukumaruan (type of *Coluzea espinosa*). The most common species and the one living in the shallowest water (about 40-250 m) of the several Recent species of *Coluzea* around New Zealand, but nevertheless an uncommon species, dredged most commonly off the north-eastern North Island, on soft substrates. Uncommon in a few beds of offshore silty sandstone facies at Castlecliff, Wanganui (Castlecliffian; notably in Pinnacle Sand at "the Pinnacles"), and rare

in Nukumaruan siltstone in Wanganui basin, Hawke's Bay, and Wairarapa. Some specimens in Hawke's Bay-Wairarapa Nukumaruan rocks (*C. espinosa*) have smaller peripheral nodules than Castlecliff ones, but this variation can be matched in Recent shells.

The rare Waipipian-Recent *Coluzea mariae* has a much lower, less strongly stepped spire and weaker nodules than *C. spiralis*; the uncommon Waipipian-Mangapanian *C. spectabilis* has more inflated whorls, and much more prominent, coarsely gemmate spiral cords than *C. spiralis*. The most similar (and so presumably ancestral) species is *C. dentata* (Pl. 21h; Otaian-Altonian; similar forms up to Tongaporutuan) which has more prominent, more consistently and evenly spaced spiral cords and more prominent axial folds, and so larger nodules around the keel than those of *C. spiralis*.

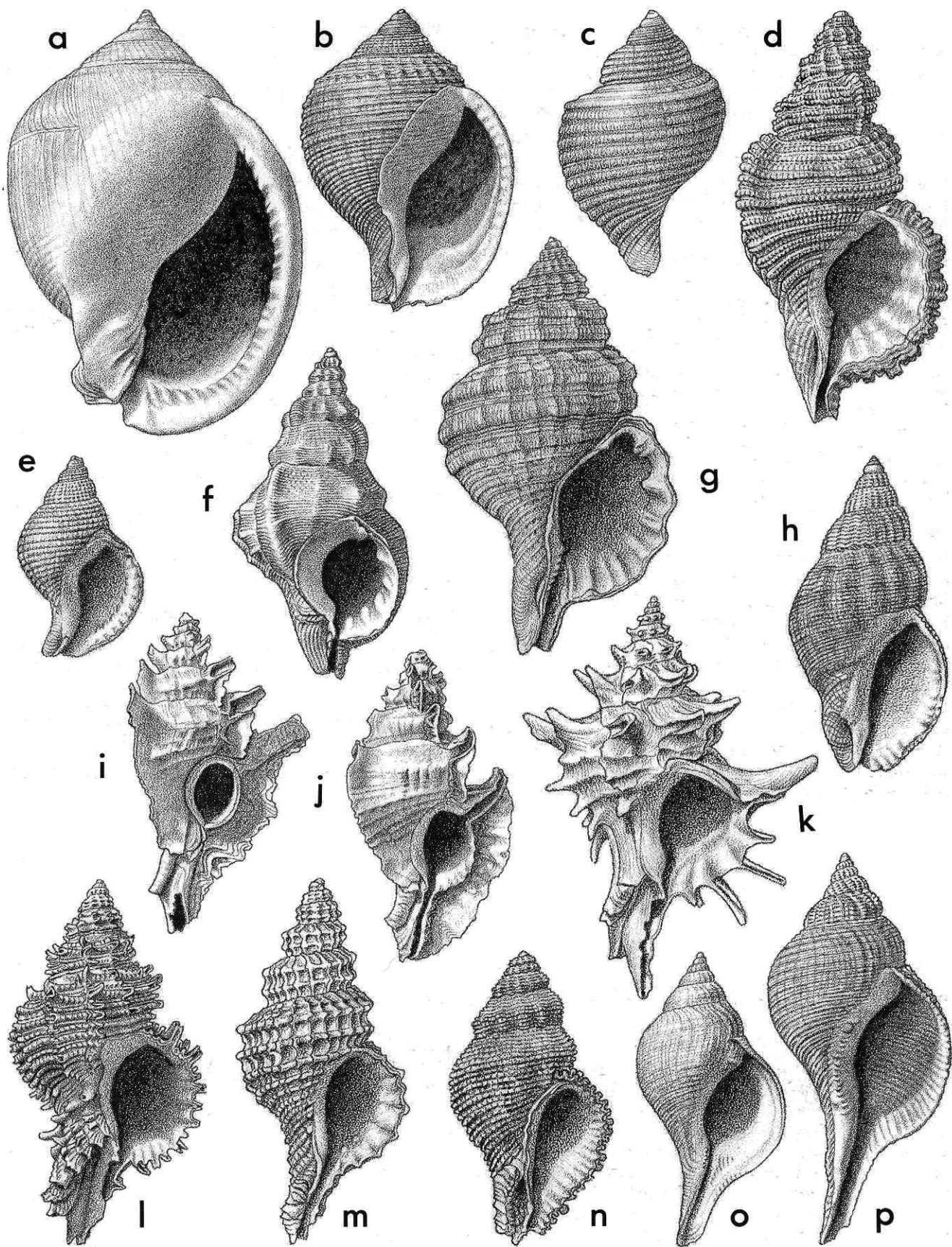
Figured specimen (Pl. 49h): Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.5.

Pl. 48 j. *Pterotyphis (Prototyphis) angasi powelli* (Fleming, 1962) [*Pterynotus (Pterochelus) angasi powelli* Fleming 1962b, p. 114; doubtfully distinct from *Typhis angasi* Crosse 1863, p. 86, *Murex eos* Hutton 1873a, p. 8, and *Pterochelus paupereques* Powell 1974, p. 199; *Pterynotus (Pterochelus) angasi*; *Pterynotus (Pterochelus) eos*]. *Typhis angasi* Crosse is type species of *Prototyphis* Ponder, 1972 (Muricidae: Muricinae?).

Small for family (25-40 mm high), with 3 wide, thin, lamellar varices per whorl, united up spire to form triangular plan. Spire slightly shorter than aperture and canal. Sculpture of several low, indistinct, narrow, widely spaced spiral cords below obvious shoulder angle on last whorl, 4-6 low nodules on shoulder angle in each intervariceal space, long, open, semitubular spine on shoulder of each varix, and thin, lacy frills on anterior (adapertural) face of each varix. Aperture small, oval, with smooth, reflected lips. Fasciole prominent, formed by former anterior canals. Anterior canal moderately long, clearly open. Protoconch of 1.5 smooth whorls, the apex flat or concave, the last half-whorl evenly convex.

Plate 48 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (6).

- a. *Semicassis (Semicassis) pyrum pyrum* (Lamarck), x 1.
- b. *Galeodea (Galeocorys) n.sp.*, x 1.
- c. *Linatella caudata* (Gmelin), x 1.
- d. *Cabestana tabulata* (Menke), x 1.
- e. *Xymene expansus* (Hutton), x 2.
- f. *Sassia (Sassia) parkinsonia* (Perry), x 1.5.
- g. *Cymatium (Monoplex) parthenopeum parthenopeum* (Salis), x 0.67.
- h. *Agnewia kempae* Powell, x 3.
- i. *Pterotyphis (Ponderia) zealandicus* (Hutton), x 2.
- j. *Pterotyphis (Prototyphis) angasi powelli* (Fleming), x 2.
- k. *Poirieria zelandica* (Quoy and Gaimard), x 1.5.
- l. *Murexsul octogonus* (Quoy and Gaimard), x 1.
- m. *Xymene bonneti bonneti* (Cossmann), x 3.
- n. *Coralliophila sertata* (Hedley), x 2.
- o. *Aeneator (Aeneator) delicatulus* Powell, x 1.
- p. *Aeneator (Aeneator) marshalli marshalli* (Murdoch), x 1.



Nukumaruan?; Castlecliffian (-Recent?); Castlecliff, Wanganui, Castlecliffian (type of *P. angasi powelli*); Recent, south-eastern Australia (type of *P. angasi angasi* Crosse); Recent, intertidal, Bay of Islands, north-eastern New Zealand (type of *P. angasi eos*); Recent, 9-18 m, Poor Knights Islands, north-eastern New Zealand (type of *P. paupereques*). *P. angasi* is rather rare today beneath large boulders and in rock crevices from low tide to about 30 m, throughout the north-eastern North Island from at least Doubtless Bay to Whangarei Heads (and probably to East Cape). It is also a moderately common living species in New South Wales, and uncommon in Victoria.

Fleming (1962) divided "*Pterynotus*" *angasi* into three subspecies—the Castlecliffian fossil *P. angasi powelli*, the New Zealand living *P. angasi eos*, and the Australian living *P. angasi angasi*—and Powell (1974) named the New Zealand subtidal, long-spined, spirally striped form as the "species" *P. paupereques*. However, examination of a much larger range of material than was available to Fleming or Powell showed that all these forms are highly variable in colour, size, sculpture, and length of spines, and even the "species" *P. paupereques* appears likely to be part of the variation of *P. angasi*. The species needs further study, but it seems likely that all these names are synonyms.

Fossils are uncommon at Castlecliff in several beds; most recently collected specimens are from Pinnacle Sand at "the Pinnacles". Fleming (1962) recorded a single poorly preserved Nukumaruan example from Wanganui. Three specimens from Devil's Elbow, Hawke's Bay (Nukumaruan), in off-shore siltstone, may belong in this species, but are at least twice as large as modern *P. angasi* specimens we have seen, and have a long shoulder spine; they are intermediate in many ways between *P. angasi* and species included in *Pterynotus* (*Pterochelus*). The Altonian *P. awamoanus* is smaller, has more numerous shoulder nodules, and has a more inflated protoconch than *P. angasi*.

The occurrence of *P. angasi* in Wanganui Castlecliffian beds from at least Kupe Formation to Pinnacle Sand is a further indication of the relatively warm temperatures at Wanganui during the time of deposition of these formations.

Figured specimen (Pl. 48j): holotype of *P. angasi powelli*, Castlecliff, Wanganui, Castlecliffian (TM3115, NZGS) x 2.

Pl. 48 i. *Pterotyphis* (*Ponderia*) *zealandicus* (Hutton, 1873) [*Typhis zealandica* Hutton 1873b, p. 2; *Murex angasi* of Suter, not of Crosse; *Pterynotus* (*Pterochelus*) *zealandicus*; *Ponderia zealandica*]. Type species of *Ponderia* Houart, 1986 (Muricidae: Muricinae?).

Small for family (25-35 mm high), similar in size and most other characters to *P. angasi* (see above), but with more prominent nodules on shoulder angle, longer closed, completely tubular shoulder spines on varices, closed, tubular anterior canal, and so aperture a complete oval with raised, thickened, continuous peristome, not interrupted by anterior and posterior canals as in *P. angasi*. Modern specimens cream or white, not brightly coloured as in *P. angasi*. Protoconch as in *P. angasi*, but with flat rather than concave apex.

Castlecliffian-Recent; "Shakespeare Cliff, Wanganui", Castlecliffian (type), certainly from Tainui Shellbed, the sole formation where it has been collected subsequently at Wanganui. Uncommon but consistently collected in

Tainui Shellbed, rare living in Cook Strait and off East Cape, in c. 70-100 m. Tainui Shellbed is an off-shore, current-swept shell accumulation, probably representing a succession of minor "hard-ground" environments (oysters and *Barbatia* are common here, only, among Castlecliff formations, and the shellbed was known to early collectors as "the oyster bed") and the shelly "lag gravel" environment appears to have been similar to those in which living specimens of *P. zealandica* have been dredged.

Although *Pterotyphis zealandicus* has previously been considered closely related to *P. angasi*, Houart (1986) pointed out that the long, closed shoulder tube and anterior canal show that this belongs in a different species group, for which he provided the generic group name *Ponderia*. The relationship to *Prototyphis* needs further study.

Figured specimen (Pl. 48i): specimen figured by Fleming (1962b, pl. 1, fig. 16), Tainui Shellbed, Castlecliff, Castlecliffian (TM3117, NZGS) x 2.

Pl. 48 k. *Poirieria zealandica* (Quoy and Gaimard, 1833) [*Murex zealandicus* Quoy and Gaimard 1833, p. 529]. Type species of *Poirieria* Jousseaume, 1880 (Muricidae: Muricinae).

Moderately large for family (40-65 mm high), prominently spinous, with thin shell, low to moderately tall spire (a little shorter than aperture and canal), moderately long, open, curved anterior canal, and relatively short, rounded whorls. Sculpture of several long, semitubular, open spines only; longest spines (up to 40 mm long) at shoulder angle; on last whorl 3 or 4 lower rows of shorter, semitubular spines formed as digitations in the thin, flared outer lip; shoulder spine and 1 small lower one visible on spire whorls. The only other sculpture is a prominent fasciole formed as a spiral row of former long anterior canals. Protoconch mamillate, of 2 bulbous whorls with a large apex, ending in a sinuous varix.

Opoitian-Recent; Recent, New Zealand (type). A common fossil in many soft-bottom shelf facies in New Zealand Pliocene and Pleistocene localities, and particularly common and well preserved at Castlecliff, Wanganui; common today, dredged on the shelf all around New Zealand in c. 20-200 m.

Species of *Poirieria* were revised by Maxwell (1971). *P. primigena* (Bortonian-Kaiatan?; Duntroonian-Opoitian) is similar to (and was presumably ancestral to) *P. zealandica*, differing in its consistently shorter spire, on which the first row of small spines below the shoulder (visible on *P. zealandica*) cannot be seen. *P. parva* (Otaian-Altonian localities in Northland: Pakaurangi Point and Parengarenga Harbour) is small (largest 28 mm high), with more prominent secondary spines and a thicker and more reflected outer lip than *P. zealandica*, and with a small but subcylindrical protoconch of 2.5 smooth whorls. The other three named species belong in a distinct species group, having weak secondary spines, or no spines below the shoulder: *P. kopua* Dell, a very small (to 20 mm high) modern bathyal species lacking secondary spines; *P. delli* (Pl. 20p), a large, solid species with a low spire, only five large peripheral spines and a mamillate protoconch of two whorls, uncommon at several Waitakian-Altonian localities in North Otago (Oamaru and Waitaki Valley); and *P. denticulifera*, a small species (also up to 20 mm high) similar to *P. delli* but with a single row of secondary spines, a denticulate outer lip, and a

tall, narrowly conical protoconch of four whorls, occurring at Bortonian to early Whaingaroan (Middle Eocene to Early Oligocene) localities in North Otago and South Canterbury. A possibly distinct species similar to *P. delli* is recorded from Hurupi Stream, Palliser Bay (Tongaporutuan). *Poirieria* therefore constitutes one of the better-known groups of New Zealand Cenozoic Mollusca.

Figured specimen (Pl. 48k): Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.5.

Pl. 48 l. *Murexsul octogonus* (Quoy and Gaimard, 1833) [*Murex octogonus* Quoy and Gaimard 1833, p. 531; *Murex peruvianus* Sowerby 1841 (in 1832-1841), pl. 195, fig. 103; *Murexsul cuvierensis* Finlay 1927a, p. 487; *Muricopsis octogonus*]. Type species of *Murexsul* Iredale, 1915 (Muricidae: Muricinae).

Moderately large for family (40-70 mm high), with moderately tall spire (about equal to aperture and canal), moderately long, open anterior canal, and large oval aperture, with lips smooth except for spinous digitations of the outer lip. Sculpture of many closely spaced, rounded, prominent, finely scaly spiral cords, each interspace filled by 1 narrow secondary cord; major cords raised into short to moderately long, backward- or upward-directed, semitubular spines where they cross thin, frilly varices; varices spaced regularly around whorls, 8-10 per whorl on large shells, producing roughly octagonal outline in plan view. Base of canal bears 2 or 3 rows of longer spines; fasciole very prominent, formed of a spiral row of many former anterior canals, producing a deep pseudumbilicus on large shells. Protoconch of 1.5 whorls, with flattened apex and margining keel, last half-whorl evenly convex.

Castlecliffian-Recent; Recent, New Zealand (types of *M. octogonus*, *M. peruvianus*, and *M. cuvierensis*). (*Murex peruvianus* Sowerby has been added to the synonymy on the authority of Vokes (1970b, p. 327) who pointed out that the name is preoccupied). Uncommon at only a few Castlecliffian fossil localities (notably the basal shellbed member of Shakespeare Cliff Sand at Wanganui, but found occasionally in Pinnacle Sand, Upper Castlecliff Shellbed, and Tainui Shellbed) and its ancestry is obscure. *M. octogonus* is common subtidally (commonly dredged on the inner-mid shelf around much of New Zealand) and occurs on intertidal rocks in a few localities in the north-eastern North Island, from Auckland to Doubtless Bay.

The most similar fossil species is *Murexsul marwicki* (Long Beach Shellbed, Clifden, Southland, late Altonian), which has the same pattern of spination as *M. octogonus*, with two coarsely spinose cords around the neck, but has weaker spiral cords and so shorter spines on the varices. Most other named fossils referred here may not be closely related. *M. espinosus* (Mangapanian-Nukumaruan; ? = *M. dilucidus*, Opoitian) differs from *M. octogonus* in its smaller size, its much weaker sculpture without obvious spines, and in having a smoothly rounded (not flattened and keeled) protoconch apex; it is moderately common in Nukumaruan siltstone in Hawke's Bay and Wairarapa. The living Northland intertidal species(?) *M. mariae* is similar to *M. espinosus*, but has a smaller protoconch; their relationship needs further study. *M. mariae* occurs fossil with *M. octogonus* in the young (Haweran, oxygen isotope stage 5a) cover beds of Hauriri Terrace, at the mouth of Wairoa Stream, Waverley Beach, west of Wanganui (where *Lorica haurakiensis* is also common; see above), indicating that the temperature at Wanganui was higher when the terrace cover was deposited than it is at present.

Ponder (1972b, p. 237) synonymised *Murexsul* Iredale, 1915 with *Muricopsis* Bucquoy, Dautzenberg and Dollfus, 1882, but most muricid taxonomists since have regarded these as distinct genera, and Radwin and D'Attilio (1976) placed them in distinct subfamilies (*Murexsul* in Muricinae, *Muricopsis* in Muricopsinae). Vokes (1971a) clearly treated *Murexsul* and *Muricopsis* as distinct genera in her catalogue of the Muricidae, and has since (e.g., Vokes and Houart 1986, p. 86, 87; see particularly the statement by Vokes 1988, p. 36) consistently maintained them as distinct genera. We agree with this action.

Figured specimen (Pl. 48l): GS4185, R22/f6502, Upper Castlecliff Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS) x 1.

Pl. 48 m. *Xymene bonneti bonneti* (Cossmann, 1903) [*Trophon stangeri* Hutton 1893, p. 38, not of Gray, 1843; *Trophon (Trophonopsis) bonneti* Cossmann 1903, p. 200; *Zeatrophon bonneti*] (Muricidae: Trophoninae).

Small for family (18-27 mm high), narrowly fusiform, with moderately tall spire (equal to aperture and canal), and moderately long, open anterior canal; very crisply sculptured. Aperture oval, with weakly reflected lips, indented inside outer lip by spiral cords on exterior. Sculpture of prominent, narrow spiral cords of rounded section, 2 on spire whorls and about 12 on last whorl, the uppermost 3 more widely spaced than remainder; all crossed by many high, thin, regularly spaced, weakly frilled axial lamellae, forming weak nodules or spines at intersections on some specimens; the uppermost spiral cord is the most prominent sculpture, and forms a sharply protruding shoulder angle and a narrow, flat, gently sloping sutural ramp. Protoconch conical, of 3 whorls, smooth except for prominent median carina on last whorl.

Nukumaruan(?); Castlecliffian. "Wanganui, New Zealand", Castlecliffian (type); moderately common in shelf siltstone facies (Kai-Iwi siltstone beds, Tainui Shellbed) at Wanganui (Castlecliffian), recorded rarely from a number of other localities in siltstone of Castlecliffian and (somewhat doubtfully) late Nukumaruan age, in Wanganui and Hawke's Bay.

Ponder (1972) regarded the Altonian-Nukumaruan *Xymene bonneti lassus* as a subspecies intergrading with *X. bonneti bonneti* in Nukumaruan rocks and differing from *X. bonneti bonneti* in its lower spire, its weaker shoulder cord, and its more prominent secondary axial and spiral sculpture. The living *X. mortenseni caudatinus* Finlay is also similar, differing from *X. bonneti bonneti* in its weaker shoulder cord, its more complex, frilled axial lamellae, and in consistently having a secondary spiral cord in each spiral interspace; unlike *X. bonneti lassus*, the spire is as high as in *X. bonneti bonneti*. Readers are referred to Ponder's (1972a) revision of *Xymene* and its relatives for details of other fossil and living species (see also *X. expansus*, Pl. 48e; *X. n. sp. aff. lepidus*, Pl. 20n), but it should be noted the some taxonomists do not accept Ponder's inclusion of several distinct teleoconch types in the one genus *Xymene*, nor do they accept all of his conclusions regarding the content of species in the genus.

Xymene bonneti washes ashore on Wellington west coast beaches (particularly at Waikanae River mouth) but the specimens are opaque and stained fawn or grey, and are undoubtedly among the many Castlecliffian fossils to be found there.

Figured specimen (Pl. 48m): Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 3.

Pl. 48 e. *Xymene expansus* (Hutton, 1883) [*Trophon*

expansus Hutton 1883c, p. 410; *Cominella drewi* Hutton 1883c, p. 410] (Muricidae: Trophoninae).

Small for family (18-23 mm high), relatively short and wide, with moderately tall spire (slightly shorter than aperture and canal), evenly and gently inflated whorls, short, widely open anterior canal directed to left, no obvious fasciole, and a large oval aperture with lips reflected and lightly to moderately thickened; interior of outer lip bearing a row of low, rounded nodules. Sculpture of low, wide, flat-topped to weakly rounded spiral cords, 4-7 (5 or 6 on most specimens) on spire whorls and about 15 to 20 on last whorl and canal, without obvious shoulder angle or nodules, all rendered weakly and evenly gemmate by many low, closely spaced axial ridges. Protoconch low, dome-shaped, of about 1.5 smooth whorls. Outer lip widely expanded in large specimens.

Late Nukumaruan-Castlecliffian; Castlecliff, Wanganui, Castlecliffian (types of both *Trophon expansus* and *Cominella drewi*); common in very shallow-water, near-shore facies (sand and shellbeds) at Castlecliff, Wanganui (Castlecliffian) and at Nukumar, Wanganui and in central and southern Hawke's Bay (Nukumaruan).

Xymene expansus is a distinctive and biostratigraphically useful species similar to and occurring sympatrically with Castlecliffian-Recent *X. plebeius*. It is easily distinguished from *X. plebeius* by its evenly rounded whorls (few specimens develop the prominent shoulder of *X. plebeius*) and its more numerous, lower and more closely spaced spiral cords (four to seven on penultimate whorl in *X. expansus*, two to three on *X. plebeius*). Small shells are weakly inflated and shaped like *X. plebeius*, but large adults develop a much more strongly expanded outer lip than small shells, and the outer lip interior is only lightly thickened, and bears a row of short transverse ridges. *X. expansus* was probably restricted to bouldery shores in estuarine and semiestuarine environments (as is *X. plebeius* now). *X. plebeius* occurs as two "subspecies" (Ponder 1972a), the older *X. plebeius moniliferus* (= *pulcherrimus* Suter, 1917; = *cocor* Marwick, 1948; Waiau-Nukumaruan) with three to five heavy spiral costae on spire whorls, and with prominent, widely spaced axial cords and a strongly lirate aperture, and the younger *X. plebeius plebeius* (= *inferus* Hutton) with weaker sculpture, particularly the narrower spiral cords. As first revisers, we select the name *Xymene expansus* as the name for the species named both *Trophon expansus* and *Cominella drewi* by Hutton (1883c).

Figured specimen (Pl. 48e): GS1163, R22/f6498, Kai-Iwi Beach (Kaimatira Pumice Sand?), west of Wanganui, Castlecliffian (NZGS) x 2.

Pl. 48 h. *Agnewia kempae* Powell, 1934 [p. 273] (Muricidae: Thaidinae).

Small for family (18-21 mm high), moderately elongate, with spire about equal in height to aperture and canal; whorls evenly and rather strongly convex, apart from a shallowly concave sutural ramp that is weak on early spire whorls and becomes more prominent on last whorl. Anterior canal short, straight, widely open, bordered by low, rounded fasciole with central hollow filled by smooth, thick area of inner lip. External sculpture of low, rounded, weak, indistinct axial folds, on most specimens fading out before last whorl, crossed by about 5 low, rounded, spiral cords on spire whorls, but again fading out before last whorl; whole surface crossed by many narrow, well raised, prominent, finely scaly spiral threads, about 5-6 on crests of each spiral cord where cords are present, but only threads remaining on last whorl of most specimens; a single low, rounded, basal cord on all specimens is generated by a protruding nodule near base of outer lip. Aperture smooth, simple. Protoconch large, bulbous, conical, of 4 smooth, polished whorls, as in the living *A. tritoniformis* (Blainville).

Haweran; Te Piki, Cape Runaway, near East Cape,

Haweran (oxygen isotope stage 7, 200 000 years B.P.) (type, and only locality), moderately common (about 10 specimens seen) in siltstone with a mixed semiestuarine to inner shelf faunule.

Agnewia kempae differs consistently from the living *A. tritoniformis* in having weaker axial folds and wide spiral cords, fading out before the last whorl (whereas they are consistently present on the last whorl in *A. tritoniformis*) and in therefore showing prominently the raised basal spiral cord. A few specimens of *A. tritoniformis* have a distinct basal cord but the protruding nodule on the outer lip of *A. kempae* has not been seen on *A. tritoniformis*. The fossils are consistently buff-brown in colour and the living specimens have a translucent yellowish buff exterior, suggesting that an outer calcitic layer is present in both species. *A. tritoniformis* is common in the intertidal zone in New South Wales but is less commonly taken by SCUBA divers in a few metres in Victoria and in northern New Zealand (notably at Cape Karikari), always in very exposed rocky situations; rarely found as far south as East Cape. The presence of *Agnewia* at Te Piki is therefore further convincing evidence for a warm climate at the time of deposition. The presence of *A. kempae* at Te Piki presumably also implies that *Agnewia* dispersed from eastern Australia to New Zealand briefly during oxygen isotope stage 7 (an interglacial period) but became genetically isolated, and so evolved into a distinct species; the occurrence of *A. tritoniformis* in New Zealand at present therefore presumably results from a later dispersal, during the present interglacial.

Figured specimen (Pl. 48h): Te Piki, Cape Runaway, Haweran (oxygen isotope stage 7) (NZGS, from a private collection) x 3.

Pl. 48 n. *Coralliophila sertata* (Hedley, 1903) [*Purpura sertata* Hedley 1903, p. 382; *Murexsul tepikiensis* Powell 1934, p. 272; *Liniaxis sertata*] (Muricidae: Coralliophilinae).

Small for subfamily (18-26 mm high), biconical, with moderately tall, gradate spire about equal in height to aperture and canal; whorls weakly to quite strongly angled at or slightly below centre on spire, angulation persisting as moderate or weakening shoulder on last whorl. Anterior canal open, moderate in length, margined on left by wide pseudumbilicus, bordered by prominent, rounded fasciolar ridge bearing large, scale-like remnants of former anterior canals. External sculpture of a few low, rounded, indistinct, axial folds crossed by many wide, high, rounded, closely spaced, coarsely scaly spiral cords; scales closely overlapping in cone-in-cone manner. Aperture smooth and simple except for outer lip, which is digitated around rim by protruding spiral cords. Protoconch not seen.

Haweran-Recent; Recent, off New South Wales, Australia (type of *Purpura sertata*); Te Piki, Cape Runaway, near East Cape, Haweran (type of *Murexsul tepikiensis*).

Powell (1934) named a specimen of *Coralliophila sertata* from Te Piki, Cape Runaway, as a species of *Murexsul* (Muricidae: Muricinae) but the one subsequently collected specimen we are aware of (illustrated) has the coarsely scaly sculpture typical of Muricidae Coralliophilinae, a subfamily living on corals of various types, feeding suctorially, and differing from most other muricids in lacking a radula. Comparison with the modern *C. sertata* showed no differences.

Laseron (1955) discussed the confusion over the identity of the juvenile holotype of *Purpura sertata* Hedley, and

provided the genus *Tolema* for the large, spinose species previously confused with the adult of *P. sertata*. He thought that, although Iredale (1929, p.348) had placed species very closely similar to *P. sertata* in *Coralliophila*, *Coralliophila* was an inappropriate location because it is a tropical inhabitant of shallow-water coral reefs, "frequently developing a stem clasping habit". He therefore, proposed the genus *Liniaxis* for *Purpura sertata* and similar species (type: *L. elongata* Laseron, 1955, Recent, New South Wales). However, comparison of *L. sertata* with the smaller, scaly, tropical *Coralliophila* species (e.g. *C. rubrococcinea* Melvill and Standen, 1901) showed no significant differences. As "*Liniaxis*" *sertata* appears to be an obligate coelenterate grazer (all live material taken in New Zealand waters was found in cavities and crevices in the stems of antipatharian "black coral trees"; pers. comm. B.A. Marshall, National Museum of N.Z.) there appear to be no morphological or ecological objections to simply regarding *Liniaxis* as a synonym of *Coralliophila*. As *C. sertata* has been collected only from antipatharian corals in 60-200 m of water around northern New Zealand and off New South Wales today, it makes an ecologically interesting and rather surprising addition to the Te Piki fauna. *Murexsul lividorupis* (Otaian, Bluecliffs, South Canterbury), which was referred to *Liniaxis* by Maxwell (1971, p. 774), is also included here in *Coralliophila*.

Kosuge and Suzuki (1985, p. 49) included "*Murex*" *sertata* in a list of species removed from relationship with *Latiaxis* (transferred to Muricidae Thaidinae), but the coarsely scaly sculpture and the habitat on antipatharian corals confirm a position in Muricidae Coralliophilinae.

Figured specimen (Pl. 48n): Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7) (M74651, National Museum of N.Z.) x 2.

Pl. 48 p. *Aeneator marshalli marshalli* (Murdoch, 1924) [*Verconella marshalli* Murdoch 1924, p. 159; *Aeneator drewi* Fleming 1943, p. 200 (a monstrosity); probably = the Recent *A. marshalli separabilis* Dell 1956c, p. 98]. Type species of *Aeneator* Finlay, 1926 (Buccinidae).

Large for genus (60-80 mm high), with moderately tall spire and long, straight anterior canal, evenly and strongly inflated whorls, broad, shallow sinus in outer lip over sutural ramp, and anteriorly expanded, lightly thickened outer lip with many long, narrow ridges inside. Spiral sculpture of many narrow, close primary cords with several intermediate threads in each interspace, crossed by low, rounded axial costae on spire whorls, fading out before last whorl of large shells. Aperture large, oval; inner lip with 1 or 2 low ridges on parietal swelling, and (in large shells) many low nodules along left edge of columellar lip. Protoconch dome-shaped, relatively small, of 2.5 smooth, inflated whorls, with low costae on last half-whorl.

Nukumaruan-Castlecliffian (-Recent?); Castlecliff, Wanganui, Castlecliffian (types of *Verconella marshalli* and *Aeneator drewi*); Recent, Ohope Beach, Whakatane (type of *A. marshalli separabilis*). A common fossil in offshore siltstone facies, deposited in mid-outer shelf depths, in Wanganui basin, Hawke's Bay, Wairarapa, and North Canterbury.

The modern form named *Aeneator marshalli separabilis* by Dell (1956c, p. 98) differs from typical Castlecliff fossils of *A. marshalli* only in its shorter spire and sparser, more prominent axial costae. Too few modern specimens are known to be able to evaluate its status, but it is certainly

closely similar to the short, costate form of *A. marshalli* found in late Nukumaruan siltstone in central Hawke's Bay, and even the modern species(?) *A. otagoensis* Finlay is conceivably part of the variation of *A. marshalli*. The protoconch is much smaller than in the similar genus *Penion*. The holotype of *A. drewi* is a specimen of *A. marshalli* with irregular growth following a healed injury. The restricted early Castlecliffian species *A. delicatulus* (below) has much finer spiral sculpture than *A. marshalli*; the Castlecliffian-Recent species(?) *A. attenuatus* differs mainly in its taller spire, and seems likely to be part of the variation of *A. marshalli*; the early Nukumaruan species *A. imperator* (Wairarapa—North Canterbury) has much coarser spiral and axial sculpture than *A. marshalli*. Figured specimen (Pl. 48p): Murdoch's (1924) figured syntype, "blue sandy clays, Castlecliff", Wanganui, Castlecliffian (TM6837, NZGS) x 1.

Pl. 48 o. *Aeneator delicatulus* Powell, 1929 [p. 91] (Buccinidae).

Moderately large for genus (42-68 mm high), with relatively low spire (0.4 height of aperture and canal) with lightly concave outlines, weakly concave sutural ramp but whorls otherwise evenly and strongly convex, last whorl contracting strongly to moderately long, almost straight, widely open canal directed slightly to left. Sculpture of very many, exceedingly fine, closely spaced spiral threads, 20 to 25 on penultimate whorl and at least 100 on last whorl and canal, poorly defined on some specimens; the only axial sculpture is faint growth ridges. Aperture large, oval; outer lip almost smooth, faintly flared, with wide, shallow sinus over shoulder and sutural ramp; a tall, narrow posterior canal at top of aperture; inner lip thin except for low parietal callus bearing 2 narrow ridges, and irregular nodes and ridges down columella and particularly on basal columellar angle. Protoconch as in *A. marshalli*.

Early Castlecliffian only; "between Kai Iwi and Okehu", Castlecliff section, west of Wanganui, Castlecliffian (type). A beautiful shell, restricted to lower beds of the type Castlecliffian sequence at Wanganui, occurring in the Lower Kai-Iwi Siltstone and Upper and Lower Okehu Siltstone, but most commonly collected from Omapu Shellbed (Fleming 1953); all occurrences are in offshore siltstone deposited in about 40-60 m of water.

Aeneator delicatulus is similar to *A. marshalli* (above) in shape, size, and protoconch, differing in its slightly lower spire, its deeper sinus in the shoulder of the outer lip, its wider aperture, and its exceedingly fine sculpture.

Figured specimen (Pl. 48o): GS10909, R22/f6391B, Omapu Shellbed, east of Kai-Iwi Beach, Castlecliff coast west of Wanganui, Castlecliffian (NZGS) x 1.

Pl. 49 a. *Penion sulcatus* (Lamarck, 1816) [*Fusus sulcatus* Lamarck 1816, pl. 424, fig. 3, "Liste", p. 6; *Fusus dilatatus* Quoy and Gaimard 1833, p. 498; *Fusus zelandicus* Quoy and Gaimard 1833, p. 500; *Fusus adustus* Philippi 1845 (in 1845-1847), p. 21; *Verconella adusta mandarinoides* Powell 1927b, p. 558; *Verconella accipitris* Finlay 1930b, p. 68; *Verconella allani* Finlay 1930b, p. 71; *Verconella falsa* Finlay 1930b, p. 71; *Austrosipho (Verconella) edita* Powell 1934, p. 271; *Verconella adpressa* Powell 1947a, p. 168; *Siphonalia mandarina* of Suter 1913c, p. 370 (not of Duclos, 1831)]. Type species of *Penion* Fischer, 1884, and of *Verconella* Iredale, 1914 (Buccinidae).

Large for family (120-170 mm high), tall and narrow, with spire slightly shorter than aperture and long, narrow, weakly twisted and recurved, widely open anterior canal. Whorls evenly convex to strongly angled (angled medially on spire whorls), with or without large, antero-posteriorly compressed nodules (present on shoulder angle of angled

specimens only; highly variable). Sculpture of many prominent spiral cords, highly variable in size, number and spacing, 1 large, high one and 1 low, narrow one alternating regularly on many specimens. Low fasciole and very shallow pseudumbilicus present on most large shells. Aperture large, oval, lips smooth and simple, with low parietal callus pad. Protoconch large (3-4 mm high), subcylindrical, of 2.5-3 smooth, weakly inflated whorls, with bluntly rounded apex.

Mangapanian-Recent. Recent, New Zealand (types of *Fusus sulcatus*, *F. dilatatus*, *F. zelandicus*, *F. adustus*, *Verconella adusta*, *mandarinoides*, *V. adpressa*); Castlecliff, Wanganui, Castlecliffian (type of *V. falsa*); Okauawa Stream, Kereru Road, central Hawke's Bay (type of *V. accipitris*); Nukumarū, "papa band", i.e., probably Tewkesbury Formation, Nukumarū Beach, west of Wanganui, Nukumaruan (type of *V. allani*); Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7) (type of *Austrosipho edita*).

Powell (1927b, 1947a) accepted relatively little variation in *Penion* species and named several forms as species that we consider to be sculptural variants of one species, although recently (Powell 1979) he listed the same names as we have (based on Recent specimens) as synonyms of *P. sulcatus*. Finlay (1930b) similarly named several fossil forms that in our opinion are merely part of the variation of *P. sulcatus*. *Penion* has a large, heavy embryonic shell (several in each large, horny egg capsule) and direct development, producing subtle genetic differences between populations around the country, but there is no evidence that the variation is regular in any geographic pattern. Ponder (1973, p. 416) showed that *P. mandarina* (Duclos) applies to an Australian species, and the earliest name for the New Zealand one is *P. sulcatus* (Lamarck); he later (Ponder 1975) illustrated the holotype of *P. dilatatus* showing that this name applies to the nodulose, *adustus* form of *P. sulcatus*. He therefore selected *P. cuvierianus* as the name for the species previously known as *P. dilatatus*. *P. cuvierianus* reaches a considerably larger size than *P. sulcatus* (to at least 250 mm high), has

a thinner and more elongate shell, consistently finer spiral sculpture (although the extremes of the two species overlap), biangled nodules around the periphery on the most common, coarsely nodulous form (biangled nodules are rare in *P. sulcatus*), and a taller protoconch of 3.5-4 whorls. It seems likely that *P. cuvierianus* has a similar range of sculptural variation to *P. sulcatus*, and that *P. ormesi* (Powell) is based on specimens of *P. cuvierianus* lacking shoulder nodules. *Penion* includes the common large buccinid "whelks" of the New Zealand area, and *P. sulcatus* is common from intertidal to outer shelf depths on a variety of hard to soft substrates, whereas *P. cuvierianus* occurs only on soft substrates on the continental shelf. Fossils of *P. sulcatus* are common at Castlecliff (particularly small specimens, in Tainui Shellbed) and are easily distinguished from *Buccinulum*, *Aeneator* and *Glaphyrina* species by their much larger, subcylindrical protoconch; *P. cuvierianus* is much less common as a fossil.

Figured specimen (Pl. 49a): Te Piki, Cape Runaway, near East Cape, Haweran (oxygen isotope stage 7, 200 000 years B.P.) (M49092, National Museum of N.Z.), a topotype of the form named *P. edita* by Powell (1934), x 1.

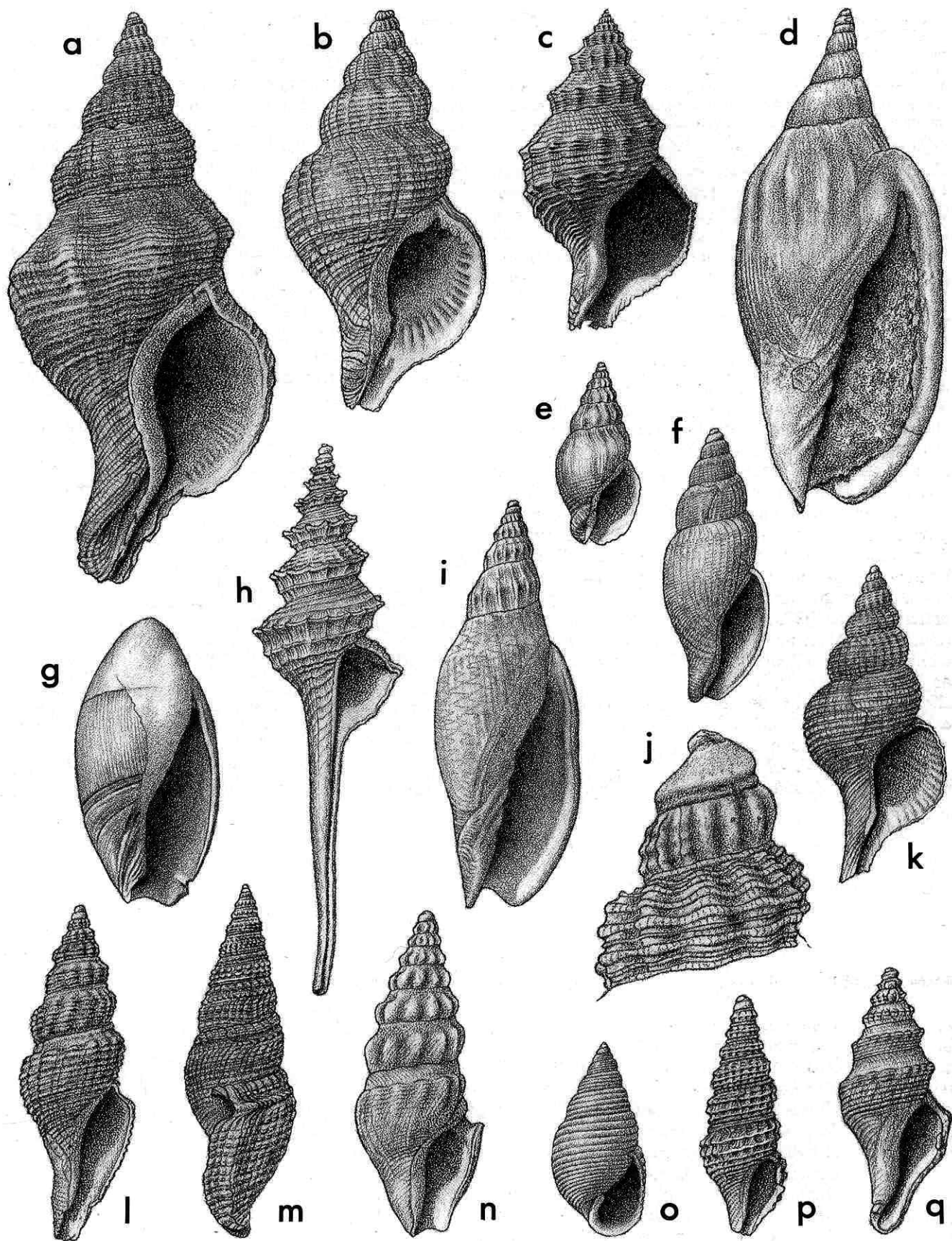
Pl. 49 b. *Buccinulum caudatum* Powell, 1929 [p. 75] (Buccinidae).

Large for genus (35-55 mm high), moderately tall and narrow, with well rounded whorls, moderately tall spire and moderately long, only weakly bent canal without fasciole; sutural ramp weakly to quite strongly concave. Sculpture of many low, wide, closely spaced spiral cords with several orders of interstitial threads, crossed by many low, closely spaced axial ridges; low peripheral gemmae or small nodules at sculptural intersections on some specimens. Aperture large, oval; inside of outer lip with a row of prominent short transverse ridges; inner lip with large parietal tubercle and 3-4 low ridges on base of columella. Protoconch small, dome-shaped, of 2 smooth whorls.

Early Castlecliffian only; "between Kai-Iwi and Okehu, Wanganui", i.e., probably from Lower Kai-Iwi Siltstone,

Plate 49 Middle-late Pleistocene (Castlecliffian-Haweran) Mollusca (7).

- a. *Penion sulcatus* (Lamarck), x 1.
- b. *Buccinulum caudatum* Powell, x 1.5.
- c. *Austrofuscus* (*Austrofuscus*) *glans* (Röding), x 1.
- d. *Alcithoe* (*Alcithoe*) *arabica* (Gmelin), x 0.67.
- e. *Cominella* (*Eucominia*) *elegantula* (Finlay), x 1.
- f. *Iredalula striata* (Hutton), x 2.
- g. *Amalda* (*Baryspira*) *mucronata* (Sowerby), x 1.
- h. *Coluzea spiralis* (A. Adams), x 1.5.
- i. *Alcithoe* (*Leporemax*) *fusus fusus* (Quoy and Gaimard), x 1.
- j,k. *Glaphyrina caudata* (Quoy and Gaimard), x 1.5(k) and x 8(j).
- l. *Antimelatoma buechanani* (Hutton), x 3.
- m. *Phenatoma rosea* (Quoy and Gaimard), x 2.
- n. *Splendrillia* (*Splendrillia*) *annectens* Powell, x 4.
- o. *Tenuiactaeon ambiguus* (Hutton), x 2.
- p. *Aoteadrillia wanganuiensis* (Hutton), x 4.
- q. *Paracomitas* (*Paracomitas*) *gemmea* (Murdoch), x 4.



beach west of Kai-Iwi, west of Wanganui, early Castlecliffian (type); common in Lower Kai-Iwi Siltstone, Omapu Shellbed, and Lower Westmere Siltstone, *only*, at Castlecliff, Wanganui, in offshore siltstone facies where *Buccinulum* is uncommon at present.

Buccinulum caudatum is a distinctive species distinguished from the contemporaneous and living *B. linea* by its much larger size, its more strongly concave sutural ramp, its consistently wide, relatively prominent spiral cords, and its longer, more prominent ridges inside the outer lip. Figured specimen (Pl. 49b): Lower Kai-Iwi Siltstone, Kai-Iwi Beach, west of Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.5.

Pl. 49 f. *Iredalula striata* (Hutton, 1873) [*Bela striata* Hutton 1873b, p. 5; *Siphonalia*(?) *cingulata* Hutton 1885b, p. 315; *Daphnella striata*; *Mitromorpha striata*]. Type species of *Iredalula* Finlay, 1926 (Buccinidae).

Small for family (20-28 mm high), tall and narrow, with weak, rounded shoulder angle high on whorls that are otherwise very gently and evenly inflated; spire slightly taller than aperture and canal; last whorl long, very gently contracted to wide neck and short, widely open anterior canal with low, rounded, poorly defined fasciole. Sculpture of many very fine, closely spaced spiral threads, crossed by extremely fine axial ridges. Aperture long and narrow; outer lip sinuous, with shallow sinus over upper half, weakly thickened; inner lip smooth, weakly thickened. Protoconch relatively large, dome-shaped, of about 1.8 spirally lirate whorls, with a slightly immersed apex, merging imperceptibly into teleoconch.

Mangapanian-Recent; "Wanganui (U); Shakespeare Cliff", type of *Bela striata*, i.e., late Castlecliffian strata at Castlecliff and at Shakespeare Cliff, in Wanganui city (probably from Shakespeare Cliff Siltstone, where the species is most common), Castlecliffian; "Wanganui", i.e., type Castlecliffian section at Castlecliff, Castlecliffian, type of *Siphonalia*(?) *cingulata*. Common in offshore siltstone facies at Castlecliff, Wanganui, Castlecliffian (notably the Kai-Iwi siltstone beds and Shakespeare Cliff Siltstone) and in Castlecliffian mudstone near Ohiwa Harbour, Whakatane, but rare at other fossil localities; dredged uncommonly today on the shelf off the north-eastern North Island in about 20-100 m.

The Mangapanian-Recent *Iredalula alticincta* (with which *I. venusta* Powell appears to intergrade) is a very rare fossil, and in the Recent fauna occurs in deeper water than *I. striata*; it differs from *I. striata* in its much more prominent spiral sculpture. The relationships of this genus have long been in doubt, most early authors referring it to the Turridae; Beu and Maxwell (1987) showed that it is related to *Metula* H. and A. Adams, 1853 and *Colubraria* Schumacher, 1817 and belongs in Buccinidae Pisaniinae.

Figured specimen (Pl. 49f): Kai Iwi siltstone beds, Castlecliff coastal section, Wanganui, Castlecliffian (NZGS, early collection) x 2.

Pl. 49 c. *Austrofusus (Austrofusus) glans* (Röding, 1798) [*Buccinum nodosum* Martyn 1784, fig. 5 (non-binomial); *Drupa glans* Röding 1798, p. 368; *Buccinum raphanus* (not of Lamarck) Quoy and Gaimard 1835, p. 428; *Buccinum triton* Lesson 1841, p. 37; *Austrofusus glans agrestior* Finlay 1927a, p. 486; *Austrofusus glans tragulatus* Iredale 1937, p. 107; probably also = *Austrofusus chathamensis* Finlay 1928b, p. 253; *Siphonalia nodosa*; *Fusus nodosus*; *Neptunea nodosa*;

Verconella (Aethocola) nodosa]. Type species of *Austrofusus* Kobelt, 1879, and of *Aethocola* Iredale, 1915 (Buccinidae).

Large and tall for genus (50-80 mm high), with stepped spire and long canal that is weakly twisted for genus, and so with weakly developed fasciole. Sculpture of many narrow, prominent spiral cords and fine axial costellae; 2 peripheral rows of nodules are highly variable, moderate to large and sharp and forming 2 prominent angulations in most specimens but absent in some, allowing evenly convex whorls (form *chathamensis*). Protoconch small, conical, of 3.5 smooth whorls.

Late Nukumaruan (?); Castlecliffian-Recent; Recent, New Zealand (types of all names in the synonymy list, above). Abundant on the inner to outer continental shelf at present all around New Zealand, and cast ashore on beaches—the most abundant buccinid of the New Zealand modern fauna. *Austrofusus glans* is a very common fossil in Castlecliffian and younger rocks throughout New Zealand, most commonly in inner-shelf, soft-bottom facies such as sandstone and mudstone, and particularly at Castlecliff, Wanganui.

The *Austrofusus glans*-*A. chathamensis* complex is poorly understood. The *A. chathamensis* form (with evenly convex whorls, and sculpture without nodules or with many small, closely spaced nodules) occurs commonly now on beaches at the Chatham Islands, and similar specimens occur in late Nukumaruan faunules in Wanganui and Wairarapa (where it seems to intergrade with the *A. cottoni*-*A. marshalli* complex). The typical *A. glans* form (with two rows of sharp peripheral nodules, forming angulations around the whorls) is unknown before Castlecliffian time, and differs from earlier relatives (*A. taitae*, Nukumaruan, Pl. 42k; *A. pagoda*, Opoitian-Mangapanian, Pl. 37g) in its markedly larger size, sharper nodules, and more elongate, narrower shape; it differs further from *A. pagoda* in its markedly finer spiral sculpture, lacking the consistent, prominent basal spiral cords of *A. pagoda*. On this evidence, it appears possible that *A. glans* and *A. chathamensis* are distinct species with different ancestors. However, the modern population around central New Zealand is highly variable in the prominence and number of peripheral nodules, and specimens indistinguishable from Chatham Islands specimens of *A. chathamensis* wash ashore on Wellington beaches not uncommonly, intergrading with the variably nodulous specimens of *A. glans*. The complex needs reevaluation by modern biochemical or genetic techniques, but it seems very likely that "*A. chathamensis*" is part of the variation of *A. glans*.

Figured specimen (Pl. 49c): Te Piki, Cape Runaway, Haweran (oxygen isotope stage 7, 200 000 years B.P.) (NZGS, from a private collection) x 1.

Pl. 49 e. *Cominella (Eucominia) elegantula* (Finlay, 1926) [*Eucominia elegantula* Finlay 1926b, p. 240; *E. elegantula verrucosa* Finlay 1926b, p. 241; probably also = *C. marlboroughensis* Powell 1946b, p. 143] (Buccinidae).

Small for subgenus (28-35 mm high), with moderately tall spire, short inflated last whorl, and short, strongly twisted canal, forming a prominent fasciole. Sutural ramp weakly concave. Sculpture of low, narrow axial costae, otherwise smooth apart from a few low spiral threads around base. Protoconch large, dome-shaped, of 2.5 smooth whorls.

Nukumaruan-Castlecliffian; Recent? Castlecliff, Wanganui, Castlecliffian (types of *Eucominia elegantula*

and *E. elegantula verrucosa*); Recent, 150 m, 40 km east of Cape Campbell, Cook Strait (type of *Cominella marlboroughensis*). Moderately common in offshore siltstone and sandstone (particularly Pinnacle Sand, Tainui Shellbed, and Upper Castlecliff Shellbed) at Castlecliff, Wanganui; uncommon in Nukumaruan siltstone in Hawke's Bay and Wairarapa; probably the same species lives uncommonly in Cook Strait today.

Cominella elegantula differs from the southern, cool-water, "typical" *Cominella* (*Eucominia*) species related to *C. nassoides* Reeve (e.g., the *C. nassoides otakaui* deep-water ecomorph, Nukumaruan-Recent, Pl. 42d) in its smaller size, weaker subsutural constriction (a narrow, concave sutural ramp) and much weaker spiral sculpture. The "subspecies" *C. elegantula verrucosa* was proposed for coarsely sculptured variants in the Castlecliff *C. verrucosa* population, and is of no taxonomic significance. The status of *C. marlboroughensis* is uncertain; the holotype has fine spiral cords all over, but many Cook Strait Recent shells intergrade with the more weakly sculptured Castlecliff population, and it seems likely that this name is based on modern specimens of *C. elegantula*.

Figured specimen (Pl. 49e): Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.

Pl. 49 g. *Amalda* (*Baryspira*) *mucronata* (Sowerby, 1830). [*Ancillaria mucronata* G. B. Sowerby I (in Broderip and Sowerby) 1830, p. 8; *Baryspira gladiolaria* Olson 1956, p. 13; *Baryspira erica* Olson 1956, p. 13; *Ancilla mucronata*; *Baryspira mucronata*] (Olividae: Ancillinae).

Largest New Zealand member of the family (30-70 mm high), tall and narrow, with short, narrow to moderately inflated spire merging smoothly into long, weakly inflated last whorl. Spire callus highly variable in thickness, so spire varying from narrowly pointed to smoothly hemispherical; base of callus an obvious line at upper quarter of outer lip; fusing to varying extent with thick parietal callus with strongly sigmoidal left margin. Aperture long and narrow, with widely open anterior end and no true siphonal canal. Depressed band narrow. Top and mid fasciolar bands weakly differentiated, equal in width to basal band; separated by deep groove from columellar base, which is grooved and ridged in varying ways, with up to 9 low, narrow, closely spaced columellar ridges.

Opoitian-Recent; Recent, New Zealand (type of *Ancillaria mucronata*); Mangatahi Stream, Kereru Road, inland central Hawke's Bay, Nukumaruan (type of *Baryspira erica*); Ashcott Road (formerly Onga Onga Road) at foot of Pukeora Hill, Waipukurau, Hawke's Bay, Nukumaruan (type of *Baryspira gladiolaria*). Widespread and moderately common on the inner to mid shelf around New Zealand today, but much less commonly encountered on beaches than its close shallower-water relative *A. australis*, and an extremely abundant fossil in offshore siltstone facies of Nukumaruan and Castlecliffian age in Wanganui basin, Hawke's Bay, Wairarapa, and North Canterbury; less common in Mangapanian and Waipipian(?) sandstone and siltstone in the same areas.

The Opoitian record is based on Olson's (1956, p. 14) record of *Baryspira gladiolaria* from Kaawa Creek, southwest Auckland (Opoitian) but the specimen is conceivably not conspecific with the holotype of *B. gladiolaria* (a normal Nukumaruan specimen of *A. mucronata*). As noted under *A. oraria*, above (Pl. 37k),

the ancestry of *A. mucronata* is unclear, and it could have evolved from either *A. oraria* or a relative of *A. tholiculus*.

Beu (1965a) showed that *Baryspira erica* Olson is a form of *A. mucronata* with a particularly heavy spire callus, intergrading with normal relatively narrow specimens of *A. mucronata* in Hawke's Bay late Nukumaruan (early Pleistocene) siltstone. The population at the type locality (Mangatahi River, Kereru Road) consists almost entirely of the *erica* form, but specimens at an equally high Nukumaruan horizon near the top of the Devil's Elbow sequence (Devil's Elbow mudstone) intergrade completely between the *erica* and *mucronata* forms. This is one of several distinctive forms that are limited to late Nukumaruan rocks in Hawke's Bay (others are *Pellicaria fossa*; *Aeneator marshalli*, axially costate form; and *Cominella excoriata*).

In the modern fauna, the common shallow-water sand-flat species *Amalda australis* (= *Baryspira australis epacra* Olson, based on a variant of no taxonomic significance) is easily distinguished from *A. mucronata* by its slightly smaller size, its lower spire with a concave outline above the aperture and, most obviously, by its dark purplish brown (rather than tan and pale pinkish brown) colour. *A. australis* is a much less common fossil than *A. mucronata*, and occurs in only a few near-shore sandstone beds. *A. depressa* is similar to *A. australis*, but shorter and much smaller, with a lower, wider spire. The restricted Nukumaruan species *A. opima* is much shorter and wider than *A. depressa*. Another restricted Nukumaruan species, *A. olsoni*, was based on small specimens from the Devil's Elbow mudstone on Devil's Elbow hill, north of Napier, Hawke's Bay, and was thought to be most closely related to *A. (Gracilispira) novaezelandiae*. Subsequent collecting has shown that it is very much more common in a few near-shore sandstone beds (e.g., Darkys Spur sandstone on Darkys Spur road, west of Devil's Elbow) and reaches a much larger size than was originally thought. It seems most closely related to *A. (Baryspira) australis*, differing in its taller, straight-sided spire and strongly bilobed spire callus.

Figured specimen (Pl. 49g): Upper Kai-Iwi Siltstone, Castlecliff, Wanganui, Castlecliffian (NZGS, early collection) x 1.

Pl. 49 j,k. *Glaphyrina caudata* (Quoy and Gaimard, 1833) [*Fusus caudatus* Quoy and Gaimard 1833, p. 503; *Fusus vulpicolor* Sowerby 1880 (in 1842-1887), p. 78; ? *Glaphyrina vulpicolor progenitor* Finlay 1926c, p. 414; ? *Glaphyrina vulpicolor annectens* Powell 1934, p. 270; *Neptunea caudata*; *Siphonalia caudata*; *Glaphyrina vulpicolor*]. Type species (as *Fusus vulpicolor*) of *Glaphyrina* Finlay, 1926 (Fascioliariidae).

Large for genus but rather small for family (27-67 mm high; fossils rarely more than 45 mm high), tall and narrow, with tall, straight-sided spire, moderately long, straight, open, narrow anterior canal lacking fasciole, and short, evenly and strongly convex whorls with very deeply indented sutures. Sculpture of high, narrow-crested spiral cords, 6-8 on spire whorls and about 15 on last whorl and neck, with many fine threads on canal and fine secondary and tertiary threads in most posterior interspaces; low, evenly rounded axial folds extend from suture to suture on early spire whorls but fade out down spire of most specimens. Aperture oval, with thin lips. Protoconch highly distinctive, of about 2 whorls, the initial one highly irregular, with central "spike", concave upper slope and peripheral keel (suggesting it is an incompletely calcified

"cariceloid" apex following a conchiolin embryonic protoconch, and so probably has direct development), second whorl taller and weakly convex, with narrow axial costae, passing gradually into teleoconch by development of spiral cords.

Castlecliffian-Recent. Recent, New Zealand (types of *Fusus caudatus* and *Fusus vulpicolor*); Castlecliff, Wanganui, Castlecliffian (type of *G. vulpicolor progenitor*); Te Piki, Cape Runaway, Haweran (oxygen isotope stage 7; type of *G. vulpicolor annectens*). Abundant in some offshore siltstone and silty sandstone beds (notably Pinnacle Sand and Tainui Shellbed) at Castlecliff, Wanganui, and occurs uncommonly throughout New Zealand Pliocene and Pleistocene rocks in offshore, soft-substrate environments.

Cernohorsky (1977b, p. 101) showed that the formerly enigmatic name *Fusus caudatus* Quoy and Gaimard, 1833 is an earlier name for the species long known as *Glaphyrina vulpicolor* (Sowerby, 1880). Modern populations of *Glaphyrina caudata* differ strongly around New Zealand; northern ones (Hauraki Gulf and northward) consist of relatively small shells with bright orange-brown colour, and with axial costae continuing onto the last whorl, whereas southern ones (Otago shelf) contain much larger, white shells with axial sculpture on early spire whorls only. While this deserves more study, it makes it difficult to recognise as distinct subspecies the young fossils *G. caudata progenitor* (Castlecliffian, Wanganui) and *G. caudata annectens* (Te Piki, Cape Runaway, Haweran, oxygen isotope stage 7 = 200 000 years B.P.), which differ from modern shells only in the degree of development of their axial costae. We tentatively list *G. caudata progenitor* as a Castlecliffian "chronosubspecies", but regard *G. caudata annectens* as part of the variation of *G. caudata caudata*. Older fossils (*G. paucispiralis*, Mangapianian-Nukumaruan, proposed as a subspecies of *G. vulpicolor* but here accorded species rank; and older unnamed taxa) have fewer, coarser spiral cords than Castlecliffian-Recent populations. The Nukumaruan-Recent *G. plicata* (Pl. 42m) has a wider shell with much larger axial folds.

The protoconch (Pl. 49j) is figured separately for this species, as its pointed apex and concave sides on the first whorl so readily distinguish *G. caudata* from the superficially similar Buccinidae *Buccinulum*, *Aeneator*, *Cominella* and *Penion*, all of which occur commonly with it at Castlecliff, and all of which have dome-shaped protoconchs with evenly convex whorls.

Figured specimen (Pl. 49j, k): GS10963, R22/f6619A, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS); Pl. 49j x 8, Pl. 49k x 1.5.

Pl. 49 d. *Alcithoe (Alcithoe) arabica* (Gmelin, 1791) [*Voluta arabica* Gmelin 1791, p. 3461; *Voluta elongata* Swainson 1821, pl. 20, 21 (not of Lightfoot, 1786, nor of Schröter, 1804); *Voluta pacifica* Perry 1810, in 1810-11, pl. 30; *Fulgoraria depressa* Suter 1908b, p. 182; *Fulgoraria turrita* var. *nukumaruensis* Marshall and Murdoch 1920, p. 133; *Alcithoe lutea* Marwick 1924c, p. 200; *Alcithoe swainsoni* Marwick 1926a, p. 294 (new name for *Voluta elongata* Swainson, preoccupied); *Alcithoe detrita* Marwick 1926a, p. 289; *Alcithoe transformis* Marwick 1926a, p. 293; *Alcithoe acuta* Marwick 1926a, p. 295; *Alcithoe swainsoni motutaraensis* Powell 1928a, p. 361].

Type species of *Alcithoe* H. and A. Adams, 1853 (Volutidae: Zidoniinae).

Large for family (80-180 mm high), with very long, only weakly tapered last whorl, moderately tall to short, conic or weakly stepped spire, and long, narrow aperture. Sculpture highly variable, smooth or with a single spiral row of nodules, nodules small to large and pointed. Outer lip reflected and strongly thickened in adults, but thin and sharp in immature specimens; inner lip a wide, thin glaze, except for a wide, flat collar extending over neck from lower part of columella of most adult specimens; bearing 4 to 6 prominent, narrow plaits low on columella. Anterior siphonal notch wide and shallow; fasciole very low, flat to weakly convex, with much more prominent axial ridges than on remainder of teleoconch surface; margined by a low ridge. Protoconch large, dome-shaped or subcylindrical, 4-5 mm wide.

Nukumaruan-Recent. Recent, New Zealand (types of *Voluta arabica*, *Voluta elongata*, *Voluta pacifica*, *Fulgoraria depressa*, and *Alcithoe swainsoni motutaraensis*); Nukumar Brown Sand, Nukumar Beach, west of Wanganui, Nukumaruan (types of *Fulgoraria turrita* var. *nukumaruensis* and *Alcithoe detrita*); Castlecliff, Wanganui, Castlecliffian (types of *A. swainsoni*, *A. transformis*, and *A. acuta*); Okauawa Stream, Kereru Road, central Hawke's Bay, Nukumaruan (type of *Alcithoe lutea* Marwick, a secondary homonym of *Voluta lutea* Watson, 1882, placed in *Alcithoe* by Dell (1978)). The widespread and abundant large volute of New Zealand shallow-water faunules (estuarine mud-flats to middle shelf) and of many different ecological situations in the fossil record, throughout Wanganui, Hawke's Bay, Wairarapa and North Canterbury.

Alcithoe arabica has direct development; a small crawling animal with a shell consisting of the protoconch plus an initial quarter-whorl of the teleoconch hatches from the large (about one cm in diameter), solitary, almost spherical, calcareous egg case. Consequently, there are marked differences between populations around the country at present, and there are some reasonably consistent differences according to ecological station—e.g., the long-spined form regarded by many earlier authors as "typical" *A. arabica* is limited to estuarine environments. Large collections from many localities (e.g., in National Museum of N.Z.) show that the many named forms are part of one species varying greatly in nodule prominence and spire height, as well as in colour pattern; less variable characters such as protoconch size, the presence of a wide columellar collar in most shallow-water specimens of *A. arabica*, and the depth and width of the anterior siphonal notch are the only ones useful for separating species. So, although there actually are several species of large *Alcithoe* living around New Zealand, there is only one common shallow-water species, *Alcithoe arabica*. The many named forms included in our synonymy that were based on Nukumaruan or Castlecliffian fossils are in our opinion also part of the variation of *A. arabica*; they show the same range of variation as modern shells.

The status of Marwick's "holotype"(?) of *Alcithoe swainsoni* is in doubt as, when he selected it, Marwick was actually renaming the preoccupied *Voluta elongata* Swainson. Legally speaking, the holotype is the specimen Swainson used to base his species upon, and Marwick's specimen has no status in nomenclature.

Figured specimen (Pl. 49d): "holotype" of *Alcithoe swainsoni* Marwick, GS1163, R22/f6498, Kai-Iwi Beach,

west of Castlecliff, Wanganui (Kaimatira Pumice Sand ?), Castlecliffian (TM6841, NZGS) x 0.67.

Pl. 49 i. *Alcithoe (Leporemax) fusus* (Quoy and Gaimard, 1833) [*Voluta fusus* Quoy and Gaimard 1833, p. 627; *Voluta gracilis* Swainson 1835 (in 1834-1835), pt. 6, pl. 42 (not *Voluta gracilis* Dillwyn, 1823); *Voluta subplicata* Hutton 1873a, p. 18; *Fulgoraria gracilis*; *Scaphella gracilis*; *Cymbiola gracilis*]. Type species of *Leporemax* Iredale, 1937 (Volutidae: Zidoninae).

Small for genus (50-80 mm high), narrow and graceful, with long, almost parallel-sided last whorl, tapering very slightly to weakly defined neck, and wide, V-shaped anterior siphonal notch with rounded apex. Surface almost smooth, apart from low but obvious axial costae on spire whorls, raised into very low nodules on a weak angulation at base of weakly concave sutural ramp; nodules are medial on spire whorls but sculpture fades out before last whorl of most large shells. Aperture as in *A. arabica*, but collar never present on inner lip; 4 or 5 narrow plaits on columella. Protoconch small, 2-3 mm wide, otherwise as in *A. arabica*. Colour pattern of bright red-brown narrow zig-zag lines retained on some Castlecliffian fossils.

Nukumaruan(?); Castlecliffian to Recent; Recent, New Zealand (types of *Voluta fusus*, *Voluta gracilis*, and *Voluta subplicata*). Widespread around the main islands of New Zealand at present, on soft substrates in inner to outer shelf depths, but nowhere very common. A common fossil in offshore siltstone facies at Castlecliff, Wanganui (Castlecliffian) and less commonly found in late Nukumaruan siltstone in Wanganui basin, Hawke's Bay and Wairarapa, although the exact time range is unclear as *A. fusus* appears to intergrade very gradually with the apparently ancestral *A. brevis* (Pl. 42n), which differs in its more prominent axial costae than those of *A. fusus*.

In the modern fauna, *Alcithoe fusus* occurs as two weakly differentiated geographic subspecies. *A. fusus fusus*, occurring from about Hawke's Bay southwards, has low, narrow axial costae; Dell (1956a, p. 54) pointed out that the type locality is Tasman Bay, Nelson. *A. fusus hedleyi* (Murdoch and Suter, 1908) (= *A. fusus haurakiensis* Dell 1956a, p. 54) from the Bay of Plenty and Auckland-Northland has more prominent and more widely spaced axial costae than *A. fusus fusus*. Although *A. hedleyi* has usually been considered a species distinct from *A. fusus*, the narrowly cylindrical *A. hedleyi* form appears to be a deep-water ecomorph of *A. fusus*, and specimens from the inner to mid shelf intergrade; *A. hedleyi* has the same relatively coarse axial costae as *A. fusus haurakiensis* and there is little doubt these two names refer to one taxon. *A. fusus resolutionensis*, from Five Fingers Peninsula, Dusky Sound, Fiordland, is Nukumaruan at youngest (Turnbull et al. 1985), and yet has still more reduced axial costae than Recent southern *A. fusus fusus*. This suggests the possibility that weak sculpture is associated with low temperature in *A. fusus*, and populations lost or gained nodules in response to movement of isotherms during Pliocene and Pleistocene time. Carter (1972, p. 312) recognised a variant, "*Leporemax fusus* phenotype *ruahiniensis* n. var." (a name composed so as to be excluded from zoological nomenclature) from early Nukumaruan strata in Te Ekaou Stream, Pohangina, eastern Wanganui basin, that seems likely to be a weakly sculptured form of *A. brevis*. *A. fusus* has a similar protoconch to *A. arabica*, and so presumably also has direct development, so it is not surprising to find it is a highly variable taxon.

Figured specimen (Pl. 49i): Castlecliff, Wanganui, Castlecliffian (NZGS, from an early collection) x 1.

Pl. 49 m. *Phenatoma rosea* (Quoy and Gaimard, 1833) [*Pleurotoma rosea* Quoy and Gaimard 1833, p. 524; *Pleurotoma novaezelandiae* Reeve 1843 (in 1843-1846), pl. 17, fig. 143; *Drillia novaezelandiae*; *Phenatoma novaezelandiae*]. Type species of *Phenatoma* Finlay, 1924 (Turridae: Borsoniinae).

Largest of New Zealand Pleistocene-Recent common shallow-water Turridae (25-38 mm high), tall and narrow, with tall, weakly stepped spire (1.3 times height of aperture and canal), and short, widely open, very weakly twisted but deeply notched anterior canal with low, rounded fasciole. Whorls weakly angled at lower margin of sinus trace high on spire, but angulation fading out down shell, last whorl evenly convex. Sculpture of many low, wide, flat-topped spiral cords, 6 or 7 on sides of spire whorls but becoming subdivided by median groove and intercalating secondary threads on last whorl, last whorl with more than 20 closely crowded cords. Many narrow axial grooves cut cords into flattened rectangular nodules. Aperture simple, with thin lips; outer lip with moderately deep, narrowly U-shaped anal sinus occupying lower part of sutural ramp. Protoconch small, narrowly conical, of 3.5 smooth whorls, with a blunt apex.

Mangapanian-Recent; Recent, New Zealand (types of *Pleurotoma rosea* and *Pleurotoma novaezelandiae*); moderately common throughout New Zealand at present in shallow water on large sand flats (notably near Collingwood, Golden Bay, western Nelson) and cast ashore on sand beaches; common in shallow-water sandstone and some offshore siltstone beds (notably Kupe Formation and Tainui Shellbed) at Castlecliff, Wanganui; less common in a wide range of shallow-water facies throughout New Zealand late Pliocene and Pleistocene rocks.

The second living species, *Phenatoma zealandica* (Nukumaruan?; Castlecliffian-Recent), occurs with but is less common than *P. rosea* at Castlecliff; it is shorter and wider than *P. rosea*, lacks obvious axial sculpture, and has fewer spiral cords, but has a wide, smooth, median zone on the last whorl. *P. zealandica* appears to be descended from *P. precursor* (Mangapanian-Nukumaruan) which is smaller and has more numerous spiral cords than *P. zealandica*. *P. rosea* is considerably larger and has more numerous spiral cords and less angled whorls than its presumed ancestor, *P. decessor* (Waipipian; Pl. 37w). Older species are discussed under *P. decessor*.

Figured specimen (Pl. 49m): GS4102, R22/f6516, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS) x 2.

Pl. 49 p. *Aoteadrillia wanganuiensis* (Hutton, 1873) [*Pleurotoma wanganuiensis* Hutton 1873b, p. 4; *Drillia wanganuiensis*]. Type species of *Aoteadrillia* Powell, 1942 (Turridae: Borsoniinae).

Small for family (10-12.5 mm high), tall and narrow, with moderately tall spire (2.2 times height of aperture and canal) but very short, widely open anterior canal with oblique, notched anterior end but no obvious fasciole. Sculpture of narrow, well raised, widely spaced spiral cords, 3-4 on spire whorls and on upper part of last whorl of most specimens, but variable in number and prominence; base with many low, closely spaced cords; crossing many low, narrow axial costae with only very weak nodules at intersections. Anal sinus deep, U-shaped, occupying shallowly concave sutural ramp, margined above by a heavy subsutural cord. Aperture simple, lips thin, without parietal callus. Protoconch relatively large, low, dome-shaped, of 2.5 whorls, initially smooth but with blunt median cord on last whorl.

Late Nukumaruan-Castlecliffian (-Recent?); Shakespeare Cliff, Wanganui (Tainui Shellbed ?), Castlecliffian (type); moderately common in most Castlecliffian siltstone beds at Wanganui, in late Nukumaruan siltstone in Wairarapa and Hawke's Bay, and in late Nukumaruan to Castlecliffian siltstone in North Canterbury.

The closely related living species(?) *Aoteadrillia chordata* (Suter) has larger nodules at the sculptural intersections than on most Castlecliff specimens of *A. wanganuiensis*, but sculpture is variable in all *Aoteadrillia* populations and the distinction of *A. chordata* from *A. wanganuiensis* is uncertain. The restricted Nukumaruan species *A. finlayi* is considerably larger, more finely sculptured, and has a taller and more prominently keeled protoconch than *A. wanganuiensis* (= "*Paracomitas* n. sp." of Marwick 1965, pl. 11, fig. 18). *A. wanganuiensis* intergrades with (and so appears to have evolved quite gradually from) a lineage of small species with fewer spiral cords and more prominent axial costae than *A. wanganuiensis* (*A. waihuaensis*, Waipipian (-Mangapanian?); *A. alpha*, Mangapanian-early Nukumaruan).

Figured specimen (Pl. 49p): GS10297, O32/f8110A, Leader River, "Mendip Hills" Station, near Parnassus, North Canterbury, Castlecliffian (NZGS) x 4.

Pl. 49 q. *Paracomitas (Paracomitas) gemmea* (Murdoch, 1900) [*Pleurotoma gemmea* Murdoch 1900, p. 217; *Surcula castlecliffensis* Marshall and Murdoch 1919, p. 255]. Type species (as *S. castlecliffensis*) of *Paracomitas* Powell, 1942 (Turridae: Turrinae).

Moderate-sized for family (15-19 mm high), tall and narrow, with moderately tall, strongly stepped spire, prominent shoulder angulation at half whorl height on spire whorls, weak peribasal angulation on last whorl, and moderately long, straight anterior canal without fasciole. Sculpture of low, narrow, closely spaced spiral cords over entire surface below shoulder, 6-8 on spire whorls and about 20 on last whorl, and of low, closely spaced, oblique nodules around peripheral keel, short and occupying only 1 or 2 spiral cords; 15-22 nodules per whorl. Anal sinus broad, rather shallowly U-shaped, occupying strongly concave sutural ramp. Aperture simple, lips thin, without parietal callus. Protoconch relatively tall, of 2.5 whorls, with a low, blunt apex, smooth except for a prominent, sharp, median keel.

Castlecliffian. "Blue-clay cliffs, west of Wanganui Heads", i.e., Castlecliff section, Wanganui, Castlecliffian (type of *Pleurotoma gemmea*); "Castlecliff, in blue sandy clay", Castlecliffian (type of *Surcula castlecliffensis*); moderately common in offshore siltstone beds (notably Tainui Shellbed) at Castlecliff, Wanganui, but the sole other record we are aware of is from the uppermost part of Mikonui-1 well, drilled in 159 m of water off Hokitika, Westland (Beu 1981b).

Powell (1942) distinguished *Paracomitas castlecliffensis* from *P. gemmea* by the smaller and more numerous nodules (20-22) of *P. castlecliffensis* and the fewer nodules (16) and more protruding shoulder carina of *P. gemmea*, but larger collections of shells from Castlecliff show that these sculptural variants intergrade completely (Maxwell 1988a, p. 60). *P. protransenna* (Nukumaruan; Pl. 42r) has a more prominent peribasal angulation than that of *P. gemmea*, and lacks nodules around the shoulder carina; the Recent *P. augusta* (Murdoch and Suter) also has a more prominent peribasal angulation than *P. gemmea*.

Figured specimen (Pl. 49q): holotype of *Pleurotoma*

gemmea Murdoch, Castlecliff, Wanganui, Castlecliffian (TM6842, NZGS, ex Marshall and Murdoch Collection) x 4.

Pl. 49 n. *Splendrillia (Splendrillia) annectens* Powell, 1942 [p. 103] (Turridae: Drilliinae).

Moderately large for genus (14-17 mm high), tall and narrow, with moderately tall spire (1.5 times height of aperture and canal), short, widely open anterior canal with shallow anterior notch and obscure fasciole, and spire strongly stepped because of prominent shoulder nodules, which commence abruptly below strongly concave sutural ramp; subsutural fold weakly developed or absent. Sculpture of many fine, low, closely spaced spiral threads over entire surface below sutural ramp (which is smooth except for growth lines), crossing prominent, rounded, closely spaced, short axial costae, about 15-16 per whorl. Aperture long and narrow, with thickened lips, prominent parietal tubercle, and prominent, spout-like, deep, U-shaped anal sinus occupying sutural ramp, with outer lip swinging well forward below; outer lip with very weak stromboid notch. Protoconch dome-shaped, of 1.5 low, smooth whorls.

Castlecliffian. "Blue clays, near base of Castlecliff beds, Wanganui", i.e., Kai-Iwi siltstone beds, Castlecliffian (type); occurs uncommonly in most siltstone beds in the Castlecliff section, but not known to us from elsewhere.

Splendrillia annectens is similar to the Recent *S. aotearoa* Finlay, but differs in its evenly and finely sculptured surface; *S. aotearoa* has spiral sculpture on the neck only. The Nukumaruan *S. aequistriata* (Pl. 42t) is considerably larger, with a longer last whorl, but otherwise similar. The other two species recorded from Castlecliff (*S. edita*, *S. anomala*) differ in their smaller size and weaker spiral sculpture.

Figured specimen (Pl. 49n): GS4013, R22/f6353, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS) x 4.

Pl. 49 l. *Antimelatoma buchanani* (Hutton, 1873) [*Pleurotoma buchanani* Hutton 1873b, p. 4; *Drillia buchanani*] (Turridae: Turrinae).

Moderate-sized for family (21-25 mm high), tall and narrow, with moderately tall, stepped spire (slightly taller than aperture and canal), long, straight, open, unnotched anterior canal without fasciole, a prominent but narrow, smooth subsutural fold, and a strongly concave sutural ramp. Whorls prominently shouldered by abrupt initiation of axial costae at base of sutural ramp (i.e., base of anal sinus), otherwise gently and evenly inflated on spire; gradually and gently tapered over base to narrow canal. Sculpture of many narrow, well raised, closely spaced spiral cords, 5-8 on spire whorls and about 18 on last whorl, with several fine spiral threads in each interspace on spire and upper part of last whorl; crossing (with only very small, rounded nodules) long, rounded, closely spaced axial costae, about 15 per whorl, prominent on spire but becoming less so on last whorl. Aperture simple, with thin lips, no parietal callus or stromboid notch; anal sinus wide, moderately deep U-shaped, occupying sutural ramp. Protoconch dome-shaped, of slightly more than 2 whorls; first whorl smooth, the second with 4 spiral cords.

Nukumaruan-Castlecliffian; "Shakespeare Cliff", Wanganui [Tainui Shellbed ?], Castlecliffian (type); common in all siltstone beds in the Castlecliff section, Wanganui, and in Nukumaruan siltstone in Hawke's Bay, Wairarapa and North Canterbury.

The Haweran and living *Antimelatoma maorum* (Smith) differs from *A. buchanani* only in having the uppermost cord around the shoulder and the second one below it raised above their neighbours, but even Powell (1942, p. 97) realised that the fossil and living populations are both highly variable in sculpture, and that *A. maorum* may not be separable from *A. buchanani*. No ancestors or

other apparently close relatives are known, other than several similar Recent species, and the genus seems to have appeared abruptly in New Zealand during Nukumaruan time (along with *Paracomitas*).

Figured specimen (Pl. 49l): GS2185, R22/f6312, Tainui Shellbed, Castlecliff, Wanganui, Castlecliffian (NZGS) x 3.

Pl. 49 o. *Tenuiactaeon ambiguus* (Hutton, 1885)
[*Admete*(?) *ambigua* Hutton 1885b, p. 320; *Leucotina ambigua*; *Odostomia sulcata* Hutton 1885b, p. 319 (not of Edwards, 1878); *Acteon praestitus* Finlay 1924a, p. 105 (new name for *Odostomia sulcata* Hutton, preoccupied)] (*Acteonidae*).

Large for family (15-27 mm high), inflated, with tall, weakly stepped spire (equal to aperture in height), large, long last whorl with evenly rounded anterior, lachrymiform aperture, no anterior canal or notch, and straight, thin outer lip. Inner lip weakly thickened, narrowly reflected over narrow umbilical slit, raised into a single low, rounded plait at top of columella; parietal area without callus. Sculpture of wide, shallow, widely spaced, punctate spiral grooves only, apart from weak growth lines. Protoconch inverted, of about 1-1.5 smooth, inflated whorls, with bulbous initiation, which is partly immersed.

Late Nukumaruan-Recent; "Wanganui", i.e., Castlecliff section, Wanganui, Castlecliffian (types of both *Odostomia sulcata* and *Admete*(?) *ambigua*). Common in many near-shore to estuarine facies of Castlecliffian and Haweran age, at Castlecliff, Wanganui (Castlecliffian), at Te Piki, Cape Runaway, and the nearby Maddox Hill (Haweran, oxygen isotope stage 7), at Cape Kidnappers, Hawke's Bay (Castlecliffian and possibly Haweran), in the Brunswick Terrace cover beds near Wanganui (Haweran, oxygen isotope stage 9), and in siltstone near Parnassus railway station, North Canterbury (Castlecliffian); rare also in Wanganui and Wairarapa (latest Nukumaruan), in younger Haweran terraces near Wanganui, in the *Anadara* beds on the summit of Kaiti Hill, Gisborne (? early Haweran), in the Teer Creek fauna beneath the Cascade Moraine, South Westland (late Haweran, oxygen isotope stage 5 ?), in Holocene beach deposits beneath the Gisborne plains (9000 years B.P.: C14) and in the modern fauna of eastern

Northland (three specimens seen). After Castlecliffian time, the species seems to have been much more common in estuarine environments (with abundant *Austrovenus stutchburyi*) rather than in the near-shore shelf siltstone facies it inhabited during Castlecliffian time.

This species has previously been included in the genus *Leucotina* A. Adams, 1860. Habe (1985, p. 11, pl. 3, fig. 7, 8) illustrated the holotype of the Recent western Pacific type species of *Leucotina*, *L. nipponensis* A. Adams, 1860. It is a very small shell (2-3 mm high) with a relatively low spire and only a very weak trace of a plait on the inner lip, and closely resembles species usually placed in *Neacteonina* Thiele, 1912 (e.g. Dell 1956c, p. 147, fig. 210). There is no doubt that *L. nipponensis* is not congeneric with the large, tall-spired species with a low columellar plait that have traditionally been included in *Leucotina*. Two genera that seem closely related contenders to replace *Leucotina* for the New Zealand species, and such large tropical Pacific species as "*Leucotina*" *gigantea* (Dunker) (Kira 1962, pl. 69, fig. 17) are *Nonacteonina* Stephenson (1941, p. 382), based on several Texan Late Cretaceous species, which however, differ from "*L.*" *ambigua* in their longer apertures, flatter whorl outlines, and lack of a columellar fold; and *Tenuiactaeon* Aldrich (1921, p. 16), based on *T. pertenuis* Aldrich (1921, p. 16, pl. 2, fig. 10) from the Tuscaloosa Formation (Lower Eocene) in Alabama, USA. *Tenuiactaeon* resembles the more elongate species previously assigned to *Leucotina* in having a single moderately prominent columellar fold, and in having a shorter aperture and slightly more inflated whorls and correspondingly more impressed sutures than species assigned to *Nonacteonina* by Stephenson (1941). As *Tenuiactaeon* is clearly a much more appropriate genus than *Leucotina* for "*L.*" *ambigua* and the New Zealand Miocene species, and we know of no other appropriate genera, we tentatively adopt *Tenuiactaeon* here.

Figured specimen (Pl. 49o): Castlecliff, Wanganui, Castlecliffian (TM5764, NZGS, from an early collection) x 2.

CHAPTER 17. AN INTRODUCTION TO THE STUDY OF FOSSIL "MICROMOLLUSCS": PLATES 50-57

Nearly all of the molluscs treated in the main part of this handbook are of relatively large size (greatest dimension larger than 20 mm) and are representative of the kinds of shells the collector is likely to notice in the field. Most can be adequately examined with the unaided eye or with a low-power magnifying glass. However, it has long been known that at many fossil localities, in addition to these species, there are diverse assemblages of much smaller molluscs—the so-called "micromolluscs", which are here rather arbitrarily defined as those having the greatest dimension less than 10 mm—many are in fact considerably less than five mm in length. Although F.W. Hutton, H. Suter, P. Marshall and R. Murdoch all described fossil micromolluscs, these seem for the most part to have been found by accident rather than by systematically processing and examining suitable matrix. H.J. Finlay was probably the first deliberately to look for micromolluscs (see his brief comments on processing North Otago Early Miocene matrices, Finlay 1924d, p. 507), but he described relatively few of the species he collected (see especially Finlay 1924c, 1924e). However, it was C.R. Laws who made the study of micromolluscs his speciality and described numerous species from such localities as Pakaurangi Point (Laws 1939a, 1941b, 1944), Kaawa Creek (1936a, 1936b, 1940a) and Otahuhu (1950), as well as from many other localities. His crowning achievement was a review of New Zealand species of the taxonomically difficult and highly diverse family Pyramidellidae, most members of which qualify as micromolluscs (Laws 1937a-d, 1938, 1939b, 1940c, 1941a). Subsequent workers have generally made a point of disaggregating promising lithologies and recovering any micromolluscs as an essential part of their studies on molluscan faunules.

The study of fossil micromolluscs is of considerable scientific importance for the following reasons:

1. They are at least as intrinsically interesting as their larger counterparts.
2. They provide a much fuller picture of the molluscan fauna that existed in the past than a study of the larger species on their own would give, as the vast majority of adult molluscs have shells smaller than 20 mm in maximum dimension. This must inevitably provide more reliable data on which to base conclusions about paleoecology, biostratigraphy, diversity changes through time, etc.
3. Because of their small size they are more likely than are large shells to be present in samples of limited volume (e.g. drill-hole cuttings).
4. Besides those molluscs that are small even as adults, micromolluscs include early growth stages of much larger species. The study of ontogeny can be useful for distinguishing between closely similar species and, more importantly, for assessing the "polarity" of individual characters (i.e. whether they are likely to be primitive or derived) for phylogenetic (cladistic) analysis.

Quite apart from these scientific aspects the study of micromolluscs can be aesthetically rewarding as they include some of the most elegant and most beautifully

sculptured of all molluscs. They have the additional advantage of requiring relatively little storage space!

Because of their small size, however, micromolluscs require special techniques for their recovery and study. These are discussed below.

Collection

Although some micromolluscs may be recognised in the field either because they are very abundant (e.g. some occurrences of *Pareora*), or through careful scrutiny of weathered outcrops, the most practical way to recover them is to collect bulk samples for later treatment. (In some cases it may be practical to sieve matrix at the outcrop or in a nearby stream, but even so, recovery of micromolluscs still requires careful examination of the residue). The quantity of matrix required for a representative micromollusc collection of course depends on their abundance, but in practice from one to 10 kg will suffice. Shellbeds or fine sandstone or siltstone containing larger molluscs are generally the most rewarding rock types, but other lithologies, particularly calcareous tuffs, may also repay collection. Particular attention should be paid to shell-rich lenses, pockets or stringers. Bulk samples should be stored in plastic or cloth bags or in cardboard boxes (carefully labelled of course!) until they can be processed.

Treatment

A variety of techniques—mostly developed by micropaleontologists—are available for the disaggregation of matrix and recovery of small fossils. Those discussed below are relatively simple and safe. The only equipment required is basins or bowls, sieves, and for some processes a source of heat (a hot-plate on a stove is perfectly adequate). (N.B. Do not sieve rocks in a sink unless it is fitted with a sediment-trap!).

1. **Dry Sieving.** Relatively few fossiliferous rocks are so unconsolidated that they can be adequately sieved without further treatment. The few that are amenable to such processing are mostly of late Cenozoic (Pliocene or Pleistocene) age though some much older friable sands (e.g. from Altonian localities such as Sutherlands, Target Gully Shellbed, etc.) are known.

Sieving—whether dry or wet—is considerably aided if two or more sieves of different mesh are used. A relatively coarse sieve (mesh c 10 mm) will retain larger fossils, shell fragments and non-disaggregated matrix, and a one mm sieve will retain all except the smallest molluscs—those that do pass through can be caught on a 0.5 mm mesh sieve although the resulting residue is almost certain to contain much more fine sand-sized matrix than micromolluscs. Other sieves can be used to ensure that the residue to be examined is of relatively uniform size (and therefore easy to sort) but it should be noted that the greater the number of sieving operations the greater is the chance of damaging the fossils.

N.B. Always ensure that sieves and basins are kept clean—micromolluscs can become lodged in small crevices only to be released later to contaminate subsequent samples.

2. Wet Sieving. Many sandstones, siltstones and mudstones, once they have been dried, will disaggregate on soaking in water. For some, water at room temperature will suffice, but hot water may be more effective and speed up the process on other rocks. The resulting slurry can then be passed over a sieve (or sieves), aided by gentle hosing (preferably with a rose attachment). A gentler method is to almost immerse the sieve in a container of water and with a combination of a swirling and an up-and-down motion (more easily learnt than described) slowly sift the fine material through it. This technique is far more effective than hosing for removing fines from shell-rich residues.

Some rocks do not respond well to a single drying/soaking cycle, but break down if the cycle is repeated. For others water on its own may be ineffective—in such cases the addition of a detergent (e.g. washing soda at one tablespoon per litre) combined with boiling may facilitate disaggregation. Other, more powerful detergents sold under a variety of trade names may also be used but are usually difficult to obtain in small quantities. One important point to be noted in all wet treatments is the size of the lumps of matrix to be processed. Micropaleontologists often crush rocks to a small size (10 mm on a side or even smaller) to speed up processing—this is satisfactory for recovery of foraminifera or ostracodes, but most micromolluscs are larger and more fragile than these microfossils and are unlikely to survive intact if such small pieces are used. For recovery of molluscs the larger the lumps the better, but if the lumps are too large they may not disaggregate efficiently, and even if they do the resulting slurry may clog up the sieves. From experience, pieces of matrix from c 30-80 mm on a side usually give good results.

3. Hydrogen peroxide. Many rocks—particularly those containing some organic matter—respond well to treatment with hydrogen peroxide. This is an unstable substance that breaks down into water and oxygen on heating or exposure to sunlight, or in the presence of certain catalysts. It is this production of gas, combined with the release of considerable quantities of heat that disaggregates the rock. In some lithologies there is an added effect resulting from oxidation of iron oxides or of organic matter.

Hydrogen peroxide is sold in a dilute form and is rated according to the volume of oxygen liberated when it breaks down. “Thirty volume” hydrogen peroxide gives off 30 times its volume of gas on decomposition—it consists of about 10% hydrogen peroxide. The strongest solution that is readily available is “100 volume”—this reacts violently with some rocks and should not be used without substantial dilution (from five to 10 times) unless one is prepared to scrape sludge off the walls and ceilings!

Some rock types react immediately and vigorously with hydrogen peroxide, but others do nothing except exude occasional bubbles. Heating the sample or adding a catalyst such as manganese dioxide will hasten the decomposition and may help to disaggregate otherwise recalcitrant rocks.

N.B. Although dilute hydrogen peroxide solution is non-toxic to humans it can cause unsightly (though temporary) white burns on the skin, and will sting painfully if splashed on open cuts or in the eyes. It will

decompose gradually during storage and unless it is to be used quickly should be kept in a dark and cool place in plastic or brown glass containers, with the cap loosed slightly to allow escape of gas. Hydrogen peroxide fumes are however, potentially dangerous and should not be inhaled.

4. Kerosene technique. This is one of the most surprisingly effective of all techniques for disaggregating rocks with at least some clay content, and has given satisfactory results even on some indurated (but not cemented) rocks. The thoroughly dried sample is covered with kerosene and allowed to stand for a short time (half to one hour is sufficient for most samples). Excess kerosene is then poured off (and may be used again if it is passed through filter-paper or a cotton-wool plug in a funnel) and the rock covered with water—if the technique is going to work the rock usually responds promptly by swelling and disintegrating. Some rocks collapse almost immediately into a slurry.

Most samples work quite well with cold water, but hot water (with or without an added detergent such as washing soda) may be more effective on some rock types. Hydrogen peroxide can also be used, but a note of caution is in order—the vapour emitted is a potentially explosive mixture of hydrocarbon and oxygen so keep well away from naked flames!

The above process also works using white spirits or petrol instead of kerosene, but in view of the high flammability of these substances we strongly recommend that they are NOT used.

5. Crystallisation technique. Some lithologies, including limestone and shelly sandstone, do not respond well to any of the methods described above. For these rocks it is worth trying a technique based on the crystallisation of a salt such as “hypo” (sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) or Glauber’s salt (sodium sulphate, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$). The dried sample is placed in a suitable container (e.g. an enamel basin), covered with the dry salt and heated gently until the salt melts in its own water of crystallisation and permeates the rock. It is then allowed to cool so crystallisation can take place, and the process repeated until the rock disintegrates and can then be sieved in the normal way.

N.B. The residue should be thoroughly washed to remove excess salt, otherwise it will gradually effloresce and possibly damage fossils in the process.

6. Acid etching. The techniques discussed above should between them be capable of disaggregating most fossiliferous Cenozoic rocks, but will make little or no impression on hard, well-cemented limestones or calcareous concretions. One technique, described by Bourbon (1957) but little-known until recently, has been used with some success on such lithologies (Milhau 1984; Wilson 1987). The crushed sample is covered with pure (glacial) acetic acid and kept at a temperature of 60°C for several days, making sure that the rock is kept immersed. After a few days the rock begins to disintegrate and any insoluble residue remaining can be sieved in the usual manner, taking great care to make sure that it is thoroughly washed (preferably by soaking in water, decanting and repeating the procedure several times). Water released during the treatment dilutes the acetic acid, which will then attack calcareous fossils; to avoid

this anhydrous copper sulphate should be added to the liquid (two grams per litre). [Because of the unpleasant smell and the corrosive nature of acetic acid vapour this technique should be carried out in a fume cupboard, preferably in a vessel fitted with a condenser].

Recovery

The residue remaining after disaggregation and sieving of the rock sample requires careful examination before micromolluscs can be recovered. The larger shells can be picked out with fingers or forceps without trouble, but the smallest specimens require at least low-power magnification for effective recovery. A hand-held magnifying glass will suffice for small quantities of material, but is tiresome to use for any length of time. One of the stand-mounted magnifiers (particularly those with built-in illumination) available from opticians, hobby shops, etc is far more satisfactory, but the ideal piece of equipment is a low-power binocular microscope with a good working distance between the objective(s) and the observing area. Professional microscopes are very expensive, but much cheaper models are available from some importers. A small quantity of residue is spread thinly on a shallow, black-painted tray and scanned systematically under low power. Specimens may be removed as located with a pair of fine-tipped forceps or—for the smallest and most delicate specimens—with a fine, moistened paint-brush (a size "00" sable hair brush is ideal).

Micromolluscs should be stored in small glass tubes or phials (available from chemical supply outlets) plugged with cotton wool, and properly labelled. (Gelatine capsules are NOT recommended—they become brittle with age and may stick to specimens if they are wetted). An alternative method of storage, suitable only for the smallest shells, is on cardboard microscope slides designed for foraminifera and other microfossils. A thin coating of gum tragacanth or some other water-soluble gum is applied to the surface of the slide and allowed to dry. Specimens to be mounted are moistened and are held to the slide in a suitable orientation with the picking brush until they have dried and have become firmly attached. The slide is then protected with a cover-slip or a glass microscope slide.

Examination

A binocular microscope is the most convenient tool for examining micromolluscs, although much can be achieved with a 10 x or 20 x hand lens. (A steady hand is also very useful!). Specimens may be placed loose on a picking tray (which can be highly frustrating if they roll easily), or attached to a microscope slide, or mounted in fine black sand. The last method has the advantage of allowing the specimen to be quickly oriented in any desired direction. A good source of illumination is essential, particularly for examination at high power. Sunlight (preferably diffused) is satisfactory, but a narrowly focussed beam from a powerful electric light is more convenient for most work.

The advent of a commercially available scanning electron microscope (SEM) in the late 1960s brought about a revolution in the examination and photography of surface details of all manner of small objects. The

combination of high resolution and great depth of field attainable with this instrument (now available in a wide range of makes and models) has made it particularly indispensable for the study of micromolluscs. The main disadvantages of the SEM are its cost (currently beyond the reach of most individuals), the need for rather time-consuming specimen preparation, and its inability to discern subsurface features (except on broken or etched specimens). Despite these drawbacks, high-quality scanning electron photomicrographs (SEPs) have in the last 20 years become a standard feature of most publications dealing with micromolluscs.

Specimens for SEM examination need careful preparation. First they must be cleaned as fully as is possible without incurring damage. Ultrasonic cleaning can be highly effective but care must be taken to avoid damaging fragile shells. Second, the specimen has to be firmly attached to a metal stub in such a way that electrical continuity is assured when it is coated. Very small specimens can be attached directly to double-sided adhesive tape, but larger ones—particularly those with a strongly convex lower surface—require seating on a blob of a suitable adhesive. PVA glue is satisfactory but requires prolonged soaking in water for removal. Certain proprietary glues soluble in acetone or other organic solvents also work well, but for the largest specimens it may be necessary to use special conducting glue developed for electron microscopy. Third, the specimen is usually coated with gold or gold-palladium alloy in a vacuum chamber, although such coating can be dispensed with if the SEM is fitted with a cathodoluminescence facility. Even if these procedures are adequately carried out the final result (the production of a high-quality photograph) depends largely on the competence of the operator, although the development of ever more sophisticated SEMs means that even relatively inexperienced operators can now produce a satisfactory picture. A selection of SEPs of Cenozoic micromolluscs is given on Plates 50-57.

Identification

Descriptions and illustrations of New Zealand Cenozoic micromolluscs are scattered throughout the literature, but the majority are to be found in relatively few publications, notably those of Finlay (1924c, 1924e) on Rissoidae and *Brookula* respectively, and those by Laws on the Kaawa Creek (1936a, 1936b, 1940a), Pakaurangi (1939a, 1941b, 1944), Hokianga (1947, 1948) and Otahuhu faunules (1950), and on the Pyramidellidae (1937a-d, 1938, 1939b, 1940c, 1941a). Illustrations in these papers are either line drawings or optical photomicrographs that range greatly in quality and hence usefulness for identification purposes. In recent publications (Marshall 1983a, 1983c, 1985; Maxwell 1988a) SEPs have become the standard method of illustrating fossil micromolluscs.

Most fossil micromolluscs remain undescribed, and many may prove difficult to assign to the most appropriate genus-group taxon or in some cases, even the correct family. Standard works such as Moore (1960; 1969), Wenz (1938-1944) and Zilch (1959) are of limited use as they are either badly out of date or for the most part have inadequate illustrations of micromolluscs. Powell (1979) is a useful source of information on extant New Zealand micromolluscs, many of which are of course

congeneric with fossil species, although the illustrations are all line drawings or paintings that do not show the detail visible on SEPs. More recent papers, particularly those by Marshall (1978a) (Cerithiopsidae) and Ponder (1985) (genus-group taxa in the Rissoidae) are illustrated with SEPs and are invaluable guides to identification of fossil species.

Taxonomic Distribution of Micromolluscs

Although some micromolluscs belong to families in which large species predominate, the majority occur in relatively few families that are composed more or less exclusively of small species. Those taxa likely to be represented in New Zealand Cenozoic faunules include the following—Nuculidae (particularly *Nucula*, *Linucula*, *Deminucula*, *Brevinucula*), Nuculanidae (*Jupiteria*, *Saccella*, *Yoldiella*, *Ledella*, *Zealeda*), Neilonellidae (*Austrotindaria*, *Pseudotindaria*), Manzanellidae (*Nucinella*), Limopsidae (some *Limopsis*, *Notolimopsis*, *Pectunculina*), Philobryidae (*Philobrya*, *Cosa*, *Lissarca*, *Aupouria*, *Cratis*), Propeamussiidae (*Parvamussium*, *Cycloclamys*), Limidae (some *Limatula*, *Limea*, *Divarilima*), Erycinidae (*Arthritica*, *Borniola*, *Melliteryx*, *Myllita* (*Zemylita*), *Myllitella*), Montacutidae (*Mysella*), Cyamiidae (*Perrierina*), Neoleptonidae (*Neolepton*, *Pachykellia*, *Puyseguria*), CondylCARDIIdae (*Benthocardiella*, *Condylocardia*, *CondylOCUNA*), Cunidae (*Cuna*, *Hamacuna*, *Volupicuna*), Scissurellidae (*Anatoma*, *Scissurella*, *Sinezona*), Orbitestellidae (*Orbitestella*), Trochidae (*Antisolarium*, some *Calliostoma*, *Conominolia*, *Euchelus* (*Herpetopoma*), *Kaiparathina*, *Levella*, *Micrelenchus*, *Spectamen*, *Zetela*), Turbinidae (*Argalista*), Liotiidae (*Lodderena*, *Munditia*), Skeneidae (*Brookula*, *Cirsonella*, *Crossea* (*Crosseola*), *Dolicrossea*, *Liotella*, *Lisstotesta*, *Lisstotestella*, *Notosetia*), Seguenziidae (*Fluxinella*, *Seguenzia*), Littorinidae (*Bembicium*, *Nodilittorina*, Rissoidae (*Alvania* (*Linemera*), *Attenuata*, *Ihungia*, *Merelina*, *Powellisetia*, *Pusillina* (*Haurakia*), *Rissoina*), Barleeidae (*Anabathron* (*Scrobs*), *Amphithalamus* (*Notoscrobs*), *Pisinnia*), Iravadiidae (*Nozeba*), Eatoniellidae (*Eatoniella* (*Dardanula*)), Vitrinellidae (*Circulus*, *Elachorbis*, *Scrupus*), Caecidae (*Caecum*, *Strebloceras*), Pareoridae (*Batillona*, *Pareora*), Fossaridae (*Korovina*, *Radinista*, *Zeradina*), Trichotropidae (*Miplioderma*, *Trichosirius*), Triviidae (*Archierato*, "*Hespererato*", *Lachryma*, some *Trivia*), Cerithiopsidae (*Seila*, *Zaclys* and undescribed genera), Triphoridae (*Bouchettriphora*, *Inella*, *Monophorus*, *Triforis*), Aclididae (*Aclis*, *Awanuia*, *Coenaculum*, *Scalargonoba*), Eulimidae (*Melanella* (sensu lato), some *Eulima* (sensu lato)), Epitoniidae (some *Epitonium* (sensu lato), *Pliciscala*), Nassariidae (*Nassarius* (*Hima*)), Columbellidae (*Anachis*, *Liratilia*, *Mitrella*, *Paxula*, "*Zafra*", *Zemitrella*), Muricidae (*Comptella*, *Pagodula*, *Terefundus*, some *Xymene*), Volutomitridae (*Microvoluta*, *Peculator*), Marginellidae (*Hiwia*, *Euliginella*, *Protoginella*, *Haloginella*, *Volvarinella*), Olividae (some *Amalda* (sensu lato), *Ancillina*), Turridae (*Anacithara*, *Austroclavus*, *Etrempsopsis*, *Eubela*, *Maoridaphne*, *Mauidrillia*, *Mitrolumna*, *Mioawateria*, some *Neoguraleus* (sensu lato), *Nepotilla*, *Rugobela*, *Tomopleura* (sensu lato)), Cancellariidae (*Anapepta*, *Inglisella*, *Oamaruia*), Mathildidae (*Brooksena*,

Fimbriatella, *Mathilda*), Acteonidae (*Acteon*, *Crenilabium*, *Triploca*), Ringiculidae (*Ringicula* (sensu lato), Cylichnidae (*Cylichnina*, *Retusa*, *Volvulella*), Pyramidellidae (*Agatha*, *Chemnitzia*, *Eulimella*, *Evalea*, *Evelynella*, *Linopyrga*, *Odostomia*, *Pyrgiscus*, *Pyrgiscilla*, *Syrnola*, *Terelimella*, *Tibersyrnola*, *Turbonilla*, *Waikura*), Spiratellidae (*Spiratella*), Dentaliidae (some *Dentalium* (sensu lato)), Gadilidae (*Cadulus* (sensu lato)), and most isolated chiton plates.

REPRESENTATIVE GENERA OF NEW ZEALAND CENOZOIC MICROMOLLUSCS

(Note: The synonymies include only those genus-group names that have been used for New Zealand species; all illustrated specimens are in NZGS).

Pl. 50 a,c,f. Genus *Linucula* Marwick, 1931 (Nuculidae: Nuculinae).

Height 2.5-8 mm, ovate to subcircular, some species almost smooth, others with fine radial and/or commarginal sculpture. Lunule and escutcheon areas with very fine subsurface prisms diverging from somewhat coarser radial prisms beneath surface of flanks, and finely crenulating dorsal margins. Hinge arched or broadly angled, chondrophore projecting.

Dunroonian—Recent, New Zealand; Recent, South America (Dell 1964b, p. 143-144). *Linucula* is the most speciose nuculid genus in the New Zealand Cenozoic and is represented by shallow-water and upper bathyal species. Distinguished from *Nucula* and other nuculids with ventral marginal crenulations (i.e. Nuculinae) in having divergent subsurface structural elements on lunule and escutcheon in addition to radial elements on flanks. The presence of dorsal crenulations is the simplest way of recognising species of the genus—other nuculines have smooth dorsal margins.

Example (Pl. 50a,c,f): *Linucula* n.sp.; GS 9500, J41/f8028, excavation for Oamaru Borough Council septic tank, South Oamaru (Altonian) x 25 (a,f), x 75 (c).

Pl. 50 i,j. Genus *Yoldiella* Verrill and Bush, 1897 [Synonym: *Ledaspina* Marwick, 1931 (Maxwell 1988a, p.40)] (Sareptidae: Yoldiellinae).

Length 2.5-7 mm, ovate, rather thin-shelled, posterior end narrowly rounded or rostrate; shell smooth or with distant, fine commarginal ridges. Hinge relatively narrow, broadly angled, anterior and posterior series separated by well defined resilifer. Pallial sinus shallow, rounded.

Mangaorapan—Recent, New Zealand; widely distributed, probably cosmopolitan. Characteristic of moderately deep-water assemblages (outer shelf to upper bathyal). Species of *Jupiteria* (to which some New Zealand species of *Yoldiella* have been assigned) are relatively robust, and are of trigonal shape with the posterior rostrum situated in a lower (more ventral) position than in *Yoldiella*.

Example (Pl. 50i,j): *Yoldiella otekaikensis* Maxwell, 1969; paratype, GS9517, I40/f9805, lime-pit behind Campbell Park School (= Otekaike Special School), Waitaki Valley (Waitakian) x 20.

Pl. 50 g,h. Genus *Zealeda* Marwick, 1924 (Nuculanidae: Ledellinae).

Length 2.3-4.4 mm, stumpy, thick-shelled, with a short, pointed posterior rostrum bounded by a prominent umbonal ridge. Sculpture of commarginal ridges and irregular radial costellae. Hinge relatively heavy with a shallow resilifer. No pallial sinus.

Altonian—Mangapanian, New Zealand; Recent, Australia and Indonesia (*Z. inopinata* (Smith, 1885)). The fossil species occur in outer shelf or bathyal assemblages; *Z. inopinata* (type species of *Magaleda* Iredale, 1929 (Maxwell 1988a, p.40)) is recorded from depths of 750–2800 m. *Zealeda* resembles *Ledella* Verrill and Bush, 1897 in shape and hinge characters, but differs from it and most other nuculanids in having definite radial sculpture.

Example (Pl. 50g,h): *Zealeda inflatella* Marwick, 1931; GS 11185, D45/f8822, Slip Point, Clifden Section, Waiau River (Clifdenian) x 20.

Pl. 50 b,d,e. Genus *Nucinella* Wood, 1851 [Synonym: *Pleurodon* Wood, 1840, not of Harlan, 1831] (Manzanellidae).

Height typically 1–3.5 mm, rarely much larger (but not in N.Z. species), ovate, thin-shelled, smooth or with weak commarginal grooves. Hinge prominent, with several large cardinal taxodont teeth, and a large anterior lateral tooth in each valve. Ligament external, sitting in shallow fossette behind beaks.

Duntroonian—Recent, New Zealand; cosmopolitan, recorded from early Jurassic to Recent. *Nucinella* superficially resembles some nuculids, but differs in being non-nacreous, in having lateral teeth as well as cardinal teeth, and in having an external ligament. Despite the great difference in shell morphology, manzanellids seem to be most closely related to solemyids (Allen and Sanders 1969). *Nucinella* is highly conservative in shell characters and there are only relatively minor differences between the known species.

Example (Pl. 50b,d,e): *Nucinella* aff. *maoriana* (Hedley, 1904); GS9520, J41/f8029, Awamoa Creek, North Otago (Altonian) x 30 (d,e), x 100 (b).

Pl. 51 c,d. Genus *Notolimopsis* Maxwell, 1969 (Limopsidae).

Length 2.5–3.5 mm, subelliptical to ovate, subequilateral, length-height ratio greater than 1. Commarginal sculpture of low, rounded ridges, radial sculpture confined to posterior region in most species, of narrow costellae. Cardinal area long, narrow, with fine vertical striations, bearing a small, central triangular resilifer.

Mangaorapan ?; Bortonian—Altonian, recorded only from shallow-water (“shelf”) assemblages in Canterbury and North Otago. *Notolimopsis* differs from other limopsids primarily in its small size and its shape, particularly in having a length-height ratio greater than one.

Example (Pl. 51c,d): *Notolimopsis pulchra* Maxwell, 1969 (type species of the genus); paratype, GS9516, I40/f9804, Trig Z, Otiake, Waitaki Valley (Waitakian) x 20.

Pl. 51 e,g,h. Genus *Cosa* Finlay, 1929 (Philobryidae).

Height 2.2–3.8 mm, quadrate, strongly inflated, beaks situated close to anterior end. Prodissoconch prominent, strongly marked off from rest of shell. Radial sculpture of prominent costae of flattened, rounded or triangular section, scaly in some species, bearing a median groove in others. Commarginal sculpture of fine ridges or lamellae. Hinge line with numerous taxodont teeth, bearing an obliquely triangular resilifer beneath beak. Ventral margin strongly crenulate.

Waitakian—Recent, New Zealand; Recent, south-eastern Australia. Recent species range from shallow waters down to the upper bathyal zone. *Cosa* is distinguished from *Philobrya* by its more robust shell and prominent radial sculpture.

Example (Pl. 51e,g,h): *Cosa wanganuica* Finlay, 1930; topotype?, GS4104, R22/f6518, Pinnacle Sand, Castlecliff, Wanganui (Castlecliffian) x 20 (e,h), x 50 (g).

Pl. 51 a,b,f. Genus *Parvamussium* Sacco, 1897 [Synonyms: *Ctenamussium* Iredale, 1929; *Variamussium* Sacco, 1897] (Propeamussiidae).

Height typically 3.5–7 mm, some species much larger, subcircular, right ears unequal with a well-developed byssal notch in anterior ear. Sculpture typically discrepant, right valve in New Zealand species usually with fine commarginal ridges, left valve usually more strongly sculptured, with radial costae or costellae in addition to commarginal ridges. Interior with prominent radial costae in both valves.

Kaiatan—Recent, New Zealand; widespread, probably cosmopolitan, recorded from Late Cretaceous—Recent. *Parvamussium* differs from *Propeamussium* (Pl. 27e) in its typically smaller size and more circular shape, and in having a distinct byssal notch. Most records of the genus are from moderately deep water (outer shelf or bathyal) assemblages. Modern species of *Parvamussium* are carnivorous on small crustaceans.

Example (Pl. 51a,b,f): *Parvamussium aucklandicum* (Zittel, 1864); GS9730, Q8/f9828, Holland’s Point, Pakaurangi, Kaipara Harbour (Otaian) x 15.

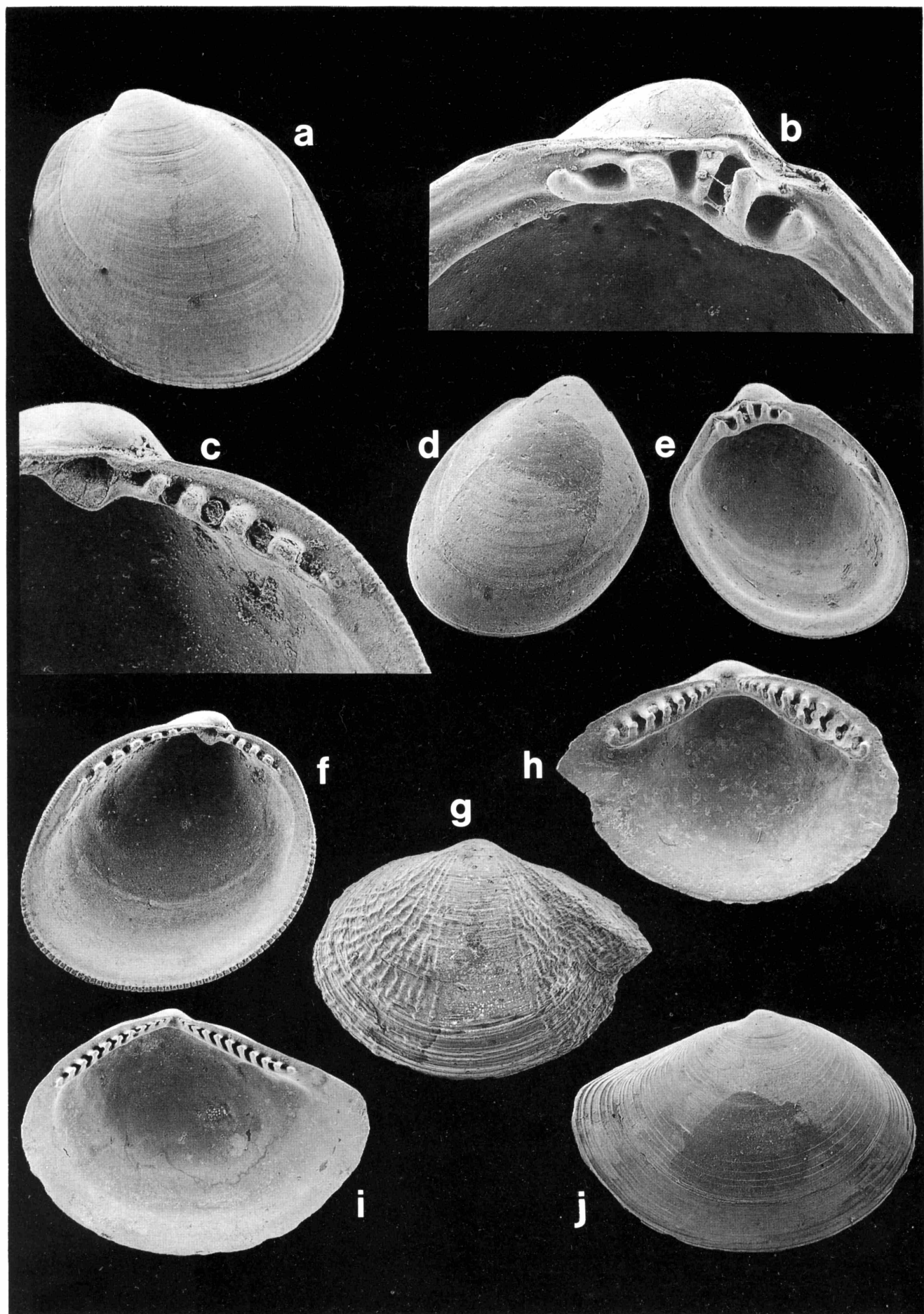
Pl. 52 f,i,j,k. Genus *Melliteryx* Iredale, 1924 (Erycinidae).

Length 2.2–3.3 mm, elliptical or subtrigonal, strongly inflated. Sculpture of numerous minute, shallow pits (punctae) in addition to commarginal grooves and ridges. Each valve with a minute cardinal tooth, an internal resilifer, and both anterior and posterior lateral teeth. No pallial sinus.

Waitakian—Recent, New Zealand; Recent, south-east Australia. The only extant New Zealand species,

Plate 50 Representative micromolluscs (1).

- a,c,f. *Linucula* n.sp., x 25 (a,f), x 75 (c, showing characteristic crenulations on posterodorsal margin).
- b,d,e. *Nucinella* aff. *maoriana* (Hedley), x 30 (d,e), x 100 (b, right hinge showing ligamental fossette indenting posterodorsal margin).
- g,h. *Zealeda inflatella* Marwick, x 20.
- i,j. *Yoldiella otekaikensis* Maxwell, x 20.



Melliteryx parva (Deshayes, 1856), occurs in shallow water, down to about 90 m.

Example (Pl. 52f,i,j,k): *Melliteryx furtiva* Laws, 1950; topotype, GS3528, R11/f7014, Otahuhu Brewery well, Auckland (Waipipian) x 20 (f,k), x 50 (i,j).

Pl. 52 b,e,g,h. Genus *Neolepton* Monterosato, 1875 [Synonym: *Notolepton* Finlay, 1927] (Neoleptonidae).

Length 2-3.6 mm, ovate to subtriangular, sculpture of commarginal ridges or grooves. Right hinge with a small triangular anterior cardinal tooth, an anterior lateral, and 2 posterior laterals; left hinge with a hooked anterior cardinal and a posterior lateral. Resilium internal, behind cardinal teeth. No pallial sinus.

Dunroonian—Recent, New Zealand; Pliocene—Recent, Europe. Usually present in considerable numbers. The most common extant New Zealand species, *Neolepton antipodum* (Filhol, 1880) is recorded from the intertidal zone (living on *Corallina*) down to at least 310 m (Ponder 1969, p. 265; Powell 1979, p. 403).

Example (Pl. 52b,e,g,h): *Neolepton antipodum* (Filhol, 1880) (topotype of *Notolepton turneri* Laws, 1950); GS 3528, R11/f7014, Otahuhu brewery well, Auckland (Waipipian) x 30 (b,e), x 100 (g,h).

Pl. 52 a,c,d. Genus *Volupicuna* Iredale, 1938 (Cunidae)

Height 1.3–3.0 mm, trigonal, robust, equilateral to subequilateral with long, steeply descending dorsal margins. Sculpture of few, broad, low radial costae (obsolete in some species) and growth ridges. Hinge triangular, left valve with narrow anterior and posterior cardinal teeth, right valve with a narrowly triangular median tooth. Anterodorsal margin on left valve, and posterodorsal margin on right valve fitting into corresponding grooves on opposite valve. Both valves with a very small resilifer at top of hinge.

Otaian—Recent, New Zealand; Recent, south-eastern Australia. Recorded from shelf and upper bathyal assemblages. Most of the New Zealand cunids previously referred to *Cuna* (which has prominent commarginal sculpture) belong in *Volupicuna* (see Powell 1979, p. 411).

Example (Pl. 52a,c,d): *Volupicuna* n.sp.; GS10365, D45/f8598, Long Beach Shellbed, Clifden Section, Waiau River (Altonian) x 25 (c,d), x 75 (a).

Pl. 53 a,b,c. Genus *Scissurella* d'Orbigny, 1824 (Scissurellidae).

Diameter 0.9-1.2 mm, protoconch with prominent axial sculpture; teleoconch spire flat or depressed, umbilicus narrow or well developed. Sculpture of prominent axial costae; spiral threads or cords variably developed, as prominent as axials in some species. Selenizone prominent, above periphery, slit deep, open at margin of outer lip.

Teurian—Recent, New Zealand; cosmopolitan, recorded from Late Cretaceous—Recent. *Sinezona* Finlay, 1926 is

similar in shape to *Scissurella* but has the selenizone closed at the outer lip, leaving a slot some distance behind the outer lip; specimens with the outer lip damaged are difficult to distinguish from those of *Scissurella*. *Anatoma* Woodward, 1859 (= *Schizotrochus* Monterosato, 1877) is higher-spined than *Scissurella*, has the selenizone at or close to the peripheral keel, and has a protoconch that is smooth except for fine anastomosing reticulation. Modern scissurellids are recorded from very shallow waters down to abyssal depths; *Scissurella* itself ranges from the intertidal down to the upper bathyal zone.

Example (Pl. 53a,b,c): *Scissurella condita* Laws, 1939; topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 75 (a,b), x 250 (b).

Pl. 53 d,g. Genus *Brookula* Iredale, 1912 (Skeneidae).

Diameter 0.9-1.5 mm, turbiniform, spire depressed or elevated, narrowly or widely umbilicate; whorls rounded, inflated. Sculpture of prominent axial costae and finer interstitial spiral cords or threads. Aperture circular, peristome continuous.

Mangaorapan ?; Kaiatan—Recent, New Zealand; Recent, Kermadec Islands, Australia, Antarctica. *Brookula* (sensu stricto) has a low, blunt spire and relatively wide umbilicus; the subgenus *Aequispirella* Finlay, 1924 has a higher, more pointed spire and is narrowly umbilicate. *Liotella* Iredale, 1915 is superficially similar to *Brookula* (sensu stricto) but has a very depressed or even sunken spire.

Example (Pl. 53d,g): *Brookula* (*Brookula*) *pukeuriensis* Finlay, 1924; GS9520, J41/f8029, Awamoa Creek, North Otago (Altonian) x 40.

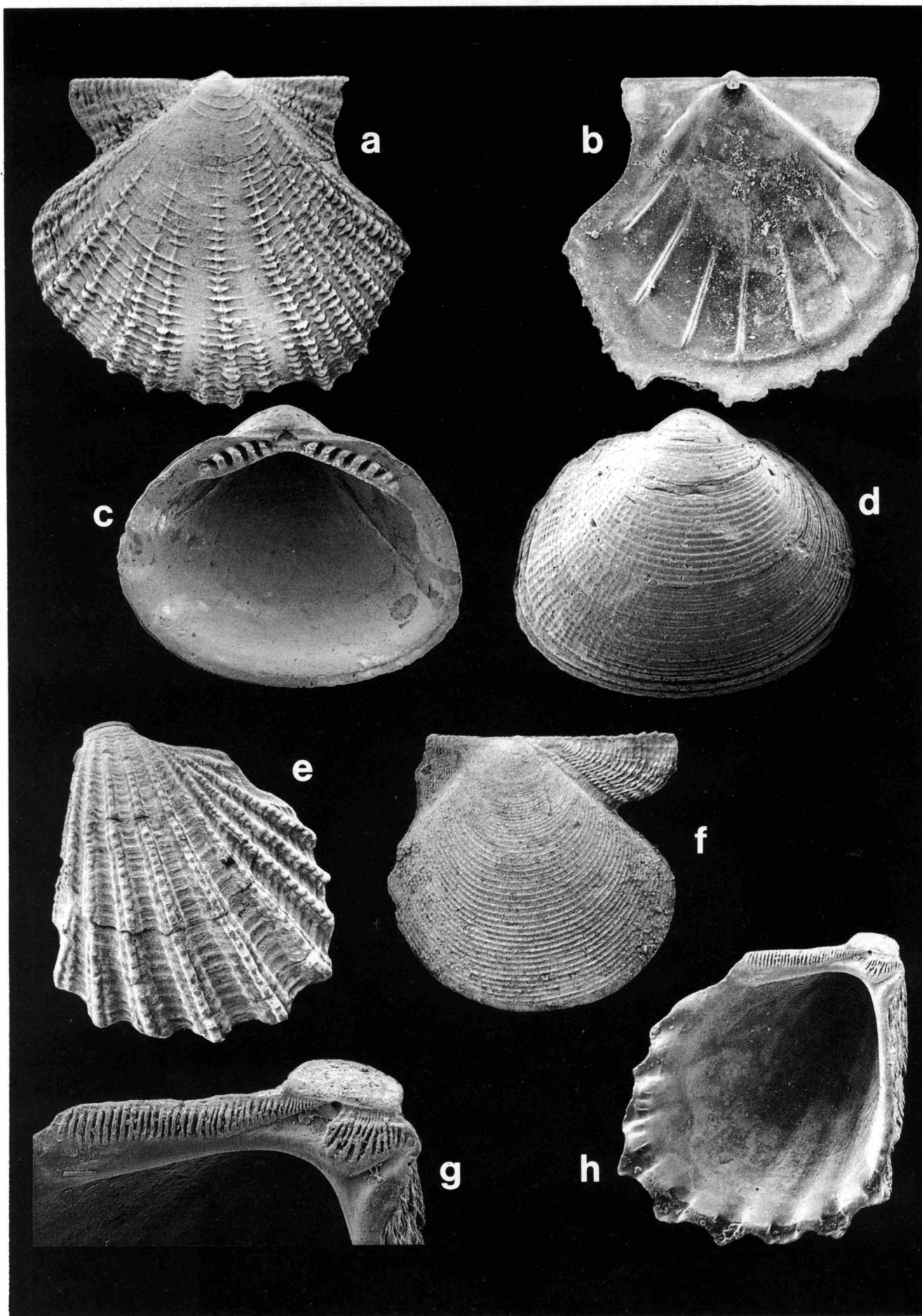
Pl. 53 e,h. Genus *Crossea* A. Adams, 1865; Subgenus *Crosseola* Iredale, 1924 (Skeneidae ?).

Height 1.4-4.3 mm, globose or turbiniform, rather solid; protoconch cap-shaped with microsculpture of fine anastomosing ridges; teleoconch whorls strongly convex or keeled, sculpture clathrate or of prominent spiral cords or keels crossed by weaker axial costae, or of spiral striae. Microsculpture of minute granules between main sculptural elements. Aperture circular, base of inner lip with a short, oblique channel (better-developed in juvenile than in adult shells in some species) forming a prominent rounded fasciole bordering a narrow pseudumbilicus.

Otaian—Recent, New Zealand; Recent, south-eastern Australia. Most modern records are from middle to outer shelf or upper bathyal depths, but some species occur in shallower waters. *Crossea* is distinguished from other skeneids primarily by the anterior notch or channel and the prominent fasciole. *Crossea* (sensu stricto) differs from *Crosseola* in having prominent varices on the adult whorls but otherwise seems similar. *Dolicrossea* Iredale,

Plate 51 Representative micromolluscs (2).

- a,b,f. *Parvamussium aucklandicum* (Zittel), x 15 (a,b, left valve; f, right valve).
c,d. *Notolimopsis pulchra* Maxwell, x 20.
e,g,h. *Cosa wangauica* Finlay, x 20 (e,h), x 50 (g).



1924 is distinguished mainly by its more elongate shape, by its much weaker sculpture (of incised spiral grooves), and by its narrow, crescentic umbilicus, which is bounded on its inner edge by a narrow ridge.

Example (Pl. 53e,h): *Crossea (Crosseola) sinemacula* (Laws, 1939); topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 35 (h), x 150 (e).

Pl. 53 j,k. Genus *Lissotestella* Powell, 1946 (Skeneidae).

Height 0.85–2.2 mm, turbiniform, narrowly umbilicate. Protoconch with sculpture of very fine anastomosing ridges; teleoconch whorls convex, sculptured with spiral cords or lirae, microsculpture of minute, irregular granules. Aperture circular, peristome continuous in some species, interrupted in others; outer lip with low, rounded varix slightly behind front edge.

Kaiatan ?, Otaian—Recent, New Zealand, from inner shelf to upper slope. Species of *Lissotesta* Iredale, 1915 are of similar shape to those of *Lissotestella*, but are smooth or have a few weak spirals in the umbilicus, and lack a varix on the outer lip.

Example (Pl. 53j,k): *Lissotestella alpha* (Laws, 1939); topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 50 (k), x 200 (j).

Pl. 53 f,i. Genus *Argalista* Iredale, 1915 (Turbinidae: Homalopomatinae).

Diameter 1.4–3.5 mm, depressed-turbiniform, rather solid, spire almost flat in some species, dome-shaped in others, non-umbilicate to widely umbilicate. Some species smooth but most with spiral sculpture of low, rounded cords or prominent keels; axial sculpture typically absent, but represented by crenulations on umbilical border on some species. Aperture circular, peristome interrupted. Operculum discoidal, calcareous, occasionally found fossil.

Kaiatan—Recent, New Zealand; Recent, Australia. Mostly shallow-water, but extending down into the upper bathyal zone. A considerable number of species of *Argalista* have been described from New Zealand, but some may be difficult to distinguish from one another unless well preserved material is available. Although *Argalista* has been considered to be a subgenus of *Homalopoma* Carpenter, 1864 by some authors (e.g. Keen in Moore 1960, p. 1270; Fleming 1966b, p. 40; Powell 1979, p. 67) it differs from *Homalopoma* in its much smaller size, in the absence of obvious nacre, and in having a calcareous operculum rather than one with both shelly and horny layers—it is here returned to generic rank.

Example (Pl. 53f,i): *Argalista kaiparaensis* Finlay, 1930; topotype, GS9730, Q8/f9828, Holland's Pt, Pakaurangi, Kaipara Harbour (Otaian) x 25.

Pl. 54 l,m,n. Genus *Orbitestella* Iredale, 1917 (Orbitestellidae).

Diameter 0.8–1 mm, discoidal, widely umbilicate. Protoconch with partly immersed initial whorl, upper edge strongly keeled, in some species elaborately sculptured. Teleoconch with 2 prominent keels or angulations, spire almost flat. Some species almost smooth except for fine spiral threads, others with prominent nodules on upper surface and on keels, and with axial costae on base. Aperture quadrate, outer lip sinuous.

Waitakian—Recent, New Zealand; Late Eocene—Recent, Australia. A similar, undescribed genus, differing from *Orbitestella* in having an unkeeled protoconch and a prominent peripheral teleoconch keel, is recorded from the Middle Jurassic of North Canterbury and sporadically from about Mangaorapan to Waipipian in New Zealand, and is also present in the Cenozoic of Europe, and in the modern fauna of Australia and elsewhere in the south-west Pacific. The suprafamilial position of the Orbitestellidae is uncertain, and it has variously been placed in the Trochacea or the Rissioacea—a more likely position is in the Euomphalacea, otherwise recorded only from the Paleozoic and Mesozoic (Maxwell in prep.).

Example (Pl. 54l,m,n): *Orbitestella praetoreuma* Laws, 1939; topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 80 (l,n), x 300 (m).

Pl. 54 i,j. Genus *Alvania* Risso, 1826; Subgenus *Linemera* Finlay, 1924 (Rissoidae: Rissioinae).

Height 1.5–3.5 mm, elongate-ovate, spire moderately elevated. protoconch of about 1.5 whorls, bulbous, smooth except for very fine granules, in some species granules fused to form short spiral striae. Teleoconch whorls convex; sculpture of axial costae crossed by spiral cords, clathrate in some species, axials dominant in others. Aperture subcircular, peristome continuous, simple; outer lip opisthocline with rather weak varix.

Kaiatan—Recent, New Zealand; Recent, Australia, South Africa. Modern species range from the inner shelf down to the upper part of the slope. *Alvania (Linemera)* is similar in teleoconch sculpture to *Merelina* (see below) but differs in having an almost smooth protoconch and a simple rather than a duplicated aperture.

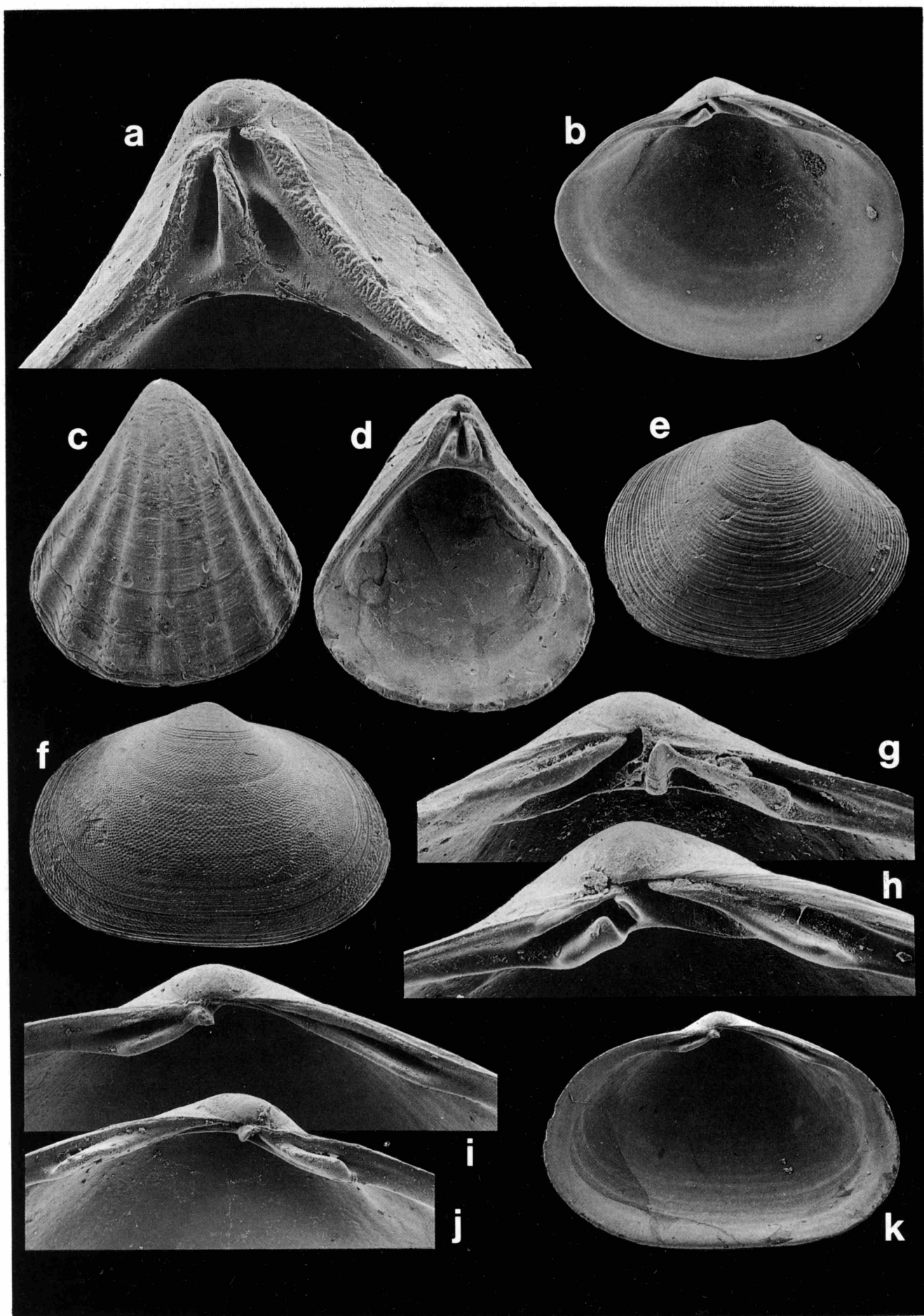
Example (Pl. 54 i,j): *Alvania (Linemera) pukeuriensis* (Finlay, 1924); topotype, GS9685, J41/f9499b, Pukeuri road-cutting, Otago (Altonian) x 25 (j), x 100 (i).

Pl. 54 a,d,e. Genus *Merelina* Iredale, 1915 (Rissoidae: Rissioinae).

Height 1.35–4.4 mm, elongate-ovate, relatively solid. Protoconch of about 1.5 whorls with sculpture of few, prominent nodulose cords. Teleoconch sculpture typically clathrate, in many species with small nodules at intersections of axial and spiral elements, some species with

Plate 52 Representative micromolluscs (3).

- a,c,d. *Volupicuna* n.sp., x 25 (c,d, left valve), x 75 (a, right hinge showing small subumbonal resilifer).
b,e,g,h. *Neolepton antipodum* (Filhol), x 30 (b,e), x 100 (g, left hinge; h, right hinge).
f,i,j,k. *Melliteryx furtiva* Laws, x 20 (f,k), x 50 (i, right hinge; j, left hinge).



microsculpture of fine spiral threads. Aperture subcircular, peristome duplicated; outer lip opisthocline, with well developed varix.

Waitakian—Recent, New Zealand; Recent, Australia, tropical western Pacific, East Africa (Ponder 1985, p. 73). Most modern records of *Merelina* are from shallow waters, but some species occur in the upper part of the bathyal zone.

Example (Pl. 54a,d,e): *Merelina avita* Marwick, 1928; GS12163, CH/f13B, Motutapu Point, Pitt Island, Chathams (Waipipian) x 20 (d,e), x 100 (a).

Pl. 54 c. Genus *Attenuata* Hedley, 1918 [Synonyms: *Nobolira* Finlay, 1926; *Adolphinoba* Powell, 1930 (Ponder 1985, p. 76)] (Rissoïdae: Rissoïnae).

Height 1.4–4.4 mm, ovate-conic to tall-spired. Protoconch dome-shaped, of about 1.5 whorls, sculptured with several simple spiral cords with minute interstitial granules. Teleoconch sculpture of prominent spiral ridges or keels and fine growth lines, a few species with low axial costae. Aperture ovate, peristome duplicated in most species; outer lip opisthocline, with varix.

Kaaitan—Recent, New Zealand; Late Eocene—Recent, temperate Australia (Ponder 1985, p. 77). Most Recent New Zealand species occur on the middle or outer shelf, or on the upper part of the slope. The prominent spiral teleoconch sculpture readily distinguishes *Attenuata* from most other rissoïds; *Lironoba* Iredale, 1915 is similar, but has a much more weakly sculptured protoconch (almost smooth except for a weak keel and/or spiral lirae on the last whorl), and differs in radular characters (Ponder 1985, p. 75–76).

Example (Pl. 54c): *Attenuata inflata* (Laws, 1939); topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 30.

Pl. 54 f. Genus *Pusillina* Monterosato, 1884; Subgenus *Haurakia* Iredale, 1915 [Synonym: *Haurakiopsis* Powell, 1937] (Rissoïdae: Rissoïnae).

Height 1.6–3.3 mm, ovate-conic. Protoconch of 1.5 whorls with large initial whorl, or of about 2.5 whorls with small initial whorl; smooth or with spiral threads or rows of minute granules. Teleoconch smooth in some species, others with axial costae that stop at peribasal cord (i.e. not at periphery but some distance below) on last whorl. Some species with spiral striae over whorls, or weak spiral cords on base. Aperture ovate with a shallow anterior excavation, outer lip thin or with weak varix.

Waitakian—Recent, New Zealand; Oligocene—Recent, temperate Australia; Recent, South Africa, tropical Indo-

Pacific (Ponder 1985, p. 30). *Pusillina* (*Haurakia*) is distinguished from other New Zealand rissoïds by its ovate-conic shape and by the absence or weakness of spiral sculpture. Some weakly sculptured species resemble species of *Powellisetia* Ponder, 1964, but they differ in having an anteriorly excavated aperture. *Powellisetia* also differs anatomically from *Pusillina* (*Haurakia*) (Ponder 1985, p. 62).

Rissoa (*Haurakia*) *curvicostata* (Grant-Mackie and Chapman-Smith, 1971) (Te Piki, Haweran) has a heterostrophic protoconch and a weak columellar plait, and is here removed to the Pyramidellidae, tentatively to *Chrysallida*.

Example (Pl. 54f): *Pusillina* (*Haurakia*) *chemnitzia* (Laws, 1948); GS12600, 05/f21, Otueka hill road-cutting, Hokianga (Otaian) x 35.

Pl. 54 b,g. Genus *Pisinna* Monterosato, 1878 [Synonyms: *Estea* Iredale, 1915; *Microestea* Ponder, 1965] (Barleeidae: Anabathroninae).

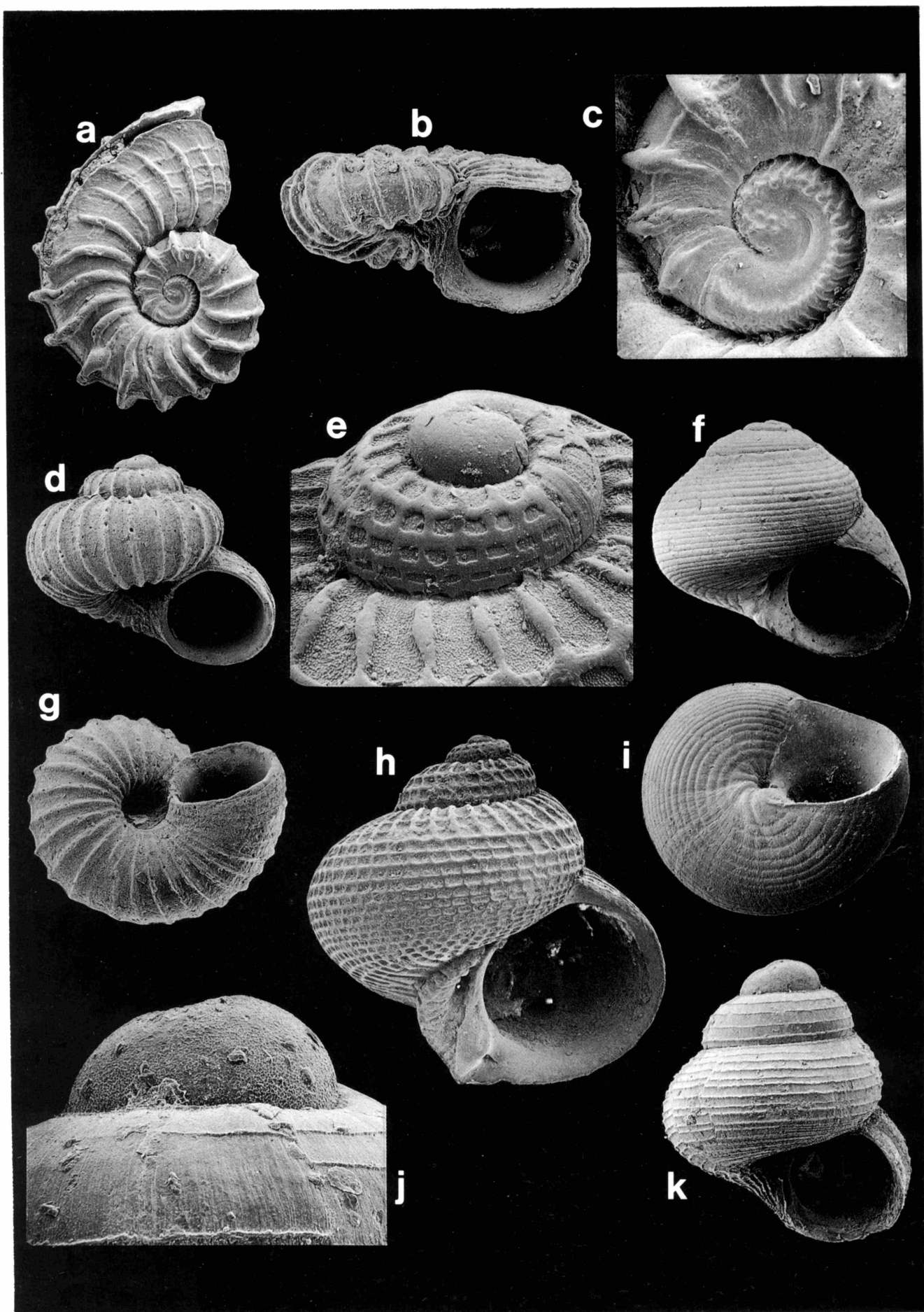
Height 1.5–5.1 mm, pupiform, spire moderately elevated. Protoconch dome-shaped, of 1.5–2 whorls, with minute, shallow pits (punctae), in some species aligned in spiral rows. Teleoconch whorls typically flat-sided or gently convex, periphery usually rounded, angulate in a few species. Some species smooth, others axially costate or costellate, a few with spiral grooves or cords. Aperture oval or circular, flared; peristome continuous, sharp-edged, attached to last whorl in parietal region but partly detached (separated from columella by groove) below.

Waitakian—Recent, New Zealand; Early Miocene—Recent, Australia, tropical West Pacific; Recent, Mediterranean, South Africa. Most species of *Pisinna* (some of them living sympatrically) inhabit very shallow waters (including intertidal mud flats) but others occur in much deeper waters (across the shelf and into the upper bathyal zone). Readily distinguished from other rissoaceans by its apertural characters, *Pisinna* was long considered to be a rissoïd, but it is now classed in the Barleeidae (Ponder 1983a). New Zealand species (living and fossil) were revised by Ponder (1965c) but a considerable number of additional fossil forms (some of them highly distinctive) are now known.

Example (Pl. 54b,g): *Pisinna subtilicosta* (Marwick, 1928) (synonymised with *P. micronema* (Suter, 1898) by Ponder (1965c, p. 141) but probably distinct); topotype, GS 12172, CH/f4B, Titirangi, Chatham Island (Nukumaruan) x 20 (g), x 100 (b).

Plate 53 Representative micromolluscs (4).

- a,b,c. *Scissurella condita* Laws, x 75 (a,b), x 250 (c, showing protoconch and early part of teleoconch).
d,g. *Brookula* (*Brookula*) *pukeuriensis* Finlay, x 40.
e,h. *Crossea* (*Crosseola*) *sinemacula* (Laws), x 35 (h), x 150 (e, apex showing protoconch and teleoconch microsculpture of granules between main sculptural elements).
f,i. *Argalista kaiparaensis* Finlay, x 25.
j,k. *Lissotestella alpha* (Laws), x 50 (k), x 200 (j, apex showing microsculpture of anastomosing ridges on protoconch).



Pl. 54 h,k. Genus *Nozeba* Iredale, 1915 (Iravadiidae).

Height 1.4-3.2 mm, ovate, spire only moderately elevated. Protoconch dome-shaped, flattened on top, of 2-2.25 smooth whorls. Teleoconch whorls flat-sided to weakly convex, last whorl capacious; sculpture absent or consisting of narrow spiral grooves. Aperture ovate, anterior end rounded or broadly excavated; inner lip thickened in parietal region, partly detached in some species; outer lip with low varix.

Mangaorapan ?; Bortonian—Recent, New Zealand; south-east Australia, Europe, North America, Late Cretaceous—Recent. *Nozeba* was long referred to the Rissoidae, but is now included in the Iravadiidae (Ponder 1984, p. 54). Most New Zealand species are from shallow-water (inner shelf) habitats, but some apparently lived in the mid- or outer shelf regions. One modern Australian species lives in estuaries (Ponder 1984, p. 56). [Finlay (1924c, p. 490-491) described two taxa, *Nozeba candida* and *N. candida* var. *effusa* from Mount Harris Formation, Pukeuri (Altonian)—they are here considered to be synonyms].

Example (Pl. 54h,k): *Nozeba couttsi* Laws, 1950; topotype, GS3528, R11/f7014, Otahuhu brewery well, Auckland (Waipipian) x 20 (h), x 100 (k).

Pl. 55 c,f,g. Genus *Pareora* Marwick, 1931 (Pareoridae).

Height 3-5 mm, elongate-ovate, spire moderately elevated. Protoconch conical or subcylindrical, of about 4 very finely granulose whorls, deviated in some species. Teleoconch whorls strongly convex or somewhat flattened medially, sculptured with spiral cords, obsolete on some species, well developed on others. Aperture ovate, outer lip very thin, rarely preserved complete, with a deep sinus on adapical half, lip swinging well forward below, abapical end somewhat pointed. Base with shallow sinus, outer edge forming a sharp, low ridge ascending within aperture.

Mangaorapan—Opoitian, New Zealand; Late Eocene, South Australia. *Pareora* occurs in vast numbers at some localities, e.g. at White Rock River, South Canterbury, the type locality of *P. striolata*. *Pareora* apparently ranged across the shelf into the upper bathyal zone.

Example (Pl. 55c,f,g): *Pareora striolata* (Hutton, 1885), type species of the genus; GS9700, J38/f9681, Sutherlands, Tengawai River, South Canterbury (Altonian) x 15 (f), x 40 (c), x 30 (g).

Pl. 55 h,j. Genus *Strebloceras* Carpenter, 1858 (Caecidae).

Length 1.8-3 mm, protoconch prominent, planorboid, of about 2 whorls; teleoconch a straight or gently twisted, slowly expanding tube of circular cross-section, lacking sculpture apart from growth lines.

Mangaorapan ?, Altonian—Waiauian, New Zealand; Late Eocene—Oligocene, Europe; Recent, Hawaii. *Strebloceras* differs from *Caecum* Fleming, 1817 and its various subgenera in retaining the protoconch instead of shedding it during development of the teleoconch. *Caecum* (sensu stricto) is not recorded from New Zealand, and the very small, smooth species *C. digitulum* (Mangapanian—Recent) and *C. pertenuis* (Otaian—Altonian, Pakaurangi Point, Northland) are here referred to the subgenus *Fartulum* Carpenter, 1857.

Example (Pl. 55h,j): *Strebloceras* n.sp.; GS11650, J40/f6612, South Branch, Waihao River near "Pentland Hills", South Canterbury (Mangaorapan?) x 25 (h), x 50 (j).

Pl. 55 a,d. Genus *Seila* A. Adams, 1861; Subgenus *Lyroseila* Finlay, 1926 (Cerithiopsidae: Cerithiopsinae).

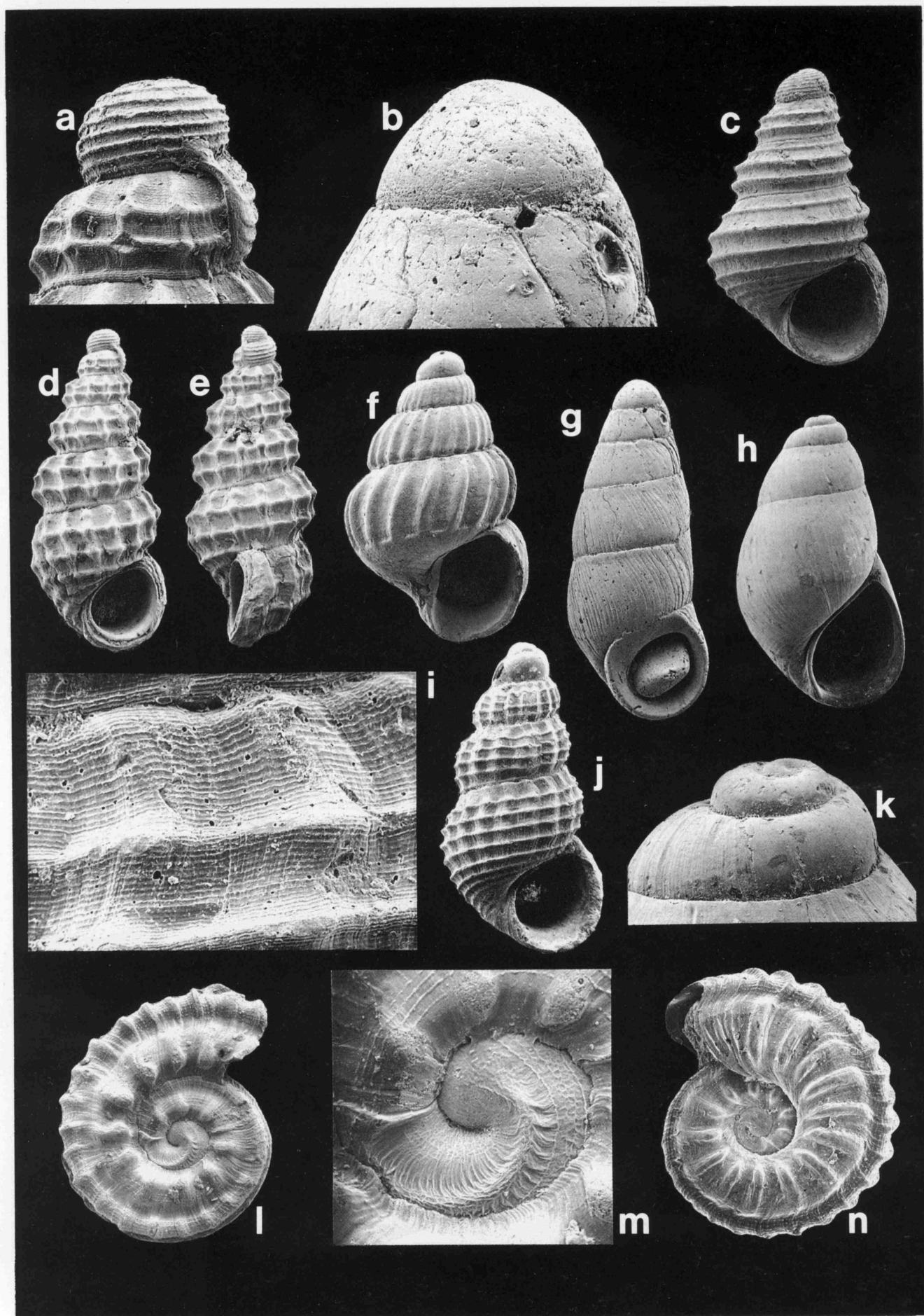
Height c. 2.5-9 mm, moderately attenuate, spire straight-sided or slightly cyrtocoid (i.e. with convex outline). Protoconch large, broadly conical, of 2-3 whorls, with prominent spiral keel or median angulation, some species with weak spiral lirae or threads, others smooth. Teleoconch whorls weakly convex, spire whorls with 3 prominent, subequal cords, some species with additional cords appearing during growth, base with 1 or 2 additional cords in some species, smooth in others. Axial sculpture of fine growth ridges or lamellae only. Aperture small, subquadrate, siphonal canal very short, open, weakly deflected to left.

Nukumaruan—Recent, New Zealand; Recent, South Australia.

Although the Cerithiopsidae is one of the most speciose groups of gastropods recorded from the New Zealand Cenozoic fauna, only a handful of fossil species have been described, and many of these are of uncertain affinities. A major problem in identifying fossil cerithiopsids is that most specimens lack the protoconch—this usually makes generic assignment very difficult, if not impossible, as many species have a very conservative teleoconch sculptural plan. In *Seila* and related taxa, axial sculpture is only weakly developed and consists of fine growth ridges or lamellae between the well developed spiral cords, but in the majority of other New Zealand species axial and spiral elements are of similar strength, intersecting

Plate 54 Representative micromolluscs (5).

- a,d,e. *Merelina avita* Marwick, x 20 (d,e), x 100 (a, apex showing spirally keeled protoconch with terminal varix, and teleoconch microsculpture of spiral threads).
- b,g. *Pisinna subtilicosta* (Marwick), x 20 (g), x 100 (b, apex showing traces of spirally arranged punctae on protoconch).
- c. *Attenuata inflata* (Laws), x 30.
- f. *Pusillina (Haurakia) chemnitzia* (Laws), x 35.
- h,k. *Nozeba couttsi* Laws, x 20 (h), x 100 (k, apex showing large dome-shaped protoconch).
- i,j. *Alvania (Linemera) pukeuriensis* (Finlay), x 25 (j), x 100 (i, showing teleoconch microsculpture).
- l,m,n. *Orbitestella praetoreuma* Laws, x 80 (l,n), x 300 (m, showing elaborately sculptured protoconch).



to form either an open reticulate or clathrate pattern, or rows of small, closely spaced gemmules. Experience has shown that some (apparently sympatric) species may have radically different protoconchs, yet differ only subtly in teleoconch characters.

Marshall (1978) has reviewed the modern New Zealand cerithiopsid fauna, and has demonstrated the great value of protoconch characters in the classification of the family; unfortunately, no similar study has yet been made on the very numerous fossil species, most of which do not seem to have close relatives in the Recent fauna.

Example (Pl. 55a,d): *Seila* (*Lyroseila*) *cincta* (Hutton, 1886) (type species (as its synonym *S. chathamensis* Suter, 1908) of *Lyroseila* Finlay, 1926 (see Marshall 1978, p. 96-97)); GS14430, Y14/f7505I, Te Piki, Cape Runaway (Haweran) x 12.5 (d), x 75 (a).

Pl. 56 c,g. Genus *Coenaculum* Iredale, 1924 (Aclididae ?).

Height 2-3.6 mm, subcylindrical, relatively solid, spire elevated. Protoconch of about 1.5 strongly spirally keeled whorls. Teleoconch whorls almost flat-sided, gently convex or medially angled; perimeter of base angled in some species. Sculpture of axial costae, typically flexuous and stopping at peribasal keel. Aperture ovate, outer lip slightly thickened in some species.

Waitakian—Recent, New Zealand; Recent, south-eastern Australia. Most New Zealand records of *Coenaculum* are from shallow-water assemblages, but the genus ranges down to the upper bathyal zone. *Coenaculum* has previously been referred to the Rissoidae and the Epitoniidae, but it is here tentatively included in the Aclididae, following Wenz (1940, p. 833) and Ponder (1967, p. 220).

Example (Pl. 56c,g): *Coenaculum* n.sp.; GS 9493, L35/f7529, sandstone above main shellbed, Burnt Hill, North Canterbury (Waiauian) x 50 (g), x 150 (c).

Pl. 55 k,l. Genus *Etremopsis* Powell, 1942 (Turridae: Clathurellinae).

Height 4-8 mm, fusiform, spire moderately elevated. Protoconch conical, of 5-6 whorls, first whorl globular, remainder sharply keeled, a few opisthocyrt costellae on last whorl. Microsculpture of short, discontinuous axial threads, and fine granules. Teleoconch whorls convex or angled, last whorl with short neck; sculpture of prominent axial costae

and spiral cords and threads; microsculpture of ubiquitous fine granules. Aperture constricted posteriorly by parietal tubercle, no other denticles on inner lip; anterior siphonal canal short; outer lip with well developed varix, lirate within; anal sinus moderately deep and narrow, on sutural ramp.

Duntroonian—Waiauian, New Zealand; Neogene, south-eastern Australia; Recent, Persian Gulf (Powell 1966, p. 112). Most New Zealand records of *Etremopsis* are from middle to outer shelf or upper bathyal assemblages. *Etremopsis* is distinguished from other clathurellines (e.g. *Clathurella* Carpenter, 1857; *Etrema* Hedley, 1918; *Glyphostoma* Gabb, 1972) primarily by having a much less strongly armoured aperture, and particularly in lacking inner lip denticles or tubercles other than the parietal one.

Example (Pl. 55k,l): *Etremopsis haroldi* Powell, 1942, GS11174, J41/f8237, shellbed behind Fallon's homestead, Ardgowan, North Otago (Altonian) x 10 (k), x 100 (l).

Pl. 55 e,i. Genus *Eubela* Dall, 1889 (Turridae: Daphnellinae).

Height 4-16 mm, elongate-ovate, spire moderately elevated. Protoconch conical, of about 4 whorls, first whorl finely reticulate, later whorls finely decussate. Teleoconch whorls flat-sided or gently convex; sculpture of a subsutural row of small gemmules, otherwise glossy and smooth or with spiral grooves on base. Aperture pyriform, columella short, almost straight, smooth; outer lip thin, with moderately deep anal sinus on upper part of whorl, swinging forwards below.

Otaian—Waiauian, New Zealand; Recent, Indo-Pacific, tropical America in deep waters (bathyal zone). New Zealand records of *Eubela* are from deep-water assemblages.

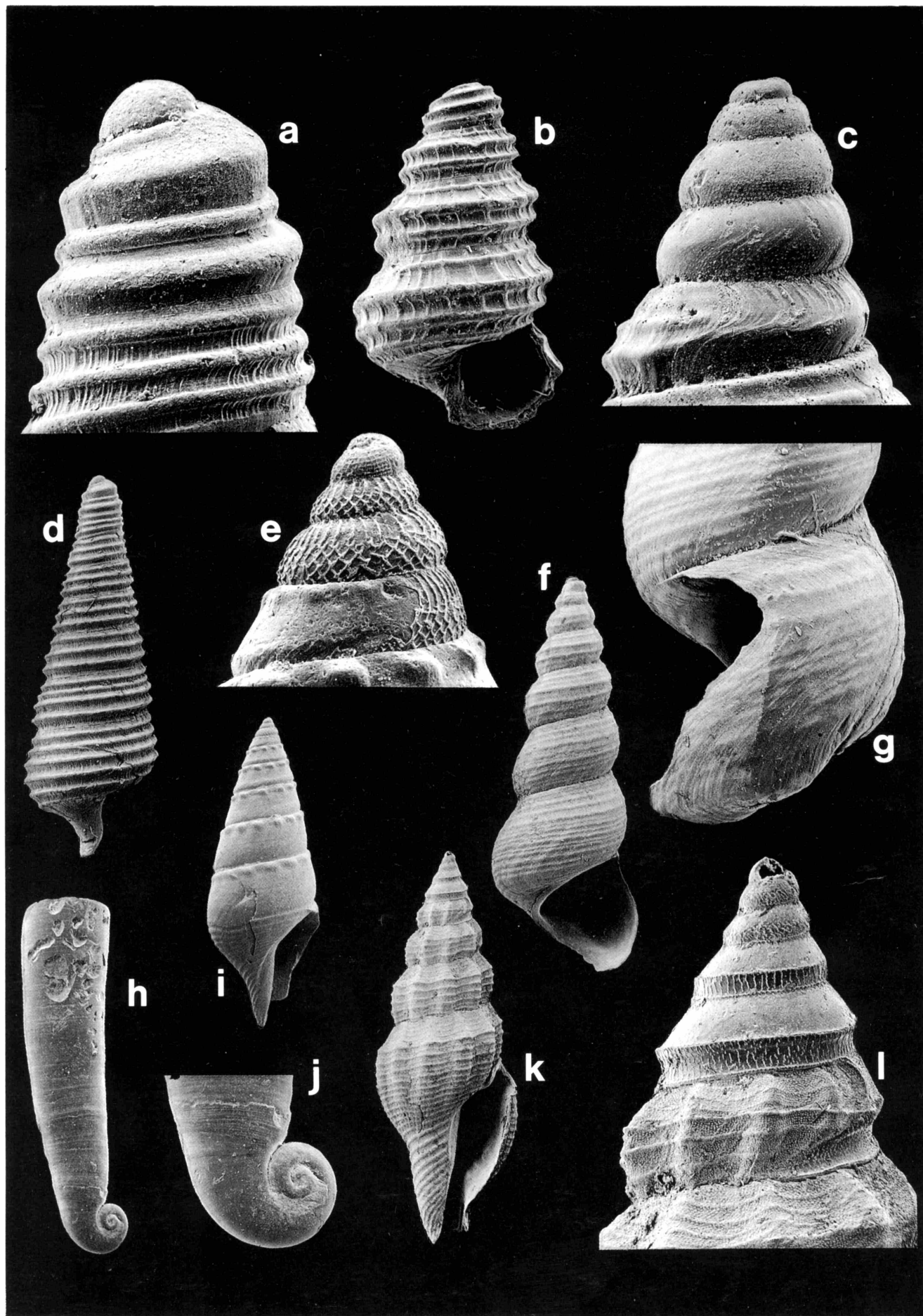
Example (Pl. 55e,i): *Eubela* aff. *awakinoensis* Powell, 1942; GS 3341, J32/f7585, abandoned brickworks quarry, Karoro, near Greymouth (Waiauian) x 10 (i), x 75 (e).

Pl. 56 a,b. Genus *Anapepta* Finlay, 1930 (Cancellariidae: Cancellariinae).

Height 6-13 mm, elongate-ovate; protoconch either smooth and bulbous, of about 1.5 whorls, or dome-shaped to subcylindrical of 3.5-4 whorls, with 2 (in a few species 3) prominent spiral cords on last whorl. Teleoconch whorls convex or weakly angled; sculpture of strongly prosocline costae (almost obsolete in some species) crossed by spiral

Plate 55 Representative micromolluscs (6).

- a,d. *Seila* (*Lyroseila*) *cincta* (Hutton), x 12.5 (d), x 75 (a, apex showing strongly keeled protoconch, and axial ridges between spiral cords on teleoconch).
- b. *Brooksena duplicincta* Laws, x 75.
- c,f,g. *Pareora striolata* (Hutton), x 15 (f), x 40 (c, apex showing protoconch with traces of granular microsculpture, and deep anal sinus), x 30 (g, lateral view of outer lip showing very deep anal sinus).
- e,i. *Eubela* aff. *awakinoensis* Powell, x 10 (i), x 75 (e, apex showing conical protoconch with characteristic "daphnelline" decussate sculpture on later whorls).
- h,j. *Strebloceras* n.sp., x 25(h), x 50 (j, showing protoconch and early part of teleoconch).
- k,l. *Etremopsis haroldi* Powell, x 10 (k), x 100 (l, apex showing elaborately sculptured protoconch, and granular microsculpture on teleoconch).



cords; no varices. Aperture reniform to ovate; columella subvertical above, twisted strongly to left near middle, bearing 2 prominent plaits. Outer lip lirate within.

Bortonian—Recent, New Zealand; Recent, Australia. Fossil species of *Anapepta* are recorded from a wide range of lithofacies indicating depositional environments extending from very shallow waters down into the upper bathyal zone. *Anapepta* is superficially similar to *Inglisella* Finlay, 1924 (see Pl. 22c) but differs in having a protoconch with strong spiral cords on the last whorl (*Inglisella* has axial costellae on the later part of the last whorl), in having strongly prosocline axial costae (but no varices), and in having a reniform aperture (in *Inglisella* the columella is almost straight and the aperture is trigonal).

Example (Pl. 56a,b): *Anapepta* aff. *finlayi* Marwick, 1931; GS12288, 045/f80, Fouraye Siltstone, left bank Waiau River, Clifden (Altonian) x 7.5 (b), x 25 (a).

Pl. 55 b. Genus *Brooksena* Finlay, 1927 (Mathildidae).

Height 1.0-3.3 mm, tall-spired; protoconch paucispiral, of about 1.5 whorls with strong spiral keels, initial whorl slightly immersed. Teleoconch whorls with 2 primary keels, additional cords appearing on later whorls on some species, and other narrow spirals on base of last whorl; axial sculpture of fine costellae. Aperture ovate, anterior end slightly effuse.

Waitakian—Recent, New Zealand; Miocene, Victoria. *Brooksena* was long included in the Rissoiidae, but Ponder (1967, p. 220) advocated its assignment to the Aclididae. More recently (Ponder 1985, p. 108) he has referred it (and *Veterator* Laws, 1941) to the Mathildidae, following Wenz (1940, p. 662). It resembles *Mathilda* Semper, 1865 in teleoconch sculpture, but differs in having a protoconch that is spirally keeled rather than smooth, and is not obviously heterostrophic. *Veterator* differs from *Brooksena* in having a smooth rather than a lirate protoconch.

Example (Pl. 55b): *Brooksena duplicincta* Laws, 1939; topotype, GS9730, Q8/f9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 75.

Pl. 56 i,j. Genus *Ringicula* Deshayes, 1838 (Ringiculidae).

Height 1.5-4.9 mm, elongate-ovate, spire moderately elevated. Protoconch narrowly dome-shaped, smooth, with small, slightly

immersed initial whorl. Teleoconch whorls convex, last whorl large, strongly convex; sculpture of incised spiral grooves. Aperture constricted posteriorly, with a shallow, strongly oblique channel immediately below columella. Columella short, bearing 2 strong plaits; some species with a prominent parietal plait as well. Outer lip thickened, smooth in some species, finely denticulate over its length or with a single strong denticle near middle in others.

Mangaorapan—Recent, New Zealand; cosmopolitan, recorded from Late Cretaceous—Recent and from a wide range of depths. Two major groups are represented in New Zealand—in one group (referred to *Ringicula* (sensu stricto)) there is a prominent parietal plait, and the outer lip typically bears a single strong denticle; in the other (subgenus *Ringiculina* Monterosato, 1884) the parietal plait is obsolete and the outer lip is smooth and typically thinner than in *Ringicula* (sensu stricto) (Maxwell 1988a, p. 75). The only described modern species from New Zealand, *R. delecta* Murdoch and Suter, 1906, belongs in *R. (Ringiculina)*.

Example (Pl. 56i,j): *Ringicula (Ringicula) castigata*, Marwick, 1929; topotype, GS9806, J45/f9668, Shell Gully, Chatton, Southland (Duntroonian) x 40 (j), x 150 (i).

Pl. 57 a,e,f. Genus *Evelynella* Laws, 1940 (Pyramidellidae: Odostomiinae).

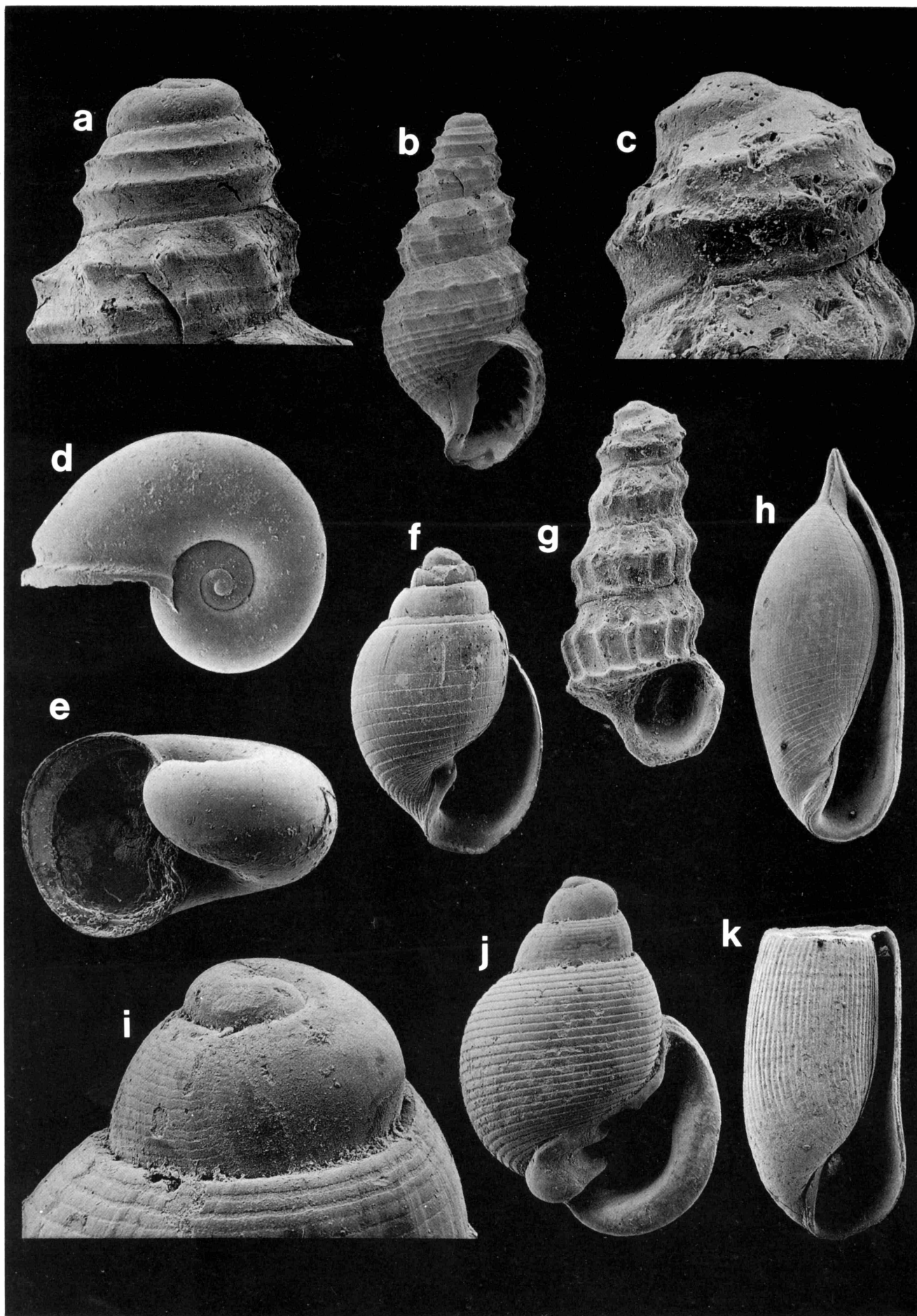
Height 2.5-4 mm, ovate-conic, spire moderately elevated. Protoconch heterostrophic, low-helicoid, of about 1.5 whorls with partly immersed initial whorl. Teleoconch whorls little-inflated, smooth except for very fine growth lines and, in some species, spiral striae or 1 or 2 grooves near suture. Columella concave, bearing a single prominent plait near posterior end; outer lip thin, almost straight, lirate within.

Duntroonian—Opoitian, New Zealand, in shallow-water to upper bathyal assemblages. *Evelynella* is similar to *Odostomia* (see below) in overall appearance, but is distinguished by the presence of lirations on the inside of the outer lip.

The Pyramidellidae is one of the most speciose and most widespread of all molluscan families in the New Zealand Cenozoic, and is represented in nearly all molluscan faunules, including those of very shallow-water and bathyal aspects. The checklist includes 175 nominal species (most of them described by Laws) but a large number of additional undescribed species are present in collections. Unfortunately, identification can be difficult

Plate 56 Representative micromolluscs (7).

- a,b. *Anapepta* aff. *finlayi* Marwick, x 7.5 (b), x 25 (a, apex showing prominent spiral keels on last whorl of protoconch).
- c,g. *Coenaculum* n.sp., x 50 (g), x 150 (c, apex showing prominently spirally keeled protoconch).
- d,e. *Spiratella ferax* Laws, x 50.
- f. *Acteon chattonensis* Marwick, x 15.
- h. *Volvulella reflexa* (Hutton), x 20.
- i,j. *Ringicula (Ringicula) castigata* Marwick, x 40 (j), x 150 (i, apex showing protoconch with partly immersed initial whorl).
- k. *Retusa* n.sp., x 20.



as the rather subtle differences between some species are not always very evident from the illustrations given in Laws' papers. It is also not clear from Laws' descriptions to what extent the individual species vary, and it is quite likely that some of the nominal taxa are superfluous. It is obviously quite impractical to cover all of the numerous genus-group taxa represented in the New Zealand fauna in this account, so we have selected several that are likely to be present in washings from fossiliferous horizons.

Laws did not make any attempt to subdivide the Pyramidellidae into suitable subfamilies, but we have followed such authors as Abbott (1974, p. 290-309) and Laseon (1959, p. 182-183) in accepting that some subdivision of this large group is desirable. The New Zealand pyramidellids fall into three groups, although it is not clear at present if these are truly monophyletic. The first, the Pyramidellinae, is characterised by relatively large shell size and by having two or three columellar plaits, and is so far known from New Zealand by only a single species (referred tentatively to *Pharcidella* Dall, 1889) from Altonian shellbeds on the north shore of Parengarenga Harbour. The second group, the Odostomiinae has a single columellar plait, and includes tall-spined forms such as *Syrnola* and *Tibersyrnola* as well as the much shorter-spined *Odostomia*, *Evelynella*, *Linopyrga*, etc. The remaining group, the Turbonillinae, is typically tall-spined and lacks a definite columellar plait, although a strong plait is present in some species currently included in *Turbonilla* (see below).

Pyramidellids are ectoparasites on other invertebrates, including polychaetes, coelenterates, bivalves and gastropods, but it seems that many species are not host-specific and that others range over the substrate looking for food, rather than remain permanently on their host. Example (Pl. 57a,e,f): *Evelynella venustas* Laws, 1940; GS11185, D45/f8822, Slip Point, Clifden Section, Waiau River (Clifdenian) x 25 (e), x 150 (a), x 50 (f).

Pl. 57 k,l. Genus *Linopyrga* Laws, 1941 (Pyramidellidae: Odostomiinae).

Height 2.2-4.5 mm, ovate-conic to elongate-ovate, spire varying considerably in height. Protoconch tilted, helicoid, of about 1.5 whorls. Teleoconch whorls flat-sided or gently convex; sculpture of prominent prosocline costae dying out gradually on base, and spiral threads between costae and on base. Aperture ovate, peristome continuous, columella with distinct plait; outer lip smooth within.

Duntroonian—Recent, New Zealand, mostly in inner to mid-shelf faunules. *Linopyrga* is characterised by the prominent prosocline costae and distinct intercostal spiral threads, and by the continuous peristome. *Bartrumella* Laws, 1940 is similar, but has a planorboid protoconch, and axial costae that are orthocline or slightly opisthocline rather than prosocline.

Example (Pl. 57k,l): *Linopyrga rugata* (Hutton, 1886) (type species of the genus); GS14430, Y14/f75051, Te Piki, Cape Runaway (Haweran) x 25 (l), x 50 (k).

Pl. 57 i,m. Genus *Odostomia* Fleming, 1817 (Pyramidellidae: Odostomiinae).

Height 1.7-6 mm, narrowly conic to elongate-ovate, spire of variable height. Protoconch tilted, apex exposed in some species, hidden by teleoconch in others. Teleoconch whorls flat-sided to distinctly convex; typically no sculpture except for very fine growth lines and in some species very fine spiral striae, but some species with 1 or 2 distinct grooves near suture. Columella with a single prominent fold; outer lip almost straight, smooth within.

Wangaloan—Recent, New Zealand; cosmopolitan, ranging from Late Cretaceous to Recent. *Odostomia* is a very "generalised" pyramidellid characterised by its relatively low spire, its absence of definite sculpture, its single strong columellar plait, and its smooth outer lip.

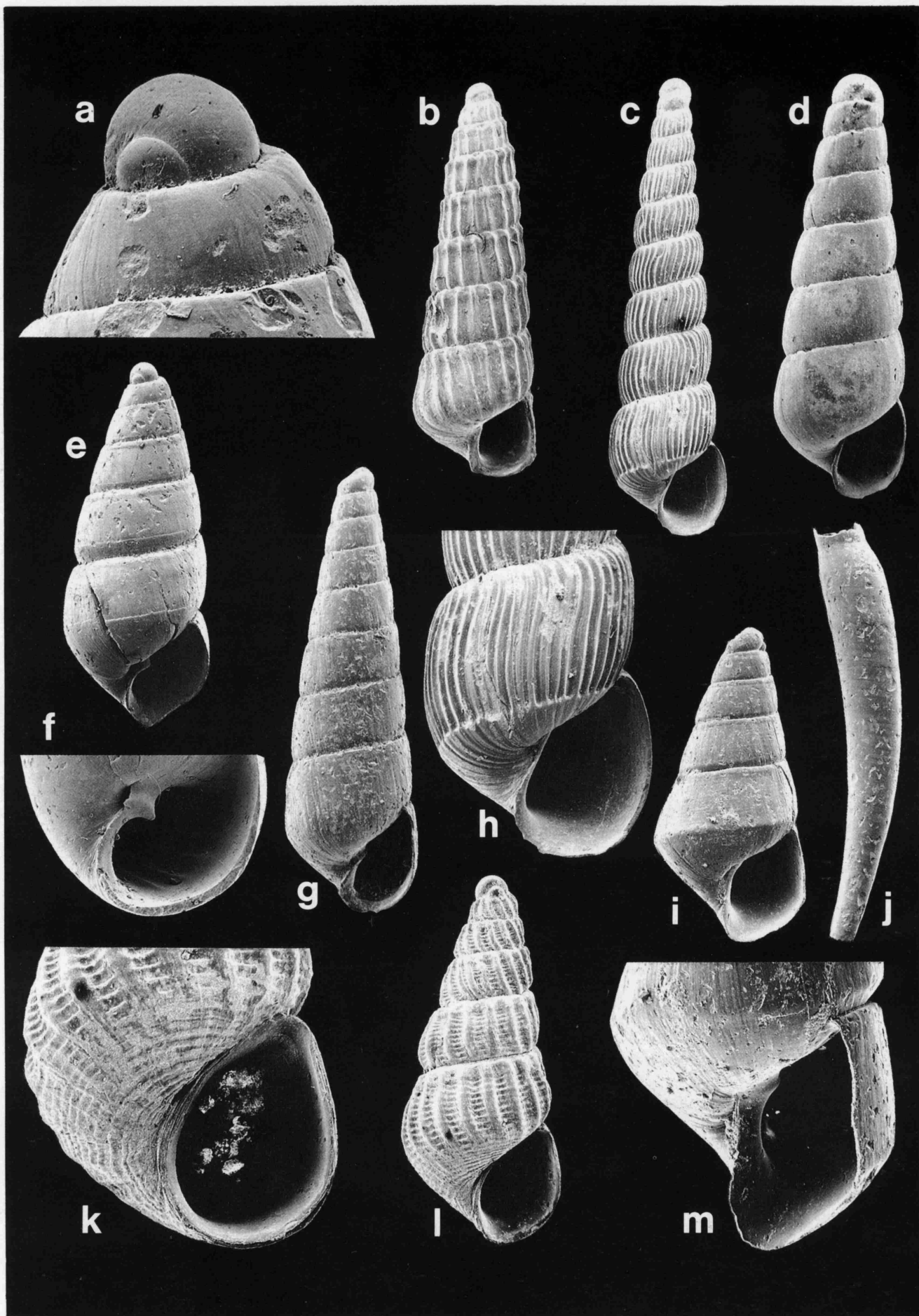
Example (Pl. 57i,m): *Odostomia obstinata* Laws, 1939; GS12324, J41/f198, Old Rifle Butts, Cape Wanbrow, Oamaru (Altonian) x 25 (i), x 50 (m).

Pl. 57 g. Genus *Syrnola* A. Adams, 1860 [Synonym: *Finlayola* Laws, 1937] (Pyramidellidae: Odostomiinae).

Height 2.3-6.7 mm, turriculate, attenuate, spire elevated, outline almost straight. Protoconch strongly tilted, planorboid or helicoid. Teleoconch whorls numerous, flat-sided or weakly convex or slightly overhanging anteriorly; no sculpture other than very fine growth lines and, in some species, spiral striae. Aperture relatively small, columella straight or

Plate 57 Representative micromolluscs (8).

- a,e,f. *Evelynella venustas* Laws, x 25 (e), x 150 (a, apex, showing typical pyramidellid heterostrophic protoconch with initial whorl partly hidden by first teleoconch whorl), x 50 (f, oblique basal view showing prominent columellar plait, and internal lirae within aperture).
- b. *Turbonilla natales* Laws, x 20.
- c,h. *Chemnitzia pliocenica* Laws, 1937, x 20 (c), x 40 (h, last whorl showing characteristic cessation of intercostal grooves on upper part of base).
- d. *Eulimella kempfi* Grant-Mackie and Chapman-Smith, x 30.
- g. *Syrnola finlayi* (Laws), x 20.
- i,m. *Odostomia obstinata* Laws, x 25 (i), x 50 (m, oblique apertural view showing columellar plait).
- j. *Cadulus (Gadila)* n.sp., x 25.
- k,l. *Linopyrga rugata* (Hutton), x 25 (l), x 50 (k, oblique basal view showing continuous peristome).



slightly concave, with a single strong plait at posterior end; outer lip smooth within.

Mangaorapan ?, Bortonian—Recent, New Zealand; widespread, probably cosmopolitan, ranging from Paleocene to Recent. *Syrnola* differs from *Odostomia* in its more slender shape, higher spire, and its more numerous teleoconch whorls, but some species may be difficult to assign confidently to one or other of these genera. *Finlayola* was proposed for species resembling *Syrnola* in general teleoconch characters, but having a planorboid rather than a helicoid protoconch. As is discussed below under *Turbonilla*, such a difference is not in itself an adequate reason for supraspecific distinction, and *Finlayola* is here synonymised with *Syrnola*.

Puposyrnola Cossmann, 1921 differs from *Syrnola* in its pupiform shape (i.e. the spire outline is distinctly convex) and in having a distinct parietal callus pad. *Tibersyrnola* Laws, 1937 is similar to *Syrnola* but has an internally lirate outer lip.

Example (Pl. 57g): *Syrnola finlayi* (Laws, 1937) (type species of *Finlayola*); GS12324, J41/f198, Old Rifle Butts, Cape Wanbrow, Oamaru (Altonian) x 20.

Pl. 57 c,h. Genus *Chemnitzia* d'Orbigny, 1839 (Pyramidellidae: Turbonillinae).

Height 2.2–5.8 mm, turriculate, spire elevated. Protoconch planorboid or helicoid, of 1–2 whorls, initial whorl noticeably projecting in helicoid type. Teleoconch whorls gently to moderately convex; axial sculpture of well developed costae of varying width, spacing and inclination, reaching from upper suture to, or almost to lower suture on spire, intercostal spaces stopping abruptly at edge of base on last whorl; no definite spiral sculpture. Aperture ovate, columella concave, typically smooth but some species with a weak posterior swelling; outer lip thin, smooth within.

Waitakian—Recent, New Zealand; widespread, probably cosmopolitan, Eocene—Recent. *Chemnitzia* differs from *Turbonilla* (see below) primarily in having the intercostal spaces stopping abruptly at the edge of the base rather than dying out gradually on the base itself. Other turbonilline taxa in which the intercostal spaces stop in this way (i.e. *Pyrgiscilla* Laws, 1937, *Striarcana* Laws, 1937 and *Gispyrella* Laws, 1937) differ from *Chemnitzia* in having definite spiral sculpture.

Example (Pl. 57c,h): *Chemnitzia pliocenica* Laws, 1937; topotype, GS14430, Y14/f75051, road cutting, Te Piki, Cape Runaway (Haweran) x 20 (c), x 40 (h).

Pl. 57 d. Genus *Eulimella* Jeffreys, 1847 (Pyramidellidae: Turbonillinae).

Height 2.7–9 mm, turriculate, spire moderately to greatly elevated. Protoconch helicoid, initial whorl not greatly projecting. Teleoconch whorls flattened to gently convex; no sculpture apart from growth lines, and in some species, very fine spiral striae. Aperture ovate, columella straight or slightly concave, some species with a weak posterior swelling, but no definite plait.

Bortonian—Recent, New Zealand; widespread, probably cosmopolitan, Eocene—Recent. *Eulimella* is distinguished from *Syrnola* (see above) by not having a definite columellar plait, and from *Turbonilla* and *Chemnitzia* in lacking axial costae. *Terelimella* Laws, 1937 also lacks axial costae, but differs in having a planorboid protoconch, a taller and narrower shell, and more strongly convex teleoconch whorls.

Example (Pl. 57d): *Eulimella kempfi* Grant-Mackie and

Chapman-Smith, 1971; topotype, GS14430, Y14/f75051, Te Piki, Cape Runaway (Haweran) x 30.

Pl. 57 b. Genus *Turbonilla* Risso, 1826 (Pyramidellidae: Turbonillinae).

Height 3–9.8 mm, turriculate, spire typically very elevated. Protoconch helicoid or planorboid, of 1–2.5 whorls, apex in helicoid type protruding laterally in some species. Teleoconch whorls typically flat-sided to moderately convex, medially concave in some species; sculpture of axial costae of varying width, spacing and inclination, typically straight but arcuate in some species, intercostal spaces dying out gradually over base (not stopping abruptly at edge); no spiral sculpture. Aperture ovate, columella typically smooth or with weak posterior swelling, but some species (see below) with definite plait.

Mangaorapan ?, Bortonian—Recent, New Zealand; cosmopolitan, Eocene–Recent. *Turbonilla* differs from *Chemnitzia* (see above) in the nature of the intercostal spaces—these do not stop abruptly at the edge of the base, but die out gradually on the base. *Pyrgolampros* Sacco, 1892, *Pyrgiscus* Philippi, 1841 and *Planpyrgiscus* Laws, 1937 differ in having distinct spiral sculpture. Those species referred by Laws (1937c, p. 175–179) to *Mormula* A. Adams, 1864 differ from *Turbonilla* in having broad, low varices in addition to axial costae; some species also have spiral sculpture. They do not seem to be congeneric with *M. rissoina* A. Adams, 1864—the type species—and require relocation.

Laws (1937a,b) subdivided both *Turbonilla* and *Chemnitzia* into two groups on the basis of the protoconch (i.e. whether it is planorboid or helicoid) and suggested that these groups are generically separable. However, it is now generally thought that such differences merely reflect differing types of larval development (i.e. non-planktotrophic and planktotrophic respectively) and do not in themselves warrant supraspecific discrimination.

Most New Zealand species of *Turbonilla* have a smooth columella or one with a weak posterior swelling, but some (i.e. *T. paleogenica*, *T. ngatapa* and *T. zesulcata*) have a prominent plait. This may indicate either that these species are incorrectly assigned to *Turbonilla*, or that the primary basis for distinguishing between the Turbonillinae and Odostomiinae is of dubious value.

Example (Pl. 57b): *Turbonilla natales* Laws, 1937; Slip Point, Clifden, Waiau River (Clifdenian) (ex C.R. Laws colln.) x 20.

Pl. 56 f. Genus *Acteon* Montfort, 1810 (Acteonidae).

Height typically 3–10 mm for New Zealand fossil species but some up to 15 mm, ovate, spire low to moderately elevated. Protoconch heterostrophic, tilted. Teleoconch whorls lightly to moderately convex, last whorl very capacious; sculpture of narrow spiral grooves, typically with fine axial costellae within. Aperture large, anterior end rounded, posterior end constricted; columella subvertical, with a single plait at posterior end.

Wangaloan—Recent, New Zealand; cosmopolitan, Late Cretaceous—Recent. Most records of modern New Zealand species of *Acteon* are from mid to outer shelf or upper bathyal depths, but at least some of the fossil species lived in shallower waters. *Pupa* Röding, 1798 has a bifid plait; *Ongleya* Finlay and Marwick, 1937 and *Tornatellaea* Conrad, 1860 have two columellar plaits; *Triploca* Tate, 1893 has three. The New Zealand acteonids formerly referred to *Leucotina* A. Adams, 1860 but herein tentatively assigned to *Tenuiactaeon* Aldrich, 1921 (see Pl. 49o) differ from *Acteon* in being higher-spined and in

typically having more prominent sculpture. *Crenilabium* Cossmann, 1889 has a concave columella lacking plaits but bearing numerous fine transverse ridges (Pl. 26r).

Example (Pl. 56f): *Acteon chattonensis* Marwick, 1929; topotype, GS9806, F45/F7668, Shell Gully, Chatton, Southland (Duntroonian) x 15.

Pl. 56 k. Genus *Retusa* Brown, 1827 (Retusidae).

Height 3-5.8 mm, cylindrical or subcylindrical, spire very low, flat or sunken. Protoconch smooth, flush or slightly projecting. Last teleoconch whorl very large, almost enveloping earlier whorls; smooth or with growth ridges and/or spiral threads. Aperture large, constricted over much of its length, anterior end rounded; columella straight or concave, smooth or with a weak plait.

Duntroonian—Recent, New Zealand; cosmopolitan, Middle Jurassic—Recent. *Retusa* is distinguished from other members of the family by the cylindrical or subcylindrical shape, by the very low spire (many species have a sharply truncate posterior end), and in not having the last whorl completely enveloping earlier whorls.

Example (Pl. 56k): *Retusa* n.sp.; GS9685, J41/F9499B, Pukeuri road-cutting, Oamaru (Altonian) x 20.

Pl. 56 h. Genus *Volvulella* Newton, 1891 [Synonym: *Rhizorus* of authors, not of Montfort, 1810 (see Harry 1967, p. 133)] (Retusidae).

Height 2.5-8 mm, ovate-fusiform, involute, spire produced into a short, open spine in most species, whorl sides gently to strongly convex; smooth or with sculpture of narrow spiral grooves. Aperture extending length of shell, constricted over most of its length, anterior end rounded; columella short, oblique, twisted but without a definite plait. A narrow pseudumbilicus present in some species.

Mangaorapan ?; Waitakian—Recent, New Zealand; widespread, Eocene–Recent. *Volvulella* is distinguished by its involute, ovate-fusiform shell, typically with the apex produced to form a short spine.

Example (Pl. 56h): *Volvulella reflexa* (Hutton, 1886); GS5354, J38/F6604, Tengawai River, near Albury, South Canterbury (Altonian) x 20.

Pl. 56 d,e. Genus *Spiratella* Blainville, 1817 [Synonym: *Limacina* Bosc, 1817 (see Curry 1981, p. 36)] (Spiratellidae).

Diameter 0.5-5 mm, sinistral, spire of variable height, elevated in some species, flat or sunken in others; some species non-umbilicate, others widely umbilicate. Most species smooth, weak spiral threads present in at least 1 species. Aperture ovate, columella vertical, somewhat twisted in some species; outer lip thin and simple, or reflected, or slightly thickened within, or with triangular protrusions.

Wangaloan—Recent, New Zealand; cosmopolitan (planktonic), Paleocene—Recent. *Spiratella* is the least derived genus of thecosome (i.e. shelled) pteropods, and probably represents the stem-group from which all other taxa have arisen. Numerous genus-group taxa have been proposed for spiratellids, based primarily on such characters as spire height, umbilical width, and the presence or absence of processes on the outer lip. Some of these taxa are probably worth recognising, e.g. *Altaspiratella* Korobkov, 1966 (as a subgenus of *Spiratella*) for the tall-spined, non-umbilicate (or very narrowly umbilicate) Early Eocene species, some of which are recorded from New Zealand. Marwick (1926b, p. 316) proposed *Lornia* for a relatively large, flat-spined, broadly umbilicate Late Eocene species—the group it represents is probably worth segregating from *Spiratella*, but it is likely to be a synonym of *Valvatina* Bornemann, 1855.

Example (Pl. 56d,e): *Spiratella ferax* Laws, 1944; topotype, GS9730, Q8/F9828, Holland's Point, Pakaurangi, Kaipara Harbour (Otaian) x 50.

Pl. 57 j. Genus *Cadulus* Philippi, 1844; Subgenus *Gadila* Gray, 1847 (Gadilidae).

Length 3-10 mm, slender, distinctly curved, ventral side convex, dorsal side gently concave; widest part of shell variable in position, just behind aperture in some species, near middle in others. Shell polished, typically without sculpture apart from growth lines, but some species with distinct transverse rings. Apex simple, without slits or notches.

Kaiatan—Clifdenian, New Zealand; cosmopolitan, Cretaceous—Recent.

Two major groups of scaphopods are recognised, primarily on the basis of anatomical differences, the Dentalioida and the Gadiloida (= Siphonodentalioida). Members of the former group are typically rather large (although they include many small species), include many strongly sculptured species (as well as smooth forms) and have the greatest diameter at the aperture. Those in the Gadiloida are relatively small (typically less than 10 mm in length, although some grow to 25-30 mm), are usually smooth (a few have distinct longitudinal or transverse sculpture), and with a few exceptions have the greatest diameter somewhere behind the aperture.

Because of their generally large size, species of the Dentalioida are usually well represented in collections, whereas the Gadiloida are often overlooked, even though they occur throughout the Cenozoic in New Zealand. To date only five fossil species of Gadiloida have been described from New Zealand, but a considerable number of undescribed species are known. Most of these belong in the Gadilidae, members of which have a constricted aperture, but a species of *Entalina* Monterosato, 1872—which is characterised by having a *Dentalium*-like shell of polygonal cross-section with distinct longitudinal sculpture and a non-constricted aperture—is recorded from the Kaiatan at McCulloch's Bridge, South Canterbury.

Some authors (e.g. Ludbrook in Moore 1960, p. 140; Emerson 1962, p. 476-480) recognise a single genus *Cadulus* in what is now known as the Gadilidae (i.e. excluding Siphonodentaliidae), and subdivide this into several subgenera. More recently (Starobogatov 1984; Palmer 1984) some of these taxa have been elevated to generic rank. We accept *Striacadulus* Emerson, 1962 as a full genus because it is amply distinguished from the other gadilids by its comparatively large size, and in having distinct longitudinal sculpture—it is here considered to include two fossil species, *S. prosperus* and *S. delli*. However, we have chosen to recognise *Cadulus* in a broad sense because some fossils are too imperfectly known to assign to an appropriate taxon, and also because some species (including the extant *C. delicatulus* Suter, 1913 and *C. teliger* Finlay, 1926) do not satisfactorily fit into any available taxon.

Cadulus (sensu stricto) is characterised by having a short, strongly inflated, cask-like shell in which the dorsal side is flat or convex, and in having a simple apex (i.e. lacking slits or notches). It may be represented in New Zealand by an undescribed species from Pakaurangi Point (Otaian). *Cadulus* (*Gadila*) differs in having a slender shell with a distinctly concave dorsal side. *Cadulus*

(*Polyschides*) Pilsbry and Sharp, 1898 has four prominent (and in some species, two additional weaker) apical slits, and is recorded from the Kaiatan at McCulloch's Bridge, South Canterbury. It should be emphasised, however, that the New Zealand scaphopod fauna is still poorly known so these taxa almost certainly have longer

stratigraphic ranges than these occurrences would indicate.

Example (Pl. 57j): *Cadulus (Gadila)* n.sp.; GS9517, I40/f9805, Campbell Park School, Waitaki Valley (Waitakian) x 25.

CHAPTER 18. CHECKLIST OF NEW ZEALAND CENOZOIC MOLLUSCA

A list follows of all named Cenozoic Mollusca we are aware of that occur in New Zealand. We have updated the list by Fleming (1966b) as fully as possible, but for many groups a modern revision is not available and the list given here is uncritical. For some groups a critical list is given but is based on our unpublished information. Some data on taxonomic positions have been given in the descriptive text for illustrated species; some taxonomic notes follow, in an appendix, about species or genera with an *asterisk in the list. We have elevated most "chronosubspecies" to species rank, following the assumption that changes in evolving lineages result in new species; most taxonomists reserve subspecies for the case of modern geographic subspecies. Time ranges are given in the same manner as by Fleming (1966b): symbols for New Zealand stages (see Figures 1 and 2 for stages and symbols), with Wq used for Haweran Stage and R for Recent. The first symbol (or symbols) following the name denotes the age of the type horizon, symbols in parentheses denote the recorded stratigraphic range. Generic names in "quotation" marks indicate that we are certain the listed species do not belong in that genus, but we are not aware of a suitable genus to place them in; i.e., they probably need a new genus. A question mark in front of a listed species name indicates that we are in doubt about its generic position. We have deliberately contravened a recommendation of the Code of Zoological Nomenclature by adopting the ending "-acea" for superfamily names, as "-oidea" is in our opinion too easily confused with the ending "oida", for orders.

The classification of the Mollusca is in a state of flux. The classification used below follows such standard works as Moore (1960, 1969), Wenz (1938-1944) and Zilch (1959-1960), with changes from all the later papers we are aware of, up to mid-1988 (most of them listed in the bibliography), but is far from final.

CLASS BIVALVIA

SUBCLASS PALEOTAXODONTA

ORDER SOLEMYOIDA

SUBORDER NUCINELLINA

SUPERFAMILY MANZANELLACEA

FAMILY MANZANELLIDAE

Nucinella Wood, 1850.

maoriana (Hedley, 1904). R(Pl?-R). Pl. 50b,d,e

ORDER NUCULOIDA

SUPERFAMILY NUCULACEA

FAMILY NUCULIDAE

SUBFAMILY NUCULINAE

Deminucula Iredale, 1931.

bergmansi Maxwell, 1988. Sw.

totangiensis (Marwick, 1931). Pl.

Lamellinucula Schenck, 1944.

ambrosia (Bartrum & Powell, 1928). Wo.

(?)*dunedinensis* (Finlay, 1928). R (Wq-R).

Linucula Marwick, 1931.

aptera (Laws, 1940). Wp.

delli Maxwell, 1988. Sw.

ruatakiensis (Marwick, 1926). Tt (Tt-Wp?).

tutamoensis (Marwick, 1931). Sl (Sl-Tt).

waiaotea (Laws, 1941). Pl (Po-Pl).

waipaoa (Marwick, 1931). Pl (Pl-Wo?).

wanganuica (Laws, 1940). Wn.

Nucula Lamarck, 1799.

hartvigiana Dohrn, 1864. R (Wn-R).

nitidula A. Adams, 1856. R (Wo-R).

otamatea Laws, 1939. Po (Po-Pl).

tersior Marwick, 1929. Ld.

vestigia Marwick, 1929. Ld.

Pronucula Hedley, 1902.

ngatutura (Laws, 1936). Wo.

Varinucula Maxwell, 1988.

crepida (Marwick, 1931). Sl (Sl-Sw).

sagittata (Suter, 1917). Pl. Pl.16b, d, f.

SUBFAMILY NUCULOMINAE

Ennucula Iredale, 1931.

grangei (Marwick, 1926). Tt.

strangei (A. Adams, 1856). R (Wc-R).

(?)*waikuraensis* (Marwick, 1931). Sl.

"*Ennucula*"

otamaringaensis (Marwick, 1926). Tt (Tt-Wo). **Pl. 28a**

SUPERFAMILY NUCULANACEA

FAMILY NUCULANIDAE

SUBFAMILY NUCULANINAE

Jupiteria Bellardi, 1875.

hampdenensis (Marwick, 1942). Ab (Ab-Ak?).

leachi (Marwick, 1931). Sc.

parleachi (Laws, 1939). Po.

vadosa (Laws, 1939). Po (Po-Pl).

Poroleda Hutton, 1893.

antiqua Marwick, 1942. Ab.

lanceolata (Hutton, 1885). R (Tk-R).

Propeleda Iredale, 1924.

trulliformis Marwick, 1931. Tt (Sl-Tt).

Pseudoportlandia Woodring, 1925.

ellisi (Marwick, 1926). Tt.

(?)*fluvilutea* (Marwick, 1931). Sc.

solenelloides (Marshall, 1919). Ab. **Pl. 5a, b.**

tahuia (Marwick, 1942). Ak (Ak-Ar).

totangiensis (Marwick, 1931). Pl?.

Saccella Woodring, 1925.

andrewi (Marwick, 1931). Sl (Sl-Sw).

arowhana (Marwick, 1931). Sc (Pl-Sc).

bellula (A. Adams, 1856). R (Wn-R).

duplicarina (Laws, 1939). Po (Po-Pl).

falcigera Marwick, 1965. Wo.

hedleyi (Fleming, 1951). R(Wc-R).

motutaraensis (Powell, 1935). Pl.

onairoensis (Marwick, 1926). Tt (Tt-Tk).

pahiensis (Fleming, 1950). Ab.

probellula (Marwick, 1929). Ld.

redunca (Dell, 1950). Po.

semiteres (Hutton, 1877). Ak? (Ab-Ak).

tenellula (Bartrum & Powell, 1928). Wo.

waihiana (Powell, 1931). Wp.

waikohuensis ((Marwick, 1931). Tt.

webbi Marwick, 1965. Wn.

Teretileda Iredale, 1929.

marwicki Maxwell, 1969. Ld.

SUBFAMILY LEDELLINAE

Ledella Verrill & Bush, 1897.

clifdenensis Powell, 1935. Sc (Po-Sl).

longirostrata Maxwell, 1969. Lw.

pakaurangiensis Laws, 1941. Po-Pl (Po-Tt).

Zealeda Marwick, 1924.

concentrica Marwick, 1931. Sl (Sl-Tt?).

crassicostata Maxwell, 1988. Sw.

hamata Marwick, 1924. Wp (Wo-Wp).

inflatella Marwick, 1931. Pl-Sc (Pl-Sc). **Pl. 50g, h.**

mutabilis Marwick, 1926. Tt (Tt-Tk).

FAMILY SAREPTIDAE

SUBFAMILY SAREPTINAE

Sarepta A. Adams, 1860.

aucklandica Marshall, 1918. Pl? (Po-Pl).

constricta (Marwick, 1942). Ab (Ab-Ak?).

SUBFAMILY YOLDIELLINAE

Ledina Dall, 1898.

taioma (Finlay & Marwick, 1937). Mw.

Yoldiella Verrill & Bush, 1897.

ardgowanica (Powell, 1935). Pl.

cuniculi (Marwick, 1965). Wn.

karaka (Marwick, 1931). Wo.

mohakana (Marwick, 1965). Wn.

otekaikensis Maxwell, 1969. Lw. **Pl. 50i, j.**

stimulea (Marwick, 1931). Sc (Sc-Sw).

uawa (Marwick, 1931). Sw-Tt?

FAMILY NEILONELLIDAE

Austrotindaria Fleming, 1948.

aequata Marwick, 1965. Wn.

benthicola Dell, 1956. R (Wc-R).

mawheraensis Maxwell, 1988. Sw.

Pseudotindaria Sanders & Allan, 1977.

catillus Maxwell, 1988. Sw.

(?)*ferrari* (Fleming, 1950). Ab.

kapua (Marwick, 1931). Wo.

kouhaiensis (Marwick, 1931). Tt? (Tt-Tk?).

nugax (Marwick, 1931). Tt.

(?)*provoluta* (Dell, 1950). Po.

FAMILY MALLETIIDAE

Minormalletia Dall, 1908.

nasuta Marwick, 1931. Sl (Pl-Wo).

simia Marwick, 1931. Sc (Pl-Wp).

tenera (Marwick, 1926). Tt.

Neilo A. Adams, 1854.

annectens Powell, 1931. Wp (Wo-R).

awamoana Finlay, 1926. Pl (Po-Pl). **Pl. 16a, c.**

australis (Quoy & Gaimard, 1835). R (Wc-R).

funiculata (Hutton, 1887). Lwh.

jugifera Marwick, 1965. Wo (Tk-Wo).

sinangula Finlay, 1926. Ld (Ld-Lw).

sublaevis Marwick, 1926. Tt (Sc-Tk). **Pl. 28b.**

wairoana Marwick, 1965. Wn.

waitaraensis Marwick, 1926. Tt.

Spineilo Finlay & Marwick, 1937.

elongata (Marshall, 1917). Mw. **Pl. 1b.**

SUBCLASS PTERIOMORPHIA

ORDER ARCOIDA

SUPERFAMILY ARCACEA

FAMILY ARCIDAE

SUBFAMILY ARCINAE

Acar Gray, 1857.

harringtoni Laws, 1947. Po.

opuraensis (Bartrum & Powell, 1928). Wo (Wo-Wm?).

powelli Laws, 1950. Wp.

sandersoni Powell, 1933. R (Wq-R).

whangaensis (Marwick, 1928). Wn.

Arca Linné, 1758.

chambersi Beu, 1973. Wp.

cottoni Waghorn, 1926. Wm (Wo-Wc). **Pl. 38d, e.**

pittensis Marwick, 1928. Wp.

subvelata Suter, 1917. Pl.

tutamoensis (Marwick, 1931). Sl.

waitemataensis (Powell & Bartrum, 1929). Po.

wharekuriensis Maxwell, 1969. Ld.

Barbatia Gray, 1842.

awamoana Finlay, 1930. Pl.

mundeformata (Laws, 1939). Po? (Po-Pl).

novaezealandiae (Smith, 1915). R (Wp-R). **Pl. 44c, f.**

SUBFAMILY ANADARINAE

Anadara Gray, 1847.

trapezia (Deshayes, 1839). R (Wc-Wq). **Pl. 44b, e.**

Bathyarca Kobelt, 1891.

bellatula Marwick, 1942. Ab (Ab-Ak).

crenulifera (Marwick, 1931). Tt? (Sl?-Wm).

cybaea Hedley, 1906. R (Wp-R).

pectinata (Marwick, 1931). Sl (Pl?-Sw).

Pugilarca Marwick, 1928.

barneaformis (Marwick, 1928). Wp.

Notogrammatodon Maxwell, 1966.

inexpectata Maxwell, 1966. Ak.

FAMILY NOETIIDAE

Quadrilatera Deshayes, 1860.

januaria (Marwick, 1926). Ak (Ak-Lwh). Pl. 7a, b.

FAMILY CUCULLAEIDAE

Cucullaea Lamarck, 1801.

(*Cucullastis*) Finlay & Marwick, 1937.

barbara Finlay & Marwick, 1937. Mw. Pl. 1a, c.

(*Cucullona*) Finlay & Marwick, 1937

inarata Finlay & Marwick, 1937. Mw. Pl. 1l, m.

(*Latiarca*) Conrad, 1862.

attenuata Hutton, 1873. Ld (Ld).

australis (Hutton, 1885). Pl (Po-Pl).

hamptoni Marwick, 1965. Tt (Tt-Tk).

ponderosa Hutton, 1873. Sl? (Sc-Sw).

singularis Zittel, 1864. Lwh.

waihaoensis Allan, 1926. Ab (Dp?-Ak).

worthingtoni Hutton, 1873. Lw (Lw). Pl. 10e, j.

SUPERFAMILY LIMOPSACEA

FAMILY LIMOPSIDAE

Limopsis Sassi, 1827.

campa Allan, 1926. Ab.

catenata Suter, 1917. Pl (Ld-Sw?). Pl. 16h, j.

cooki Marwick, 1931. Tt.

gisbornensis Maxwell, 1978. Sl (Sc?-Sl).

invalida Marwick, 1928. Wp.

lawsi King, 1933. Tt.

marwicki Powell, 1938. Wn.

parma Marwick, 1929. Ld.

peteri Beu, 1969. Wm (Wm-Wn).

producta Finlay & McDowall, 1923. Sw.

propeinvalida Laws, 1939. Po (Po-Pl).

waihaoensis Allan, 1926. Ak (Ab-Ar). Pl. 7c, d.

zealandica Hutton, 1873. Pl (Lw-Pl). Pl. 16e, g.

zitteli Ihering, 1907. Lwh.

(*Limopsista*) Finlay & Marwick, 1937.

microps Finlay & Marwick, 1937. Mw.

Notolimopsis Maxwell, 1969.

caelata Maxwell, 1969. Ld.

hampdenensis (Marshall, 1919). Ab (Ab-Ak).

pulchra Maxwell, 1969. Lw. Pl. 51c,d.

Pectunculina d'Orbigny, 1843.

aoteana Vella, 1954. Tt (Sw?-Tt).

FAMILY PHILOBRYIDAE

Aupouria Powell, 1937.

elongata Laws, 1940. Wo.

(?)*pristina* Maxwell, 1969. Lw.

rotunda Laws, 1940. Wo (Wo-Wn).

Cosa Finlay, 1926.

costata (Bernard, 1896). R (Wq-R).

filholi (Bernard, 1897). R (Wq-R).

kaawaensis Laws, 1936. Wo.

orbicula Laws, 1950. Wp.

separabilis Laws, 1940. Wo.

trigonopsis (Hutton, 1885). Wn (Wp-Wn).

wanganuica Finlay, 1930. Wc. Pl. 51e,g,h.

Cratis Hedley, 1915.

miocenica Laws, 1936. Sw.

ovata Marwick, 1931. Sw-Tt (Po?-Tt?).

pliocenica Laws, 1936. Wo.

Lissarca E.A. Smith, 1877.

fossilis Marwick, 1928. Wp.

inuitata (Laws, 1944). Po.

obsoleta (Laws, 1944). Po-Pl.

stationis Fleming, 1948. R (Wq-R).

Philobrya Carpenter, 1872.

awamoana (Laws, 1941). Pl.

dupliradiata (Laws, 1941). Po.

galerita Marwick, 1928. Wn.

kaawa (Laws, 1936). Wo.

meleagrina (Bernard, 1896). R (Wq-R).

modiolus Suter, 1913. R (Wp-R).

pinctada (Finlay, 1930). R (Wp-R).

pinctagrina (Laws, 1936). Wo.

tela (Laws, 1936). Wo.

waitotara (Laws, 1940). Wm.

zearana (Laws, 1941). Po.

FAMILY GLYCYMERIDIDAE

SUBFAMILY GLYCYMERIDINAE

Glycymeris Da Costa, 1778.

callaghani Marwick, 1923. Tt.

hunti Marwick, 1928. Wp.

mahiana Marwick, 1931. Wo (Tk-Wp).

marshalli Laws, 1930. Ld.

shrimptoni Marwick, 1923. Wn (Wm?-Wn). Pl. 38f, g.

trelissickensis Marwick, 1923. Ld.

waipipiensis Marwick, 1923. Wp (Wp-Wm).

waitakiensis Marwick, 1923. Ld.

(*Glycymerula*) Finlay & Marwick, 1937.

modesta (Angas, 1879). R (Wo-R).

Glycymerita Finlay & Marwick, 1937.

concava (Marshall, 1917). Mw. Pl. 1e, h.

cordata (Hutton, 1873). Lwh?

organi (King, 1934). Wp.

rangatira (King, 1934). Tt (Sc?-Wo). Pl. 28g, h.

robusta (Marwick, 1923). Pl (Pl-Sc).

subglobosa (Suter, 1917). Ab.

thomsoni (Marwick, 1929). Ld.

tohunga (King, 1934). Wo (Tk-Wo).

(*Manaia*) Finlay & Marwick, 1937.

hurupiensis (Marwick, 1923). Tt (Sw-Tt).

huttoni (Marwick, 1923). Tk? (Pl?-Tk).

kaawaensis (Marwick, 1923). Wo.

manaiaensis (Marwick, 1923). Wp (Wp-Wn). Pl. 32d, e.

marwicki (Matsukuma & Grant-Mackie, 1979). Sl.

SUBFAMILY MELAXINAEINAE

Tucetona Iredale, 1931.

aucklandica (Powell, 1938). Po.

(?)*brachytone* (Suter, 1917). Wo?

chambersi (Marshall & Browne, 1909). Wo.

finlayi (Laws, 1939). Sl (Pl-Sw). Pl. 23a, c.

laticostata (Quoy & Gaimard, 1835). R (Tt?-R).

lornensis (Marwick, 1923). Ak (Ak-Lwh). Pl. 7g, h.

monsadusta (Marwick, 1932). Sw.

traversi (Hutton, 1873). Wp.

wairarapaensis (Powell, 1938). Wn.

SUPERFAMILY MYTILACEA

FAMILY MYTILIDAE

SUBFAMILY MYTILINAE

Aulacomya Mörch, 1853.

ater maoriana (Iredale, 1915). R (Wp-R). Pl. 45a.

Hormomya Mörch, 1853.

(?)*willesti* (Marwick, 1928). Dw. Pl. 3e.

Mytilus Linné, 1758.

edulis aoteanus Powell, 1958. R (Wq-R). Pl. 45d, h.

Perna Retzius, 1788.

canaliculus (Gmelin, 1791). R (Wo-R).

tetleyi (Powell & Bartrum, 1929). Po.

Septifer Récluz, 1848.

torquatus (Marshall, 1918). Pl? (Po-Sw). Pl. 23d, e.

Trichomya Ihering, 1900.

huttoni (Cossmann, 1916). Pl (Pl). Pl. 16k.

SUBFAMILY CRENELLINAE

Crenella Brown, 1827.

radians (Suter, 1908). R (Wp-R).

Modiolarca Gray, 1843.

impacta (Hermann, 1782). R (Wp-R).

Musculus Röding, 1798.

elongatus (Hutton, 1873). Ld.

Trichomusculus Iredale, 1924.
barbatus (Reeve, 1858). R (Wo?-R).
lornensis (Laws, 1932). Ak.

SUBFAMILY LITHOPHAGINAE

Lithophaga Röding, 1798.
nelsoniana Suter, 1917. Lwh.

Zelithophaga Finlay, 1926.
truncata (Gray, 1843). R (Wn-R).

SUBFAMILY MODIOLINAE

Amygdalum Megerle, 1811.
dolichum (Suter, 1917). P? (Ld-Pl).
striatum (Hutton, 1873). Wc (Tk-Wc). Pl. 45b.

Dacrydium Torell, 1859.
simulator Laws, 1936. Wo

Modiolus Lamarck, 1799.
areolatus (Gould, 1850). R (Wo-R).

Notobotula Fleming, 1959.
molina (Fleming, 1959). Wc.

Xenostrobus Wilson, 1967.
altijugatus (Marwick, 1931). Tt (Tt-Wo). Pl. 28d.
huttoni (Suter, 1914). Wp (Wp-Wc). Pl. 39b.
securis (Lamarck, 1819). R (Wq-R).

SUPERFAMILY PINNACEA

FAMILY PINNIDAE

Atrina Gray, 1840.
pectinata zelandica (Gray, 1835). R (Tk?-R).

Pinna Linné, 1758.
distans Hutton, 1873. Po-Pl. (Ld?-Pl). Pl. 16i.
lata Hutton, 1873. Lwh (Ar-Lwh).

ORDER PTERIOIDA

SUBORDER PTERIINA

SUPERFAMILY PTERIACEA

FAMILY PTERIIDAE

Electroma Stoliczka, 1871.
intecta Finlay & Marwick, 1937. Mw.
rectangula Finlay & Marwick, 1937. Dp?

Pteria Scopoli, 1777.
oneroaensis (Powell & Bartrum, 1929). Po.

FAMILY ISOGNOMONIDAE

Isognomon Lightfoot, 1786.
fortissimus (King, 1933). Tt.
wellmani Crampton, 1988. Dt.

"Isognomon"

zelandicus (Hutton in Suter, 1917). Wn (Lw?-Wn). Pl. 23k,l.

SUPERFAMILY PECTINACEA

FAMILY PECTINIDAE

Athlopecten Marwick, 1928.
athleta (Zittel, 1864). Lw. (Ld-Lw). Pl. 11b.

Chlamys Röding, 1798.
araroensis Beu, 1970. Tk.
chathamensis (Hutton, 1873). Ld. Pl. 10a.
fischeri (Zittel, 1864). Po.
gemmulata (Reeve, 1853). R (Tt?-R). Pl. 44j, k.
mercuria Marwick, 1928. Dw. Pl. 4e, f.
patagonica delicatula (Hutton, 1873). Wn (Wm?; Wn-R). Pl. 38j.
scandula (Hutton, 1873). Wo?
seymouri Marwick, 1928. Wo.
williamsoni (Zittel, 1864). Lwh.
zelandiae (Gray, 1843). R (Wn-R).

Duplipecten Marwick, 1928.
(?)devinctus (Suter, 1917). Ab.
parki (Marwick, 1942). Ab (Ab-Ak).
waihaoensis (Suter, 1917). Ab. Pl. 5d.

Eburneopecten Conrad, 1865.
(?)imperfectus (Marwick, 1928). Dw.

"*Hinnites* Defrance, 1821."
marwicki Allan, 1946. Sw (Sl-Sw).
trailli Hutton, 1873. Pl. Pl. 17a, b.

Janupecten Marwick, 1928.
polemicus (Marwick, 1928). Lwh.
subteres Marwick, 1943. Ld.
uttleyi (Marwick, 1924). Lwh? (Ar?-Lwh) Pl. 10f.

Kaparachlamys Boreham, 1965.
hectori (Hutton, 1873). Wp.

Lentipecten Marwick, 1928.
hochstetteri (Zittel, 1864). Ld-w (Ld-Tk). Pl. 10c, d.

Mesopeplum Iredale, 1929.
burnetti (Zittel, 1864). Lw (Ak?-Tt?).
convexum (Quoy & Gaimard, 1835). R (Tt?-R). Pl. 44g.
costatostratum (Marshall, 1918). Po-Pl (Po-Pl).
dendyi (Hutton, 1902). Wo. Pl. 32b, g.
kaiparaense (Finlay, 1924). Po-Pl (Po-Pl).
polymorphoides (Zittel, 1864). Ld?
syagrus (Marwick, 1924). Pl (Pl-Wo?)
waikohuense (Marwick, 1931). Wo (Wo-Wp?)
(*Borehamia*) Beu, 1978.
crawfordi (Hutton, 1873). Wp (Wp; Wn?) Pl. 33f, g.
hilli (Hutton, 1873). Wm? (Wo-Wn).
toense (Marwick, 1928). Wo (Tk?-Wo).

Pecten Müller, 1776.

benedictus marwicki (Finlay, 1930). Wc. Pl. 45i.
kupei Fleming, 1957. Wc.
novaezelandiae Reeve, 1853. R (Wc-R).
tainui (Finlay, 1930). Wc (Wc-Wq). Pl. 45j.

Phialopecten Marwick, 1928.

marwicki (Beu, 1970). Wp. Pl. 33a.
ongleyi Marwick, 1965. Wo. Pl. 33e.
tolagaensis (Marwick, 1931). Tk.
triphooki (Zittel, 1864). Wn (Wm-Wn). Pl. 33b.

Sectipecten Marwick, 1928.

allani Marwick, 1928. Wo (Wo-Wm). Pl. 33c.
diffusus (Hutton, 1873). Sw.
grangei Boreham, 1961. Tt. Pl. 28c.
mariae (Finlay, 1927). Wn (Wp?; Wm-Wn). Pl. 38 h,i.
wollastoni (Finlay, 1927). Tk. Pl. 28f.

Serripecten Marwick, 1928.

enfieldensis (Marwick, 1926). Ak (Ak-Ar?).
hutchinsoni (Hutton, 1873). Pl (Pl-Tt). Pl. 17f, g.
tahuianus Laws, 1935. Ab.
tiorioriensis Marwick, 1928. Dw. Pl. 4b.
venosus (Hutton, 1873). Ar. Pl. 7i.

FAMILY PROPEAMUSSIIDAE

Cycloclamys Finlay, 1926.
aupouria (Powell, 1937). R (Wp-R).
shepherdii (Laws, 1939). Po (Po-Pl).
transenna (Suter, 1913). R (Wq-R).

Parvamussium Sacco, 1897.

aucklandicum (Zittel, 1864). Po (Po-Pl). Pl. 51a,b,f.
maorium Dell, 1956. R (Wm-R).
paradoxum (Maxwell, 1969). Ld.
vafer (Marwick, 1931). Sl.

Propeamussium de Gregorio, 1884.

papakureense (Clarke, 1905). Po.
zitteli (Hutton, 1873). Lwh (Lwh-Tt?). Pl. 27e.

FAMILY SPONDYLIDAE

Spondylus Linné, 1758.
aucklandicus Marshall, 1918. Po-Pl (Po-Sc).

FAMILY DIMYIDAE

Dimya Rouault, 1850.
kaiparaensis Laws, 1944. Po? (Po-Pl).
westonensis Maxwell, 1978. Ar.

SUPERFAMILY ANOMIACEA

FAMILY ANOMIIDAE

SUBFAMILY ANOMIINAE

Anomia Linné, 1758.

trigonopsis Hutton, 1877. Pl (Ab-R). Pl. 18a, b.

Patro Gray, 1850.

undatus (Hutton, 1885). Wn (Tk?-Wn). Pl. 39d, f.

SUBFAMILY PLACUNANOMIINAE

Pododesmus Philippi, 1837.

incisurus (Hutton, 1873). Pl? (Lw-Pl). Pl. 18c, f.

maxwelli Beu, 1967. Ld (Lwh?-Ld).

paucicostatus Beu, 1967. Sc (Sc-Sw).

(*Monia*) Gray, 1850.

zelandicus (Gray, 1843). R (Tk-R).

SUPERFAMILY LIMACEA

FAMILY LIMIDAE

Acesta H. & A. Adams, 1858.

imitata (Suter, 1917). Lw.

levitesta (Finlay, 1927). Lw (D?-Wm?-R?).

regia (Suter, 1917). Lwh?

Ctenoides H. & A. Adams, 1858.

gracilissimus Beu, 1967. Wm.

naufagus Marwick, 1928. Wp.

Divarilima Powell, 1958.

aucklandensis (Laws, 1950). Wp.

Lima Bruguière, 1797.

becki Fleming, 1955. Tk.

colorata Hutton, 1873. Pl (Po-Sw?). Pl. 18e, h.

paleata Hutton, 1873. Lw (Lwh-Lw).

robini Fleming, 1950. Wo.

vasis Marwick, 1928. Wp.

waipipiensis Marshall & Murdoch, 1919. Wp (Tk?-Wp). Pl. 33d.

watersi Marwick, 1926. Tt.

zealandica Sowerby, 1876. R (Wn-R).

Limaria Link, 1807.

orientalis (A. Adams & Reeve, 1850). R (Ld?-R). Pl. 44m, n.

Limatula Searles Wood, 1839.

arcis Fleming, 1978. Ld (Ld-Lw?).

craigensis Fleming, 1955. Tk (Lw-Tk).

maoria Finlay, 1926. Wc (Wp-R).

pontis Fleming, 1978. Ak.

suteri (Dall, 1908). R (Lw-R).

trulla Marwick, 1926. Ak (Ak-Lwh).

(*Limatulella*) Fleming, 1978.

delli Fleming, 1978. R (Wo-R).

moriaria Marwick, 1928. Tk.

waitahana Fleming, 1978. Ak (Dw-Lwh).

(*Stabilima*) Iredale, 1939.

exulans Fleming, 1978. Pl. Pl. 17c.

gagei Fleming, 1978. Sc.

maxwelli Fleming, 1978. Sw.

waiaotea Laws, 1944. Po.

waipipiensis Fleming, 1978. Wp (Wp-Wm?).

Limea Bronn, 1831.

chathamensis Marwick, 1928. Tk.

(?)*inconspicua* (Marwick, 1926). Ak.

Notolimea Iredale, 1924.

broccha Marwick, 1931. Sl.

SUBORDER OSTREINA

SUPERFAMILY OSTREACEA

FAMILY GRYPHAEIDAE

SUBFAMILY PYCNODONTEINAE

Crenostrea Marwick, 1931.

cannoni (Marwick, 1928). Dw. Pl. 3a, f.

gittosina (Powell & Bartrum, 1929). Po.

wuellerstorfi (Zittel, 1864). Ld-Lw. Pl. 12a, b.

Pycnodonte Fischer de Waldheim, 1835.

mackayi (Suter, 1917). Ab.

(*Notostrea*) Finlay, 1928.

subdentata (Hutton, 1873). Lwh. Pl. 9b, f.

tarda (Hutton, 1873). Dw. Pl. 3b, c.

FAMILY OSTREIDAE

SUBFAMILY OSTREINAE

Crassostrea Sacco, 1897.

ingens (Zittel, 1864). Wm (?Tt-Wn). Pl. 32f.

(?)*nelsoniana* (Zittel, 1864). Po.

Cubitostrea Sacco, 1897.

gudexi (Suter, 1917). Ab (Dp?-Ab). Pl. 5c, e.

Flemingostrea Vredenburg, 1916.

(?)*suteri* (Ihering, 1907). ?Ld-Lw.

wollastoni (Finlay, 1927). Lw-Po (Ld-Lw). Pl. 11g, i.

Ostrea Linné, 1758 (sensu lato).

arcula Marwick, 1928. Wo.

waitangiensis Marwick, 1928. Dw.

Tiostrea Chanley & Dinamani, 1980.

chilensis lutaria (Hutton, 1873). R (Tk-R). Pl. 44i, l.

SUBCLASS PALAEOHETERODONTA

ORDER UNIONOIDA

SUPERFAMILY UNIONACEA

FAMILY UNIONIDAE

SUBFAMILY UNIONINAE

Cucumerunio Iredale, 1934.

websteri websteri (Simpson, 1902). R (Wq?-R).

SUBFAMILY HYRIINAE

Hyridella Swainson, 1840.

(*Velesunio*) Iredale, 1934.

(?)*huttoni* (McMichael, 1956). Lwh.

menziesi (Gray, 1843). R (Wq?-R).

SUBCLASS HETERODONTA

ORDER VENEROIDA

SUPERFAMILY LUCINACEA

FAMILY LUCINIDAE

Dilora Marwick, 1948.

lorea Marwick, 1948. Wp.

Divaricella Martens, 1880.

(*Divalucina*) Iredale, 1936.

huttoniana (Vanatta, 1901). R (Ab?, Ld-R). Pl. 46b.

Gonimyrtea Marwick, 1929.

alta Marwick, 1965. Wo.

bucculenta Marwick, 1929. Ld (Ld-Lw).

concinna (Hutton, 1885). Wc (Wo-R).

discus Marwick, 1943. Pl.

Loripinus Monterosato, 1883.

(?)*arapaoa* Fleming, 1950. Ab.

Lucinoma Dall, 1901.

galathea Marwick, 1953. R (Wo-R). Pl. 34e, f.

taylori (Powell, 1935). Pl.

Miltha A. Adams, 1857.

agilis Finlay & Marwick, 1937. Mw.

neozelanica Marshall & Murdoch, 1921. Wp (Lw-Wp). Pl. 35a, j.

Milthona Marwick, 1931.

glomerosa Marwick, 1931. Tt?

Myrtea Turton, 1822.

haurangiensis Vella, 1954. Tt.

maoria Powell, 1935. Pl.

microlirata (Finlay & Marwick, 1937). Mw.

papatikiensis Marwick, 1926. Tt (Sw-Tt).

sera Marwick, 1965. Wo.

staminifera (Marwick, 1929). Ld.

supraflexa (Marwick, 1931). Sc.

valdesculpta Marwick, 1943. Pl. Pl. 18j, l.

Pteromyrtea Finlay, 1926.

auriculata (Bartrum, 1919). Po-Pl (Po-Pl).

cristata Marwick, 1931. Tt.

dispar (Hutton, 1873). Wo (Wo-Wn). **Pl. 35g.**
disparilis Laws, 1944. Pl (Po-Pl).
exilis Marwick, 1943. Pl.
laminata (Hutton, 1885). Pl.
motutaraensis Powell, 1935. Pl.
obesa Finlay & Marwick, 1937. Mw.
tirangiensis (Marwick, 1926). Tt.

FAMILY UNGULINIDAE

Diplodonta Brown, 1831.
 (*Zemysina*) Finlay, 1926.
densiscalpta Marwick, 1960. Dp?
globus (Finlay, 1926). R (Pl?-R).
striatula (Finlay, 1926). R (Wc-R).

Felaniella Dall, 1899.

(*Zemysia*) Finlay, 1926.
ampla (Hutton, 1885). Wc.
infrequens (Marwick, 1926). Ak.
zelandica (Gray, 1835). R (Sw-R).

FAMILY THYASIRIDAE

Genaxinus Iredale, 1930.
cookianus Fleming, 1950. R (Wc-R).

Maorithyas Fleming, 1950.
marama Fleming, 1950. R (Wq-R).

Thyasira Lamarck, 1818.
bartrumi Powell, 1935. Pl.
motutaraensis Powell, 1935. Pl.
peregrina (Iredale, 1930). R (Wp-R).
planata Marwick, 1926. Tt.
waikanae Fleming, 1950. R (Wc-R).

SUPERFAMILY CHAMACEA

FAMILY CHAMIDAE

Chama Linné, 1758.
huttoni Hector, 1886. Wn.
pittensis Marwick, 1928. Wp.

SUPERFAMILY GALEOMMATACEA

FAMILY ERYCINIDAE

Arthritica Finlay, 1926.
ambotruncata Laws, 1944. Po.
bifurca (Webster, 1908). R (Wo-R).
crassitesta Laws, 1950. Wp.
dispar Laws, 1940. Wo (Wo-Wn).
elongata Laws, 1936. Wo.
finlayi Laws, 1950. Wp.
perfragilis Laws, 1950. Wp.

Borniola Iredale, 1924.
brevitas (Laws, 1944). Po-Pl (Po-Pl).
kaawaensis (Bartrum & Powell, 1928). Wo.
reniformis (Suter, 1908). R (Wo-R).

Lasaea Brown, 1827.
dingleyi Laws, 1950. Wp.
hinemoa Finlay, 1928. R (Wq-R).

Myllita d'Orbigny & Récluz, 1850.
 (*Zemylita*) Finlay, 1926.
bartrumi (Laws, 1940). Wo.
praecursor (Laws, 1940). Wo.

Myllitella Finlay, 1926.
finlayi (Marwick, 1924). Wn (Wp-Wn).
fragilis Laws, 1936. Wo.
vivens vivens Finlay, 1926. R (Wq-R).
vivens pinguis Marwick, 1928. Wn (Wn-R).

Melliteryx Iredale, 1924.
angulata Laws, 1936. Wo.
effosa (Hutton, 1885). Wn.
furtiva Laws, 1950. Wp. **Pl. 52f,i,j,k.**
parva (Deshayes, 1857). R (Wo-R).
mirifica Powell & Bartrum, 1929. Po (Po-Sc?).

Semeloidea Bartrum & Powell, 1928.
 (?)*abdiplex* (Marwick, 1931). Pl?

donaciformis Bartrum & Powell, 1928. Wo.
miocenica Laws, 1932. Pl.

FAMILY KELLIIDAE

Kellia Turton, 1822.
antiqua Marwick, 1926. Ak.
cycladiformis (Deshayes, 1839). R (Wo-R).
inchoata Marwick, 1926. Pl.

FAMILY MONTACUTIDAE

Mysella Angas, 1877.
apudalpha Laws, 1940. Po (Po-Pl).
hounselli (Powell, 1931). Wc (Wn-R).
larochi Powell, 1940. R (Wq-R).
putealis Laws, 1950. Wp.
tellinula (Odhner, 1924). R (Wo?-R).

FAMILY GALEOMMATIDAE

Scintillona Finlay, 1926.
zelandica (Odhner, 1924). R (Pl?, Wc-R).

FAMILY CYAMIIDAE

Cyamium Philippi, 1845.
 (*Cyamiomactra*) Bernard, 1897.
problematicum (Bernard, 1897). R (Wn?-R).

Kidderia Dall, 1876.
aupouria fiordlandica Fleming, 1948. R (Wq-R).
otamatea Laws, 1939. Po.
 (*Costokidderia*) Finlay, 1926.
lyallensis (Finlay, 1926). R (Wq-R).

Perrierina Bernard, 1897.
bensoni King, 1933. Wn.
ovata Marwick, 1928. Wn.
sola Laws, 1936. Wo.

FAMILY LEPTONIDAE

Lepton Turton, 1822.
neozelanicum Laws, 1950. Wp.

FAMILY NEOLEPTONIDAE

Neolepton Monterosato, 1875.
antipodum (Filhol, 1880). R (Pl-R). **Pl. 52 b,e,g,h.**
subobliquum (Powell, 1937). R (Wc-R).

Pachykellia Bernard, 1897.
bernardi Powell, 1927. R (Wc?-R).
concentrica Powell, 1927. R (Wm-R).
edwardsi Bernard, 1897. R (Wc-R).

Puyseguria Powell, 1927.
crenulifera Maxwell, 1969. Lw.
wanganuica Powell, 1931. Wc (Wn-Wc).

FAMILY SPORTELLIDAE

Anisodonta Deshayes, 1858.
 (*Tahunanuia*) Powell, 1952.
alata (Powell, 1952). R (Wq-R).

SUPERFAMILY CARDITACEA

FAMILY CARDITIDAE

SUBFAMILY CARDITINAE

Cardita Bruguière, 1792.
aoteana Finlay, 1929. R (Wo-R).
marwicki Laws, 1944. Po-Pl.
northcrofti Marwick, 1928. Wp.

SUBFAMILY VENERICARDIINAE

"*Cyclocardia*" Conrad, 1867.
awamoensis (Harris, 1897). Pl (Ld?-Pl). **Pl. 17h, i.**
christiei (Marwick, 1929). Ld. **Pl. 10g, i.**
marama (Maxwell, 1969). Lw.
pseutella (Marwick, 1929). Ld.

Glyptoactis Stewart, 1930.
 (*Fasciculocardia*) Maxwell, 1969.
acanthodes (Suter, 1917). Ab. **Pl. 5g, h.**
bartrumi (Fleming, 1950). Ab.

benhami (Thomson, 1908). Lwh. **Pl. 9c, d.**
faceta (Suter, 1917). Ld.
healyi (Fleming, 1950). Ab.
nuntia (Marwick, 1928). Dw. **Pl. 3j.**
subintermedia (Suter, 1917). Po-Pl (Po-Sl). **Pl. 23g.**

Megacardita Sacco, 1899.
ponderosa (Suter, 1913). Ld (Ld). **Pl. 12i, j.**
squadronensis (Powell, 1938). Po.

Pleuromeris Conrad, 1867.
finlayi Powell, 1938. Wn (Wm-Wn).
hectori Powell, 1938. Wn (Wm?-Wn). **Pl. 39a, c.**
instata Laws, 1944. Pl (Pl-Sc).
kapuaensis (Marwick, 1931). Wo (Tt-Wo).
koruahinensis (Bartrum & Powell, 1928). Wo.
marshalli (Marwick, 1924). R (Wn-R).
miniscula (Bartrum & Powell, 1928). Wo.
murdochi Powell, 1938. Wn.
otamateaensis Laws, 1944. Po.
paucicostata Laws, 1940. Wn (Wn-R).
prolutea (Marwick, 1929). Ld.
waitotara Laws, 1940. Wo.
zelandica (Deshayes, 1854). R (Wm?-R).

Pteromeris Conrad, 1862.
minima (Marwick, 1924). Wn.

Purpurocardia Maxwell, 1969.
beata (Marwick, 1928). Wp (Tk?-Wp).
(?)fyfei (Finlay & Marwick, 1937). Mw. **Pl. 1f, i.**
haskelli (Fleming, 1950). Wo.
lilliei (Fleming, 1943). Wm? (?Wo?-Wm).
penerectangularis (Bartrum & Powell, 1928). Wo.
perscrupulosa (Marwick, 1932). Pl (Pl-Sw). **Pl. 17d, e.**
purpurata (Deshayes, 1854). R (Wo?; Wp-R). **Pl. 32a, c.**
southlandica Fleming, 1955). Tk.
titirangiensis (Marwick, 1943). Wn.
waikohuensis (Marwick, 1926). Wo (Tk-Wo).
urutiensis (Marwick, 1926). Tt.

Verticipronus Hedley, 1904.
mytilus Hedley, 1904. R (Wq-R).
stirps Laws, 1936. Wo.

FAMILY CONDYLOCARDIIDAE
Benthocardiella Powell, 1930.
orbicula Powell, 1930. R (Wo-R).
pusilla Powell, 1930. R (Wc-R).

Condylocardia Bernard, 1896.
crassicosta Bernard, 1896. R (Wq-R).

Condylocuna Iredale, 1936.
concentrica (Bernard, 1896). R (Wn?-R).
dupliora (Laws, 1940). Wn (Wo-Wn).
flemingi Maxwell, 1969. Ld (Ld-Lw).
subaequilateralis (Maxwell, 1966). Ak.
torquata (Marwick, 1928). Wn.

FAMILY CUNIDAE
Cuna Hedley, 1902.
crassicardo Laws, 1936. Wo.
morator Laws, 1940. Wp.

Hamacuna Cotton, 1931.
kaawa (Laws, 1936). Wo.
nukumaruensis (Laws, 1940). Wn (Wm-Wn).
otagoensis (Powell, 1927). R (Wc?-R).

Volupicuna Iredale, 1938.
antiqua (Marwick, 1928). Wp.
awheaensis (Beu, 1970). Tt.
caerulea (Fleming, 1955). Tk.
(?)cerussata (Bartrum & Powell, 1928). Wo.
fictilia (Laws, 1936). Wo.
firma (Marwick, 1928). Wn.
kaipara (Laws, 1944). Po.
laqueus (Finlay, 1926). R (Wm-R).
mayi (Powell, 1930). R (Wc-R).
ngatutura (Laws, 1940). Wo.

otahuica (Laws, 1950). Wp.
tuta (Marwick, 1931). Sl (Pl?-Sl).

FAMILY CRASSATELLIDAE

Eucrassatella Iredale, 1924.
ampla (Zittel, 1864). Po (Ld-Tt). **Pl. 12d, e.**
australis (Hutton, 1873). Ab (Dm?-Ak). **Pl. 5f, i.**
marshalli Powell, 1931. Wp (Tk-Wp).

Salaputium Iredale, 1924.
animula (Marwick, 1929). Ld.
tinopaica Laws, 1939. Po-Pl (Po-Pl).

Spissatella Finlay, 1926.
acculta Finlay, 1926. Ld.
clifdenensis Finlay, 1926. Pl (Pl-Sc?).
concisa Finlay, 1926. Pl.
discrepans Finlay, 1926. Ld-Lw.
luteophila Marwick, 1931. Sc.
media (Marwick, 1926). Ak (Ak-Lwh?).
poroleda Finlay, 1926. Ld.
scopalveus Finlay, 1926. Pl (Pl-Tt?).
subobesa (Marshall & Murdoch, 1919). Ld. **Pl. 11a.**
trailli (Hutton, 1873). Pl (Po-Pl). **Pl. 18i, k.**

Talabrica Iredale, 1924.
nummaria Powell, 1931. Wn.
inornata Wild & King, 1932. Wn.
senecta Powell, 1931. Wn (Wm-Wn). **Pl. 40b, f.**

SUPERFAMILY CARDIACEA

FAMILY CARDIIDAE

SUBFAMILY CARDIINAE

Maoricardium Marwick, 1944.
(?)coxi (Hector, 1886). Lw?
gudexi (Laws, 1933). Pl (Pl-Sl).
oneroaense (Powell, 1938). Po.
spatiosum (Hutton, 1873). Wm (Sl-Wm). **Pl. 34i, j.**
strangi (Laws, 1930). Ld.

SUBFAMILY TRACHYCARDIINAE

Trachycardium Mörch, 1853.
(Ovicardium) Marwick, 1944.
rossi Marwick, 1944. Wp (Tk-Wm). **Pl. 34a, b.**
(Regozara) Iredale, 1936.
delectabile Maxwell, 1978. Sc.

SUBFAMILY PROTOCOLIINAE

Hedecardium Marwick, 1944.
brunneri (Hector, 1886). Ak (Ab-Ak).
collinsi Marwick, 1960. Dp?
olssoni Marwick, 1944. Ld.
subcordatum (Suter, 1917). Ld.
waitakiense (Suter, 1907). Ld. **Pl. 13d, e.**
(Titanocardium) Maxwell, 1978.
cantuariense (Laws, 1933). Pl. **Pl. 19d, e.**
greyi (Hutton, 1873). Po (Lw-Po).
marwicki Maxwell, 1978. Sl.

Nemocardium Meek, 1876.

(Pratulium) Iredale, 1924.
finlayi Bartrum & Powell, 1928. Wo (Tk-Wp).
**(1)marwicki* Beu & Maxwell, nom. nov. Dw.
modicum Marwick, 1944. Mw.
pulchellum (Gray, 1843). R (Wm-R). **Pl. 46k.**
quinarium Marwick, 1944. Wo (Tt-Wp). **Pl. 34c.**
semitectum Marwick, 1926. Ak (Ak-Ar).
(Varicardium) Marwick, 1944.
patulum (Hutton, 1873). Pl (Pl-Sw). **Pl. 19b, i.**
serum (Hutton, 1873). Ld.

FAMILY LAHILLIIDAE

Lahillia Cossmann, 1899.
neozelanica Marshall & Murdoch, 1923. Mw. **Pl. 1j, k.**
(?)praeobtusata Finlay & Marwick, 1937. Mw.

SUPERFAMILY MACTRACEA

FAMILY MACTRIDAE

SUBFAMILY MACTRINAE

Cyclomactra Dall, 1895.

- (?)*altitulum* (Marwick, 1927). Sl (Sl-Sw).
- ovata* (Gray, 1843). R (Wp?-R). Pl. 45f, g.
- rudis* (Hutton, 1873). Wc (Wn-Wc?).
- tristis* (Reeve, 1854). R (Wn?-R).
- williamsi* (Marwick, 1948). Wp.

Mactra Linné, 1767.

- discors* Gray, 1837. R (Wo?-R).

**(2)murchisoni* Deshayes in Reeve, 1854. R (Tt?-R).

(*Mactrona*) Marwick, 1952.

- mula* Marwick, 1948. Wp (Wp-Wn). Pl. 35c, i.

Maorimactra Finlay, 1928.

- acuminella* Finlay, 1930. Pl. Pl. 19c, h.
- chrydaea* (Suter, 1911). Wo (Tk-Wp). Pl. 35b, e, f.
- ordinaria* (Smith, 1898). R (Wo-R).

Oxyperas Mörch, 1853.

(*Pseudoxyperas*) Sacco, 1901.

- elongata* (Quoy & Gaimard, 1835). R (Wn-R).
- exensis* Maxwell, 1978. Lw.
- flemingi* (Marwick, 1960). Dp?
- komakoensis* (Carter, 1972). Wn (Wp?; Wm-Wn).
- leda* (Finlay, 1924). Ld. Pl. 12g, h.

Scalpomactra Finlay, 1928.

- biconvexa* Powell & Bartrum, 1929. Po.
- continua* Finlay, 1930. Pl (Ld-Pl).
- scalpellum* (Reeve, 1854). R (Tt?-R).

Spisula Gray, 1837.

(*Crassula*) Marwick, 1948.

**(3)aequilatera* (Deshayes in Reeve, 1854). R (Tk?-R).

- gilberti* Bartrum, 1919. Wo.
- (*Spisulona*) Marwick, 1948.
- couttsi* Marwick, 1948. Wp.
- crassitesta* (Finlay, 1927). Wn. Pl. 39g, i.

SUBFAMILY LUTRARIINAE

Lutraria Lamarck, 1799.

- solida* Hutton, 1873. Wp (Wp-Wn). Pl. 39j, k.
- trapezoidalis* Powell & Bartrum, 1929. Po (Po-Pl).

SUBFAMILY RESANIINAE

Resania Gray, 1853.

- elongata* Beu, 1966. Tt (Sl?-Wo).
- exoptata* Bartrum & Powell, 1928. Wo (Tt-Wm).
- lanceolata* Gray, 1853. R (Wn-R).

SUBFAMILY ZENATIINAE

Zenatia Gray, 1853.

- acinaces* (Quoy & Gaimard, 1835). R (?Tt-R).
- "*cretacea* (Woods, 1917)". (Ld-Sw).
- flemingi* Marwick, 1948. Wp. Pl. 35d, h.
- tepikiensis* Beu, 1966. Wq.
- (*Zenatraria*) Beu, 1966.
- vellai* Beu, 1966. Wn.
- waipipiana* Beu, 1966. Wp.

SUPERFAMILY MESODESMATACEA

FAMILY MESODESMATIDAE

Paphies Lesson, 1831.

- anteaustralis* (Dell, 1950). Po.
- australis* (Gmelin, 1791). R (Wn-R).
- crassiformis* (Marshall & Murdoch, 1920). Wn. Pl. 40a, e.
- donacina* (Spengler, 1793). R (Wm?-R).
- porrecta* (Marwick, 1928). Wn Pl. 40c, d.
- subtriangulata* (Gray in Wood, 1828). R (Wq?-R).
- ventricosa* (Gray, 1843). R (Wc-R).

SUPERFAMILY TELLINACEA

FAMILY TELLINIDAE

SUBFAMILY TELLININAE

Barytellina Marwick, 1924.

- crassidens* Marwick, 1924. Wn (Wp?-Wq). Pl. 41e, f.
- tertia* Fleming, 1943. Wn. (Wp?-Wn).

Elliptotellina Cossmann, 1887.

- donaciformis* (Marwick, 1928). Dw.
- protensa* (Powell, 1935). Pl.
- urinatoria* (Suter, 1913). R (Wo?-R).

Eurytellina Fischer, 1887.

- (?)*solitaria* Powell, 1931. Wp.

Finlayella Laws, 1933.

- imbellica* (Marwick, 1929). Ld.
- (?)*marshalli* Fleming, 1950. Ab.
- sinuaris* Laws, 1933. Pl.
- subtriquetra* (Bartrum & Powell, 1928). Wo.

Macomona Finlay, 1926.

- liliana* (Iredale, 1915). R (Wn-R).
- williamsi* Laws, 1950. Wp.

Moerella Fischer, 1887.

- huttoni* (Smith, 1885). R (Wo-R).

Peronaea Poli, 1791.

- gaimardi* (Iredale, 1915). R (Wn-R).
- (?)*pahiensis* (Fleming, 1950). Ab.

Pseudarcopagia Bertin, 1878.

- disculus* (Deshayes, 1855). R (Wq-R).

Rexithaerus Conrad MS, in Tryon, 1869.

- spenceri* (Suter, 1907). R (Wo?-R).

Serratina Pallary, 1922.

- charlottae* (Smith, 1885). R (Wc-R).
- eugonia* (Suter, 1913). Wc (Wc-R).
- ferrari* (Marwick, 1931). Pl? (Po-Pl).

"*Tellina*" Linné, 1758.

- decisa* (Marwick, 1931). Tt.
- fragosa* (Marwick, 1931). Tt.
- hesterna* (Powell & Bartrum, 1929). Po.
- robini* (Finlay, 1924). Lw.

Tellinota Iredale, 1936.

- arta* (Laws, 1933). Pl.
- edgari* (Iredale, 1915). R (Tt?-R).
- tumens* (Laws, 1933). Pl.

SUBFAMILY MACOMINAE

Bartrumia Marwick, 1934.

- oneroaensis* (Powell & Bartrum, 1929). Po.
- tenuiplicata* (Bartrum, 1919). Sl? (Pl-Tt). Pl. 27d, f.

FAMILY PSAMMOBIIDAE

Gari Schumacher, 1817.

- aucklandica* Marwick, 1948. Wp.
- cacuminata* Finlay & Marwick, 1937. D.
- hodgei* Willan, 1980. R (Wc?-R).
- lineolata* (Gray, 1835). R (Wo-R).
- oamarutica* Finlay, 1930. Pl.
- (*Gobraeus*) Brown, 1844.
- stangeri* (Gray, 1853). R (Wo-R).

**(4)Hiatula* Modeer, 1793.

- nitida* (Gray, 1843). R (Wc?-R).
- siliqua* (Reeve, 1857). R (Wc?-R).
- waitemata* (Marwick, 1948). Wp.

FAMILY SEMELIDAE

Abra Lamarck, 1818.

- inflata* (Laws, 1939). Po.
- (?)*marshalli* (Finlay, 1927). Po? (Po-Pl).

Leptomya A. Adams, 1864.

- breviformis* Laws, 1950. Wp (Wo-Wp).
- concentrica* Marwick, 1928. Wp.
- retiaria* (Hutton, 1885). Wc (Wp-R).
- simplex* Marwick, 1926. Tt.
- waitemataensis* Powell & Bartrum, 1929. Po.

FAMILY SOLECURTIDAE

Solecurtus Blainville, 1824.

- bensoi* Finlay, 1924. Pl (Pl-Sl). Pl. 23f.

- chattonensis* Finlay, 1924. Ld.
evolutus Finlay, 1924. Pl.
- SUPERFAMILY GAIMARDIACEA**
FAMILY GAIMARDIIDAE
Gaimardia Gould, 1852.
asinuata Laws, 1940. Wn.
forsteriana Finlay, 1926. R (Wq?-R).
- Neogaimardia* Odhner, 1924.
elegantula Marwick, 1928. Wn.
- SUPERFAMILY VENERACEA**
FAMILY VENERIDAE
SUBFAMILY VENERINAE
Dosina Gray, 1835.
crebra (Hutton, 1873). R (Wo-R).
firmocosta (Marwick, 1927). Pl (Pl-Sl).
marwicki (Laws, 1936). Wo.
(?)*morgani* (Suter, 1917). Tt.
suboblonga (Marwick, 1927). Pl.
uttleyi (Marwick, 1927). Lw.
zelandica Gray, 1835. R (Wn-R).
- Globivenus* Coen, 1934.
neozelanica Marwick, 1965. Wp.
- Kuia* Marwick, 1927.
maddowelli Marwick, 1927. Sw (Sw-Tk). Pl. 29f.
vellicata (Hutton, 1873). Pl (Ak?, Lw-Pl). Pl. 11d, f.
- Marama* Marwick, 1927.
elegans (Hutton, 1873). Tt?
hurupiensis Marwick, 1927. Tt. Pl. 29b, c.
murdochi Marwick, 1927. Wp (Tk-Wn). Pl. 41c, d.
ovata Marwick, 1927. Pl.
pristina Marwick, 1927. Ak?
(*Hina*) Marwick, 1927.
hendersoni Marwick, 1927. Sl (Sc-Sl).
mackenziei Marwick, 1927. Pl.
pinguis Marwick, 1927. Po-Pl (Po-Pl).
singularis (Marwick, 1927). Tk.
tumida (Marshall, 1918). Po-Pl (Po-Pl).
vaga Marwick, 1927. Ak.
williamsi Marwick, 1927. Pl.
- Plurigens* Finlay, 1930.
(?)*carri* (Marwick, 1927). Tt.
fusidens Beu, 1970. Wo.
- Proxichione* Iredale, 1929.
darraghi Maxwell, 1978. Ld.
otikensis Maxwell, 1978. Lw.
- SUBFAMILY CHIONINAE**
Austrovenus Finlay, 1926.
crassitesta (Finlay, 1924). (?) Wc (Wn-Wq). Pl. 41a, b.
stutchburyi (Gray in Wood, 1828). R (Wo?-R).
tamakiensis (Marwick, 1948). Wp.
- Bassina* Jukes-Brown, 1914.
katherinae Marwick, 1948. Wp (Wp-Wm?).
lawsi Fleming, 1971. Wo.
macclurgi (Marwick, 1928). Wn.
parva Marwick, 1927. Wn (Wm-Wn). Pl. 39e, h.
southlandica Fleming, 1962. Wo.
speighti (Suter, 1913). Sw (Ld-Tt). Pl. 10h.
yatei (Gray, 1835). R (Wo-R).
- Hinemoana* Marwick, 1927.
acuminata (Hutton, 1873). Ld?. Pl. 9n, o, p.
- Placamen* Iredale, 1925.
morgani (Marwick, 1924). Ld.
- Protothaca* Dall, 1892.
crassicosta (Deshayes, 1835). R (Wc-R). Pl. 46a, c.
- Tawera* Marwick, 1927.
assimilis (Hutton, 1873). Wn.
bartrumi Marwick, 1927. Wo.
duobrunnea Marwick, 1948. Wp.
- errans* Marwick, 1927. Wp.
marshalli Marwick, 1927. Pl (Po-Pl).
marthae Marwick, 1928. Wn.
spissa (Deshayes, 1835). R (Wn-R).
subsulcata (Suter, 1905). Wn (Wn-Wq). Pl. 41g, j.
wanganuiensis Marwick, 1927. Wc.
- Turia* Marwick, 1927.
bortonensis Marwick, 1927. Ab.
chattonensis Marwick, 1927. Ld.
fausta Marwick, 1960. Dp?
pukeuriensis Marwick, 1927. Pl.
waitauensis Marwick, 1927. Sw (Sl-Sw; Tt?).
- SUBFAMILY DOSINIINAE**
Dosinia Scopoli, 1777.
(*Asa*) Basterot, 1825.
lambata (Gould, 1850). R (Ld-R). Pl. 46d, f.
(*Austrodosinia*) Dall, 1902.
anus (Philippi, 1848). R (Wn-R).
horrida Marwick, 1927. Wn.
kaawaensis Marwick, 1927. Wo (Wo-Wn).
magna Hutton, 1873. Pl.
sodalis Marwick, 1929. Ld. Pl. 11c, e.
waitakiensis Marwick, 1927. Lw.
(*Dosinobia*) Finlay & Marwick, 1937.
ongleyi Marwick, 1927. Mw.
perplexa Marwick, 1927. Mw.
(*Kakahuia*) Marwick, 1927.
suteri Marwick, 1927. Ab.
(*Kereia*) Marwick, 1927.
(?)*castigata* Marwick, 1960. Dp?
chathamensis Marwick, 1928. Wp (Tk-Wp).
cottoni Marwick, 1927. Tt (Sw?-Tt). Pl. 29a.
densicosta Marwick, 1927. Pl.
greyi Zittel, 1864. Wp? (Tk-R).
mackayi Marwick, 1927. Ab. Pl. 5k, m.
macroptera Fleming, 1943. Tt?
waiparaensis Marwick, 1927. Wm-Wn.
(*Phacosoma*) Jukes-Brown, 1912.
maoriana Oliver, 1923. R (Wc-R).
subrosea (Gray, 1835). R (Wp-R). Pl. 46j, l.
(*Raina*) Marwick, 1927.
bartrumi Laws, 1930. Wo.
benereparata Laws, 1930. Ld.
bensoni Marwick, 1927. Pl (Pl-Sw). Pl. 19a, k.
imperiosa Marwick, 1929. Ld.
nukumaruensis Marwick, 1927. Wn (Wp-Wn).
paparoaensis Marwick, 1927. Sw.
powelli Marwick, 1948. Wp.
waipipiensis Marwick, 1927. Wp.
- SUBFAMILY PITARINAE**
Costacallista Palmer, 1926.
hectori (Finlay & Marwick, 1937). Dp?. Pl. 3k, l.
- Marwickia* Finlay, 1927.
parthiana (Marwick, 1927). Mw. Pl. 1d, g.
- Notocallista* Iredale, 1924.
(*Fossacallista*) Marwick, 1938.
parki (Marwick, 1927). Pl (Po-Sl).
tecta Marwick, 1938. Ld.
tersa Marwick, 1938. Pl.
watti Marwick, 1938. Lw. Pl. 13h, k.
(*Striacallista*) Marwick, 1938.
kapitea Beu, 1970. Tk (Tt?-Tk).
makoensis (Marwick, 1931). Wo (Tt-Wo).
multistriata (Sowerby, 1851). R (Wp-R). Pl. 45c, e.
- Pitar* Römer, 1857.
(*Hyphantosoma*) Dall, 1902.
sculpturata (Marshall, 1918). Po-Pl (Po-Pl). Pl. 23h.
- Rohea* Marwick, 1938.
trigonalis (Marwick, 1924). Pl (Pl-Sl). Pl. 23i, j.
- SUBFAMILY TAPETINAE**
Eumarcia Iredale, 1925.
awateria Beu, 1970. Tk.

- kaawaensis* Marwick, 1927. Wo (Wo-Wp). **Pl. 34d, g.**
pareoraensis (Suter, 1917). Pl.
plana Marwick, 1927. Wn (Wp-Wn). **Pl. 40g, h.**
(Atamarcia) Marwick, 1927.
benhami Marwick, 1927. Wp (Tk-Wn). **Pl. 36a, b.**
crassa Marwick, 1927. Lwh.
crassatelliformis Marwick, 1927. Tk.
curta (Hutton, 1873). Pl.
enysi (Hutton, 1873). Sw? (Pl-Sw).
sulcifera Marwick, 1927. Pl.
summersae Beu, 1970. Wn.
thomsoni Marwick, 1927. Tt (Sl-Tt). **Pl. 28e.**
(Opimarcia) Marwick, 1948.
healyi Marwick, 1948. Wp.
- Gomphina* Mörch, 1853.
(Gomphinella) Marwick, 1927.
maorum Smith, 1903. R (Wo-R).
- Irus* Schmidt, 1818.
(Notirus) Finlay, 1928.
caudex (Laws, 1936). Wo.
reflexus (Gray, 1843). R (Wq-R).
(Notopaphia) Oliver, 1923.
elegans (Deshayes, 1854). R (Wq-R).
- Katelysia* Römer, 1857.
(?)lunulata Marwick, 1931. Sl.
- Paphia* Röding, 1798.
(Callistotapes) Sacco, 1900.
finlayi Marwick, 1927. Sl (Sl-Tt).
- Ruditapes* Chiamanti, 1900.
largillierti (Philippi, 1847). R (Wp-R). **Pl. 46e, h.**
- Tapes* Megerle, 1811.
parki (Marshall & Murdoch, 1923). Ld. **Pl. 13a, b.**
- ORDER MYOIDA
 SUBORDER MYINA
 SUPERFAMILY MYACEA
 FAMILY CORBULIDAE
Caryocorbula Gardner, 1926.
howesi (Marwick, 1928). Wp.
kaiparaensis (Suter, 1917). Po-Pl (Po-Pl).
nitens (Marshall, 1919). Po-Pl (Po-Pl).
tophina (Marwick, 1928). Dw. **Pl. 3h.**
waihaensis Finlay & Marwick, 1937. Dp?.
zelandica (Quoy & Gaimard, 1835). R (Wo-R).
- Notocorbula* Iredale, 1930.
humerosa (Hutton, 1885). Pl (Ld-Tk).
illecta Laws, 1941. Pl.
(?)innerans Laws, 1941. Pl (Po-Sw).
(?)pumila (Hutton, 1885). Pl (Ak?-Pl).
- FAMILY HIATELLIDAE
Hiatella Bosc (ex Daudin), 1801.
arctica (Linné, 1767). R (Dm?-R).
- Panopea* Menard, 1807.
smithae Powell, 1950. R (Wq-R).
wanganuica Powell, 1952. Wc (Wp?-Wc). **Pl. 41o, p.**
worthingtoni Hutton, 1873. Lw? (D-Tt).
zelandica Quoy & Gaimard, 1835. R (Tk-R).
- SUBORDER PHOLADINA
 SUPERFAMILY PHOLADACEA
 FAMILY PHOLADIDAE
 SUBFAMILY PHOLADINAE
Barnea Leach in Risso, 1826.
(Anchomasa) Leach, 1852.
similis (Gray, 1835). R (Wo-R). **Pl. 47a, e.**
- Zirlona* Finlay, 1930.
concentrica (Suter, 1917). Ld.
- SUBFAMILY MARTESIINAE
Parapholas Conrad, 1848.
aucklandica Powell, 1938. Po. **Pl. 24a, b.**
- Pholadidea* Turton, 1819.
finlayi Laws, 1936. Wo.
suteri Lamy, 1926. R (Wc-R). **Pl. 47b, d.**
thomsoni Suter, 1917. Lw?
- SUBFAMILY XYLOPHAGINAE
Xylophaga Turton, 1822.
(?)aemula (Laws, 1944). Po.
(?)cupedia (Laws, 1944). Po.
- FAMILY TEREDINIDAE
Bankia Gray, 1842.
turneri Powell & Bartrum, 1929. Po.
- "*Teredo* Linné, 1758".
directa (Hutton, 1877). Ak?
heaphyi Zittel, 1864. Po.
- SUBCLASS ANOMALODESMATA
 ORDER PHOLADOMYOIDA
 SUPERFAMILY PHOLADOMYACEA
 FAMILY PHOLADOMYIDAE
Pholadomya Sowerby, 1823.
neozelanica Hutton, 1885. P? (Ld?-Tt). **Pl. 27b.**
- FAMILY PARILIMYIDAE
 "*Parilimyia* Melvill & Standen, 1899".
neozelanica (Suter, 1914). Wc (Wc-R). **Pl. 46g, i.**
waitotarana (Powell, 1931). Wp (Wo-Wp).
warrenae (Dell, 1952). Tt.
- Procardia* Meek, 1871.
dolicha (Suter, 1917). Lwh-Ld (Ak-Pl?). **Pl. 9h, i.**
- SUPERFAMILY THRACIACEA
 FAMILY THRACIIDAE
Asthenothaerus Carpenter, 1864.
matauensis (Finlay & Marwick, 1937). Dp?.
pusillior (Laws, 1936). Wo.
- Thracia* Sowerby, 1823.
magna Marshall & Murdoch, 1921. Wp (Wp-Wn). **Pl. 34h.**
vegrandis Marshall & Murdoch, 1919. Wc (Wc-R).
vitrea (Hutton, 1873). R (Wq-R).
- FAMILY LATERNULIDAE
Laternula Röding, 1798.
synthetica Marwick, 1948. Wp.
- FAMILY PERIPLMATIDAE
Offadesma Iredale, 1930.
angasi (Crosse & Fischer, 1864). R (Pl?-R).
marwicki Fleming, 1950. Ab.
- Periploma* Schumacher, 1817.
(?)macphersoni Marwick, 1931. Sw (Pl-Tk?).
- SUPERFAMILY PANDORACEA
 FAMILY MYOCHAMIDAE
Hunkydora Fleming, 1948.
novozelandica (Reeve, 1859). R (Wm-R).
- Myadora* Gray, 1840.
antipodum Smith, 1880. R (Wn-R).
boltoni Smith, 1880. R (Wn-R).
delta Marwick, 1929. Ld (Ld-Pl). **Pl. 12c, f.**
kaiwiensis Powell, 1931. Wc (Wn-Wc).
novaezelandiae Smith, 1880. R (Wn-R).
stephaniae Carter, 1972. Wm-Wn (Wm-Wn). **Pl. 41k,m.**
striata (Quoy & Gaimard, 1835). R (Wn-R).
subrostrata Smith, 1880. R (Wm-R).
waitotarana Powell, 1931. Wp (Wo-Wp).
- SUPERFAMILY VERTICORDIACEA
 FAMILY VERTICORDIIDAE
Euciroa Dall, 1878.
ulrichi Fleming, 1970. Pl.
- Haliris* Dall, 1886.
(Setaliris) Iredale, 1930.
setosa (Hedley, 1907). R (Wp-R).

Kurinuia Marwick, 1942.
areolata (Marshall, 1919). Ab. Pl. 5p.

Pecchiolia Savi & Meneghini, 1850.
bensoni (Marwick, 1942). Ar. Pl. 7e, f.

"*Verticordia*" Gray, 1840.
densicostata Marshall, 1919. Ab.
neozelanica (Suter, 1915). Ab.

FAMILY CLEIDOTHAERIDAE
Cleidothaerus Stutchbury, 1830.
albidus (Lamarck, 1819). R (Lw-R). Pl. 13f, i.

SUPERFAMILY CLAVAGELLACEA
FAMILY CLAVAGELLIDAE
Clavagella Lamarck, 1818.
oamarutica Maxwell, 1978. Pl (Pl-Sw?). Pl. 19f.

ORDER POROMYOIDA
SUPERFAMILY POROMYACEA
FAMILY POROMYIDAE
Poromya Forbes, 1844.
laevis Smith, 1884. R (Wp-R).

FAMILY CUSPIDARIIDAE
Austronera Powell, 1937.
hornibrooki Marwick, 1965. Wo (Wo-Wn).

Cardiomya A. Adams, 1864.
stenhousei (Marwick, 1931). Pl.

Cuspidaria Nardo, 1840.
beneansata Marwick, 1931. Sl-Tt (Sc-Tt?).
fairchildi Suter, 1908. R (Ak-R).
kirki (Hutton, 1873). Lwh.
morioria Dell, 1956. R (Wp?-R).
trailli (Hutton, 1873). R (Pl-R).
willetti Fleming, 1948. R (Wc-R).

CLASS GASTROPODA
SUBCLASS PROSOBRANCHIA
ORDER ARCHAEOGASTROPODA
SUPERFAMILY PLEUROTOMARIACEA
FAMILY PLEUROTOMARIIDAE
Perotrochus Fischer, 1835.
allani Marwick, 1928. Dw. Pl. 4i.
marwicki Fleming, 1970. Pl.
masoni Maxwell, 1978. Ld.

FAMILY SCISSURELLIDAE
Anatoma Woodward, 1859.
miocenica (Laws, 1939). Po (Po-Pl).

Incisura Hedley, 1904.
lytteltonensis (Smith, 1894). R (Wn?-R).

Scissurella d'Orbigny, 1824.
apudornata Laws, 1935. Pl.
condita Laws, 1939. Po. Pl. 53a,b,c.
geoffreyi Laws, 1940. Wo.
stellae Fleming, 1948. R (Wc-R).

Scissurona Iredale, 1924.
fossilis Laws, 1940. Wn (Wm-Wn).

Sinezona Finlay, 1926.
brevis (Hedley, 1904). R (Wq-R).
finlayi (Laws, 1948). Po.
kaiparaensis (Laws, 1941). Po-Pl.
koruahina (Laws, 1936). Wo.
laquea (Finlay, 1926). R (Wq-R).
lyallensis (Finlay, 1926). R (Wq-R).
ngatutura (Laws, 1936). Wo.
tertia (Laws, 1940). Wo.

FAMILY HALIOTIDAE
Haliotis Linné, 1758.
(Notohaliotis) Cotton & Godfrey, 1933.
waitemataensis Powell, 1938. Po.
(Paua) Fleming, 1952.

iris Gmelin, 1791. R (Wo?-R).
(Sulculus) H. & A. Adams, 1854.
flemingi Powell, 1938. Po.
powelli Fleming, 1952. Wc (Wn?-Wc). Pl. 47c.
virginea Gmelin, 1791. R (Wq-R).

SUPERFAMILY EUOMPHALACEA ?
FAMILY ORBITESTELLIDAE
Orbitestella Iredale, 1917.
praehinemoa Laws, 1939. Po.
praetoreuma Laws, 1939. Po. Pl. 54 l,m,n.

SUPERFAMILY FISSURELLACEA
FAMILY FISSURELLIDAE
Emarginula Lamarck, 1801.
galeriformis Marwick, 1928. Wp.
haweraensis Powell, 1931. Wp (Wp-Wn).
kaiparica Laws, 1939. Po-Pl.
komitica Laws, 1939. Po.
lophelia Beu, 1967. Wm.
paucicostata Laws, 1936. Wo.
pittensis Marwick, 1928. Wp.
striatula Quoy & Gaimard, 1834. R (Wo-R).

Monodilepas Finlay, 1927.
(?)annulata (Suter, 1917). Ld.
monilifera (Hutton, 1873). R (Wn-R).

Montfortula Iredale, 1915.
kaawaensis (Bartrum, 1919). Wo.

Puncturella Lowe, 1827.
pseudanalogia Powell, 1957. R (Wp?-R).

Scutus Montfort, 1810.
antipodes Montfort, 1810. R (Wq-R).
petrafixus Finlay, 1930. Ar?

Tugali Gray, 1843.
aranae Marwick, 1928. Wp.
elata (Suter, 1917). Lw.
elegans Gray, 1843. R (Wq?-R).
kumeroa Fleming, 1943. Wn (Wm-Wn).
opuraensis Bartrum & Powell, 1928. Wo.
navicula Finlay, 1927. Pl.
phiocenica Finlay, 1926. Wc (Wn-Wc). Pl. 47h, i.
superba Powell, 1934. Wq.
suteri (Thiele, 1916). R (Wo-R).

SUPERFAMILY PATELLACEA
FAMILY LOTTIIDAE
SUBFAMILY LOTTIINAE
Asteracmea Oliver, 1926.
oliveri Laws, 1950. Wp.
suteri (Iredale, 1915). R (Wq-R).

Atalacmea Iredale, 1915.
elata Marwick, 1928. Wn.
fragilis (Sowerby, 1823). R (Wq-R).

Notoacmea Iredale, 1915.
chattonensis Laws, 1932. Ld.
daedala (Suter, 1907). R (Wq-R).
helmsi (Smith, 1894). R (Wq-R).
nukumaruensis Oliver, 1926. Wn.
otahuhuensis Laws, 1950. Wp.
parviconoidea (Suter, 1917). R (Hol.-R).

SUBFAMILY PATELLOIDIDAE
Patelloida Quoy & Gaimard, 1834.
corticata (Hutton, 1880). R (Wq-R).

FAMILY ACMAEIDAE
Pectinodonta Dall, 1882.
coniformis (Marwick, 1931). Pl-Sc.
komitica Marshall, 1985. Po.
waitemata Marshall, 1985. Po.

FAMILY NACELLIDAE
Cellana H. Adams, 1869.
cophina Powell, 1973. Po.

ornata (Dillwyn, 1817). R (Wn-R).
radians (Gmelin, 1791). R (Wc-R).
stellifera (Gmelin, 1791). R (Wq-R).
strigilis (Hombron & Jacquinot, 1841). R (Wn-R).
taberna Powell, 1973. Lw.
thomsoni Powell & Bartrum, 1929. Po.

FAMILY PATELLIDAE

Patella Linné, 1758.
(Scutellastra) H. & A. Adams, 1854.
aurorae Fleming, 1973. Ld-Lw.
cooperi (Powell, 1938). Po.

SUPERFAMILY COCCULINACEA

FAMILY COCCULINIDAE

Paracocculina Harszprunar, 1987.
pristina (Marshall, 1986). Po.

Coccopigya Marshall, 1986.
compuncta (Marwick, 1931). Pl-Sc?
komitica Marshall, 1986. Po.
otaiana Marshall, 1986. Po.

FAMILY PSEUDOCOCCULINIDAE

Kaiparapelta Marshall, 1986.
singularis Marshall, 1986. Po.

Notocrater Finlay, 1926.
craticulata (Suter, 1908). R (Wp-R).
maxwelli Marshall, 1986. Po.

SUPERFAMILY LEPETELLACEA

FAMILY LEPETELLIDAE

Lepetella Verrill, 1880.
clypidellaeformis (Suter, 1908). R(Wc?-R).
parallela (Laws, 1950). Wp.

SUPERFAMILY TROCHACEA

FAMILY SKENEIDAE

Brookula Iredale, 1912.
endodonta Finlay, 1924. Pl (Po?-Pl).
fossilis Finlay, 1924. Wc.
funiculata Finlay, 1924. Wc.
pukeuriensis Finlay, 1924. Pl. **Pl. 53 d,g.**
(Aequispirella) Finlay, 1924.
corula (Hutton, 1885). Wc (Wm-Wc).
finlayi Powell, 1933. R (Wm?-R).
iredalei Finlay, 1924. Pl.
kaawaensis Laws, 1940. Wo.
tenuilrata Finlay, 1924. Pl.

Cirsonella Angas, 1877.
aedicula Laws, 1936. Wo.
amplector Laws, 1944. Po.
(?)congrua (Laws, 1941). Po (Po-Pl).
maoria (Powell, 1937). R (Wp-R).
parvula Powell, 1926. R (Wq?-R).
propelaxa Dell, 1956. R (Wp-R).
(?)proava (Marwick, 1931). Sl.
waimamakuica Laws, 1948. Po.
zeornata Laws, 1948. Po.

Crossea A. Adams, 1865.
(Crosseola) Iredale, 1924.
emilyae (Laws, 1950). Wp.
henryi (Laws, 1950). Wp.
munditia (Laws, 1936). Wo.
proerrata (Finlay, 1930). Pl.
sinemacula (Laws, 1939). Po. **Pl. 53 e,h.**
sultan (Finlay, 1930). Pl.
tenuisculpta (Laws, 1936). Wo.
waitotara (Laws, 1940). Wm.

Dolicrossea Iredale, 1924.
(?)atypica Laws, 1939. Po.
awamoana Finlay, 1930. Pl.
clifdenensis Finlay, 1930. Sc (Po-Sc).
vesca Finlay, 1926. R (Wo-R).

Kaawatina Bartrum & Powell, 1928.
turneri Bartrum & Powell, 1928. Wo.

Liotella Iredale, 1915.
polypleura (Hedley, 1904). R (Wp-R).
rotula (Suter, 1908). R (Wp-R).

Lissotesta Iredale, 1915.
beta Laws, 1939. Po-Pl.
errata Finlay, 1926. R(Wc?-R).
exigua (Suter, 1917). Pl.
formosa (Powell, 1930). R (Wo-R).

Lisstotestella Powell, 1946.
alpha (Laws, 1939). Po. **Pl. 53 j,k.**
waimamakuensis Laws, 1948. Po.

"*Lodderia* Tate, 1899".
kaiparaensis Laws, 1939. Po-Pl.
supralevi Laws, 1941. Po-Pl.

Notosetia Iredale, 1915.
neozelanica (Suter, 1898). R (Wp-R).
tantilla Laws, 1936. Wo.

Zalipais Iredale, 1915.
probenthicola Laws, 1940. Wo.

FAMILY TROCHIDAE

SUBFAMILY MARGARITINAE

Margarella Thiele, 1893.
(?)runcinata Marwick, 1928. Dw.

SUBFAMILY AMBERLEYINAE

Calliotropis Seguenza, 1903.
fenestrata (Suter, 1917). Ar.
motutaraensis Powell, 1935. Pl.
(Solaricida) Dall, 1919.
wakefieldi Hayward, 1981. Pl.

Danilia Brusina, 1865.
neozelanica Laws, 1935. Ar.

Euchelus Philippi, 1847.
(Herpetopoma) Pilsbry, 1889.
alacerrimus (Dell, 1956). R (Wq-R).
bellus Hutton, 1873. R (Wq-R).
komiticus (Laws, 1939). Po.
parvumbilicatus (Laws, 1939). Po-Pl.

SUBFAMILY GIBBULINAE

Cantharidella Pilsbry, 1889.
tesselata (A. Adams, 1853). R (Wq-R).

SUBFAMILY MONODONTINAE

Bankivia Krauss, 1848.
fasciata (Menke, 1830). R (Wc).

Cantharidus Montfort, 1810.
opalus (Martyn, 1784). R (Wq-R).
purpureus (Gmelin, 1791). R (Wc-R).

Diloma Philippi, 1845.
bicanaliculata (Dunker, 1844). R (Hol.-R).
arida (Finlay, 1926). R (Wq-R).
subrostrata (Gray, 1835). R (Wn-R).
(Cavodiloma) Finlay, 1926.
coracina (Philippi, 1851). R (Wq-R).

Levella Marwick, 1943.
exaggerata (Marwick, 1965). Wo.
tersa Marwick, 1943. Pl.

Melagraphia Gray, 1847.
aethiops (Gmelin, 1791). R (Wn-R).

Micrelenchus Finlay, 1926.
caelatus bakeri Fleming, 1948. R (Wq-R).
caelatus caelatus (Hutton, 1884). R (Wm-R).
caelatus morioria Powell, 1933. R (Wn-R).
dilatatus (Sowerby, 1870). R (Wn-R).
rufozona (A. Adams, 1853). R (Wc-R).

sanguineus sanguineus (Gray, 1843). R (Wc-R).
sanguineus cryptus Powell, 1946. R (Wq-R).
tenebrosus (A. Adams, 1853). R (Wn-R).

Miofractarmilla Laws, 1948.
bartrumi Laws, 1948. Po.

Pachydontella Marwick, 1948.
etiampicta Marwick, 1948. Wp.

SUBFAMILY SOLARIELLINAE

Conominolia Finlay, 1926.
aflexura Laws, 1941. Pl.
conica (Marshall, 1917). Mw. Pl. 2a.
covei Beu, 1969. Wm.
sulcatina (Suter, 1917). Lwh. Pl. 9l.
vixincisa (Marwick, 1929). Ld.
woodsii Laws, 1933. Pl.

"*Monilea* Swainson, 1840".
grantmackiei Hayward, 1981. Pl.

Solariella Wood, 1842.
(?)*susanae* Maxwell, 1988. Sw.

Spectamen Iredale, 1924.
carinatum (Laws, 1935). Pl.
fossa (Laws, 1932). Ld.
lene (Marwick, 1928). Wp.
ordo (Laws, 1941). Pl.
venustum (Maxwell, 1969). Lw.

Zetela Finlay, 1926.
awamoana Laws, 1939. Pl. Pl. 19g.
castigata (Marwick, 1931). Sl.
hutchinsoniana Laws, 1939. Po (Po-Pl).
praetextilis Suter, 1917. Ld.

SUBFAMILY TROCHINAE

Clanculus Montfort, 1810.
(*Paraclanculus*) Finlay, 1926.
adesus (Marwick, 1931). Sl?

Kaiparathina Laws, 1941.
praecellens Laws, 1941. Po.

Thoristella Iredale, 1915.
chathamensis (Hutton, 1873). R (Wn?-R).
dunedinensis (Suter, 1897). R (Wq-R).
fossilis Finlay, 1926. Pl.
gracilis Laws, 1936. Wo.

Trochus Linné, 1758.
(*Thorista*) Iredale, 1915.
viridis Gmelin, 1791. R (Wc-R).
(*Coelotrochus*) Fischer, 1880.
avarus Suter, 1917. Ld.
bibaphus Bartrum & Powell, 1928. Wo.
browni (Fleming, 1943). Wn.
tiaratus Quoy & Gaimard, 1834. R (Wm-R).

SUBFAMILY UMBONINAE

Antisolarium Finlay, 1926.
conominolium Laws, 1936. Wo.
egenum (Gould, 1849). R (Wn-R).
stoliczkai (Zittel, 1864). Wp.
spectandrum Laws, 1950. Wp.

Zethalia Finlay, 1926.
coronata Marwick, 1948. Wp (Wp-Wm).
russellii Marwick, 1965. Wo. Pl. 36e, h.
zelandica (Hombron & Jacquinot, 1854). R (Wn-R). Pl. 47l, p.

SUBFAMILY CALLIOSTOMATINAE

"*Astele* Swainson, 1855."
boileaui Marwick, 1931. Tt.

Benthastelena Iredale, 1936.
(?)*muta* (Finlay, 1924). Ld?
(?)*transenna* (Suter, 1917). Pl.

Calliostoma (sensu lato) Swainson, 1840.
acutangulus Suter, 1917. Ld.
correlatum (Fleming, 1943). Wo.
couperi (Vella, 1954). Wn.
(?)*filiferum* Suter, 1917. Ld.
finlayi (Marwick, 1928). Wp.
foveauxanum (Dell, 1950). R (Wq-R).
fragile Finlay, 1923. Pl. Pl. 19j.
(?)*gracile* Marshall, 1918. Pl.
granti (Powell, 1931). Wp.
hawera Oliver, 1926. Wp. Pl. 36j.
hodgei Hutton, 1875. Wc.
nukumaruense (Laws, 1930). Wn.
pellucidum (Valenciennes, 1846). R (Wc-R).
ponderosum (Hutton, 1885). Wc.
punctulatum (Martyn, 1784). R (Wq-R).
selectum (Dillwyn, 1817). R (Wc?-R).
suteri Finlay, 1923. Pl.
undulatum Finlay, 1923. Wc.
waiareka (Laws, 1935). Ak. Pl. 7m.
waiparaense Suter, 1917. Wp. Pl. 36c, g.
wanganuicum Oliver, 1926. Wc.

"*Fautor* Iredale, 1924."
marwicki (Finlay, 1923). Pl.
temporemutatus (Finlay, 1924). Pl.

FAMILY TURBINIDAE

SUBFAMILY TURBININAE

Astraea Röding, 1798.
bicarinata Suter, 1917. Pl (Ld?-Pl). Pl. 14i, j.
heliotropium (Martyn, 1784). R (Tt-R).
stirps Laws, 1932. Sl (Pl-Sl).

Bolma Risso, 1826.
(*Ormastralium*) Sacco, 1896.
marshalli (Thomson, 1908). Lwh (Ar?-Lwh). Pl. 9e, j.

Cookia Lesson, 1832.
kawauensis Powell, 1938. Po.
sulcata (Gmelin, 1791). R (Tt?-R).

Guildfordia Gray, 1850.
(*Opella*) Finlay, 1926.
hendersoni (Marwick, 1934). Pl.
subfimbriata (Suter, 1917). Po-Pl (Po-Pl).
(*Fractopella*) Beu, 1970.
megapex (Beu, 1970). Tk?

Modelia Gray, 1840.
granosa (Martyn, 1784). R (?Tt-R).

Sarmaturbo Powell, 1938.
colini (King, 1931). Tt.
superbus (Zittel, 1864). Po.

Turbo Linné, 1758.
(?)*barbara* (Marwick, 1942). Ab.
(?)*oryctus* (Suter, 1917). Ld.
smaragdus Gmelin, 1791. R (Wc-R).
(*Marmarostoma*) Swainson, 1829.
moorei Hayward, 1981. Pl.

SUBFAMILY HOMALOPOMATINAE

Argalista Iredale, 1915.
aequor Laws, 1941. Po.
arta Marwick, 1928. Wp.
effusa Marwick, 1928. Wp.
fluctuata (Hutton, 1883). R (Wm-R).
impervia Finlay, 1930. Pl.
kaiparaensis Finlay, 1930. Po-Pl (Po-Pl). Pl. 53 f,i.
kingi Powell, 1938. Wn.
leniumbilicata Laws, 1935. Ar (Ak?-Ar).
proimpervia Laws, 1935. Ar (Ak-Lwh).
promicans Laws, 1936. Wo.
proumbilicata Finlay, 1930. Pl.
provariecostata Laws, 1948. Po.
sola Laws, 1940. Wo.

Cirsochilus Cossmann, 1888.
priscus (Powell, 1935). Pl.
tricarinatus (Laws, 1939). Po.

- Rangimata* Marwick, 1928.
pervia Marwick, 1928. Wn (Wp-Wn).
- Tipua* Marwick, 1943.
tricincta (Marshall, 1919). Ab.
- FAMILY LIOTIIDAE**
Liotina Fischer, 1885.
turua Maxwell, 1978. Dm?. **Pl. 4 l, m.**
- "*Lodderena* Iredale, 1924".
anceps Laws, 1941. Po.
- Munditia* Finlay, 1926.
proavita Laws, 1936. Wo.
- ORDER MESOGASTROPODA**
SUPERFAMILY SEGUENZIACEA
FAMILY SEGUENZIIDAE
Calliobasis Marshall, 1983.
eos Marshall, 1983. Ar.
- Fluxinella* Marshall, 1983.
maxwelli Marshall, 1983. Po.
- Seguenzia* Jeffreys, 1876.
glabella Marshall, 1983. Po.
prisca Marshall, 1983. Po (Po-?Sc).
serrata Marshall, 1983. Sc.
- SUPERFAMILY NERITACEA**
FAMILY NERITIDAE
Nerita Linné, 1758.
(*Melanerita*) Martens, 1889.
melanotragus Smith, 1884. R (Wo-R).
- Neritoplica* Oppenheim, 1892.
pomahakaensis (Finlay, 1924). Ld? **Pl. 9 q.**
- SUPERFAMILY LITTORINACEA**
FAMILY LITTORINIDAE
Bembicium Philippi, 1846.
*(5) *hokianga* (Laws, 1948). Po.
"Group of *B. melanostoma* (Gmelin, 1791)". (Wc).
priscum Powell & Bartrum, 1929. Po.
- Nodilittorina* Martens, 1897.
cincta (Quoy & Gaimard, 1833). R (Wq-R).
unifasciata antipodum (Philippi, 1847). R (Wn-R).
- Risellopsis* Kesteven, 1902.
varia (Hutton, 1873). R (Wq-R).
- SUPERFAMILY RISSOACEA**
FAMILY RISSOIDAE
SUBFAMILY RISSOINAE
Alvania Risso, 1826.
(*Linemera*) Finlay, 1924.
awamoensis (Finlay, 1924). Pl.
kaawaensis (Laws, 1940). Wo.
interrupta (Finlay, 1924). Wn-Wc (Wn-Wc).
minuta (Finlay, 1924). Pl.
pukeuriensis (Finlay, 1924). Pl. **Pl. 54 i,j.**
waimamakuensis (Laws, 1948). Po.
- Attenuata* Hedley, 1918.
charassa (Finlay, 1924). Wn (Tt-Wn).
inflata (Laws, 1939). Po-Pl (Po-Pl). **Pl. 54 c.**
manawatawhia (Powell, 1937). R (Wc?-R).
orientalis (Dell, 1956). R (Wp-R).
polyvineta (Finlay, 1924). Pl.
- Ihungia* Marwick, 1931.
acantha Marwick, 1965. Wo.
aequalis Laws, 1941. Po.
amberleya Marwick, 1931. Sc.
bicarina Marwick, 1931. Sl.
inflata Marwick, 1943. Pl.
luteophila Marwick, 1931. Sc.
moniliata Marwick, 1931. Wn.
ponderi Maxwell, 1988. Sw.
- Manawatawhia* Powell, 1937.
aedicula Laws, 1940. Wm.
- Merelina* Iredale, 1915.
avita Marwick, 1928. Wp. **Pl. 54 a,d,e.**
gemmata Powell, 1927. R (Wn-R).
kaawaensis Laws, 1936. Wo.
maoriana Powell, 1939. R (Wq-R).
saginata Laws, 1939. Po (Po-Pl).
waiotemarama Laws, 1948. Po.
- Onoba* H. & A. Adams, 1854.
cryptolira (Laws, 1950). Wp.
obessa (Grant-Mackie & Chapman-Smith, 1971). Wq.
(*Ovirissoa*) Hedley, 1916.
gibbera (Laws, 1950). Wp.
lactea (Finlay, 1926). Pl.
zebina (Finlay, 1930). Lw.
- Powellisetia* Ponder, 1965.
(?)*bucina* (Laws, 1941). Po.
comes (Finlay, 1926). Pl.
epulata (Laws, 1941). Po-Pl.
paroea (Finlay, 1924). Pl? (Pl-Sc).
prisca (Finlay, 1924). Pl?
subtenuis (Powell, 1937). R (Wc?-R).
- Pusillina* Monterosato, 1884.
(*Haurakia*) Iredale, 1915.
(?)*basispiralis* (Grant-Mackie & Chapman-Smith, 1971). Wq.
buccella (Marwick, 1931). Sc?
chemnitzia (Laws, 1948). Po. **Pl. 54 f.**
hamiltoni (Suter, 1898). R (Wo-R).
infecta (Suter, 1908). R (Wc-R).
marshalli (Grant-Mackie & Chapman-Smith, 1971). Wq.
oamarutica (Finlay, 1924). Pl.
onerata (Laws, 1939). Po-Pl (Po-Pl).
otagoensis (Dell, 1956). R (Wc?-R).
sodalis (Laws, 1939). Po-Pl (Po-Pl).
subsuturalis (Dell, 1956). R (Wp?-R).
tenuisculpta (Laws, 1950). Wp.
- SUBFAMILY RISSOININAE**
Rissoina Orbigny, 1840.
chathamensis (Hutton, 1873). R (Wo-R).
emilyae Laws, 1948. Po.
fictor Finlay, 1930. R (Wn?-R).
heterolira Laws, 1941. Pl?
koruahina Laws, 1940. Wo.
ngatutura Laws, 1940. Wo.
(?)*perplexa* Finlay, 1924. Pl.
- FAMILY BARLEEIDAE**
SUBFAMILY BARLEEINAE
Fictonoba Ponder, 1967.
similis (Laws, 1950). Wp.
- SUBFAMILY ANABATHRONINAE**
Amphithalamus Carpenter, 1865.
(*Notoscrobs*) Powell, 1937.
semiornatus (Laws, 1948). Po.
waitemata (Laws, 1950). Wp.
- Anabathron* Frauenfeld, 1867.
(*Scrobs*) Watson, 1886.
bartrumi (Laws, 1950). Wp.
chattonensis (Laws, 1948). Ld.
hedleyi (Suter, 1908). R (Wq-R).
kaawaensis (Laws, 1936). Wo.
latoscrobis (Laws, 1948). Po.
ovata (Powell, 1927). R (Wc?-R).
praeco (Laws, 1941). Pl.
quartus (Laws, 1950). Wp.
scrobis (Laws, 1950). Wp.
- Microdryas* Laseyron, 1950.
prostriatus (Laws, 1950). Wp.
- Pisinna* Monterosato, 1878.
angustata (Powell, 1927). R (Wp?-R).

asymmetrica (Laws, 1941). Po-Pl (Po-R).
cadus (Laws, 1950). Wp.
impressa (Hutton, 1885). Wn (Po-R).
insulana (Marwick, 1928). Wn.
jocosa (Laws, 1940). Wm.
koruahina (Laws, 1940). Wo.
micronema (Suter, 1898). R (Wn-R).
minor (Suter, 1898). R (Wq-R).
missile (Laws, 1940). Wm (Wm-Wn).
ngatutura (Laws, 1940). Wo.
polysulcata (Finlay, 1924). Wn.
rekohuana (Powell, 1933). R (Wq-R).
rekominor (Laws, 1940). Wn.
rufoapicata (Suter, 1908). R (Wn?-R).
rugosa (Hutton, 1885). Wn (Wm-Wc?).
seminsulcata (Hutton, 1885). Wc (Wo-Wc).
subtilicosta (Marwick, 1928). Wn. Pl. 54 b,g.
zosterophila (Webster, 1905). R (Wq?-R).

FAMILY IRAVADIIDAE

Chevallieria Cossmann, 1888.
 (?)*fossilis* (Finlay, 1924). Pl.
pakaurangia (Laws, 1944). Po-Pl.
waitotarana (Laws, 1940). Wo.

Nozeba Iredale, 1915.

candida Finlay, 1924. Pl (Po-Sc).
couttsi Laws, 1950. Wp. Pl. 54 h,k.
emarginata (Hutton, 1885). Wn-Wc (Wm-R).
perparva Laws, 1939. Po.
plana Laws, 1940. Wo.

FAMILY EATONIELLIDAE

Eatoniella Dall, 1876.
 (*Albosabula*) Ponder, 1965.
lampira (Suter, 1908). R (Wq-R).
 (*Dardanula*) Iredale, 1915.
insueta (Laws, 1950). Wp.
laevicordata (Laws, 1940). Wn.
limbata (Hutton, 1883). R (Wn-R).
olivacea (Hutton, 1882). R (Wm-R).
praecursor (Laws, 1939). Po-Pl.
rivertonensis (Finlay, 1924). Pl?
roseola (Iredale, 1915). R (Wq-R).
sedicula (Laws, 1941). Po-Pl.
subexcavata (Laws, 1941). Po.

Pupatonia Ponder, 1965.

minutula (Powell, 1933). R (Wc-R).

FAMILY CINGULOPSIDAE

Eatonina Thiele, 1912.
 (*Otatara*) Ponder, 1965.
subflavescens (Iredale, 1915). R (Wc-R).

FAMILY ASSIMINEIDAE

Assimineia Fleming, 1828.
waitemata Laws, 1950. Wp.

FAMILY TORNIDAE

Naricava Hedley, 1913
huttoni (Marwick, 1924). Pl.

FAMILY HYDROBIIDAE

Potamopyrgus Stimpson, 1865
antipodarum (Gray, 1843). R (Wp-R).

FAMILY VITRINELLIDAE

Circulus Jeffreys, 1865.
duplicarina (Marwick, 1929). Ld.
 (?)*edomitus* (Marwick, 1931). Sl.
helicoidea (Hutton, 1877). Pl.
inornatus Marshall, 1919. Ab.
politus Suter, 1917. Pl.

Conjectura Finlay, 1926.

glabella (Murdoch, 1905). R (Wq-R).

Elachorbis Iredale, 1915.

albolapis Laws, 1930. Pl.

(?)*subedomita* Laws, 1936. Wo.
subtatei (Suter, 1907). R (Wc?-R).
unicarina Laws, 1940. Wm (Wm-Wn).

Pterolabrella Maxwell, 1969.

cingulata (Bartrum, 1919). Wo.
 (?)*hawera* (Laws, 1940). Wp.
gliscens (Marwick, 1965). Wp-Wm.
lirata Maxwell, 1969. Ld.

Scrupus Finlay, 1926.

sinuatus Laws, 1940. Wo.
tumidus Laws, 1948. Po.

FAMILY CAECIDAE

Caecum Fleming, 1817.
 (*Fartulum*) Carpenter, 1857.
digitulum Hedley, 1904. R (Wm-R).
pertenuis Laws, 1941. Po.

Strebloceras Carpenter, 1859.

hinemoa Finlay, 1931. Pl (Pl-Sw).

SUPERFAMILY CERITHIACEA

FAMILY CERITHIIDAE

Bittium Gray, 1847.
 (*Zebittium*) Finlay, 1926.
exilis (Hutton, 1873). R (Wm-R).
tenuicordatum (Laws, 1940). Wo.
vicinum (Laws, 1941). Pl.

Taxonia Finlay, 1926.

gudrenae Wells, 1986. Tt.
suteri (Marwick, 1924). Wn (Wm-Wn). Pl. 41i.
tesserata Marwick, 1948. Wp.

Zefallacia Finlay, 1926.

australis (Suter, 1919). Pl.
benesulcata Powell & Bartrum, 1929. Po.
chattonensis Marwick, 1929. Ld.
lawsi Marwick, 1948. Wp. Pl. 36m.
ruamahanga Wells, 1986. Tt.

FAMILY DIASTOMATIDAE

Keilostoma Deshayes, 1848.
malindi Marwick, 1943. Ab. Pl. 6f.

FAMILY PAREORIDAE

Batillona Finlay, 1927.
amara Finlay, 1927. Ld? Pl. 9s, t.

Pareora Marwick, 1931.

incincta Marwick, 1931. Sc (Pl-Sl).
pinguis Laws, 1941. Po (Po-Pl).
striolata (Hutton, 1885). Pl (Pl-Wo). Pl. 55 c,f,g.
sublaevis Maxwell, 1966. Ak.

FAMILY POTAMIDIDAE

Batillaria Benson, 1842.
hectori (Harris, 1897). Pl.
pomahakensis Harris, 1897. Ld? Pl. 9u.

Bittiscala Finlay & Marwick, 1937.

communis Finlay & Marwick, 1937. Mw.
simplex (Marshall, 1917). Mw.

Pyrasmus Montfort, 1810.

consobrinus Powell & Bartrum, 1929. Po.
sutherlandi Marwick, 1929. Ld.
waitemataensis Powell & Bartrum, 1929. Po.

Zeacumantus Finlay, 1926.

delicatus Laws, 1950. Wp.
lutulentus (Kiener, 1842). R (Wm-R).
perplexus (Marshall & Murdoch, 1919). Wn.
subcarinatus (Sowerby, 1855). R (Wq-R).
tirangiensis (Marwick, 1926). Tt.

FAMILY THIARIDAE

Melanopsis Férussac, 1807.
trifasciata Gray, 1843. R (Wo-R).

- (*Stilospirula*) Rovereto, 1899.
(?)*pomahaka* (Hutton, 1873). Ld?. **Pl. 9r.**
- FAMILY TURRITELLIDAE**
Colposigma Finlay & Marwick, 1937.
gairi Marwick, 1960. Dp?
imparicincta Finlay & Marwick, 1937. Dp?
mesalia Finlay & Marwick, 1937. Mw.
plebeia Marwick, 1960. Dp?
- Gazameda* Iredale, 1924.
grindleyi (Marwick, 1971). Ld (Ld-Lw?). **Pl. 14f.**
- Maoricolpus* Finlay, 1926.
doni Marwick, 1971. Lw.
horni Marwick, 1971. Pl (Pl-Sw).
ongleyi Marwick, 1931. Sl (Po?-Tk). **Pl. 24h.**
roseus (Quoy & Gaimard, 1834). R (Wo-R).
solomoni (Marwick, 1928). Wp.
waitemataensis (Powell & Bartrum, 1929). Po.
- Spirocolpus* Finlay, 1926.
carsoni Finlay & Marwick, 1937. Dp?
rudis (Marshall, 1919). Ab.
tophinus (Marwick, 1926). Ak (Ak-Ld).
waihaoensis (Marwick, 1924). Ak (Ab-Ak). **Pl. 7l.**
- Stiracolpus* Finlay, 1926.
blacki (Marwick, 1957). R (Wc?-R).
delli delli (Marwick, 1957). R (Wc?-R).
delli granti (Marwick, 1957). Wc. **Pl. 47g.**
delli murchisoni (Marwick, 1957). Wc. **Pl. 47g.**
delli vellai (Marwick, 1957). Wn.
hurunuiensis (Marwick, 1957). Wp?
huttoni huttoni (Cossmann, 1912). Wp (Wo-Wn). **Pl. 36l.**
huttoni ohopeus (Marwick, 1957). Wc.
kaawaensis (Laws, 1936). Wo.
nanulus (Marwick, 1957). Wn.
pagoda (Reeve, 1849). R (Wq-R).
procellosus (Marwick, 1931). Wo.
propagoda Laws, 1940. Wp.
quennelli (Marwick, 1957). Wm.
robiniae (Marwick, 1957). Wc.
shepherdii (Marwick, 1957). Wc.
symmetricus (Hutton, 1873). R (Wn-R).
uttleyi uttleyi (Marwick, 1957). Wn (Wn-Wc?).
uttleyi ruahinensis (Marwick, 1957). Wn.
vigilax (Marwick, 1957). Wc.
waikopiroensis (Suter, 1917). Wn (Wn-Wc).
wiltoni (Marwick, 1957). Wo (Wo-Wn).
- Tropicolpus* Marwick, 1931.
abscisus (Suter, 1917). Pl. **Pl. 20e.**
brycei Marwick, 1971. Ld.
chattonensis (Marwick, 1929). Ld.
harringtoni Marwick, 1971. Ld.
hornibrooki Marwick, 1971. Lw?
mackellari Marwick, 1971. Lw.
milleri Marwick, 1931. Pl (Pl-Tt).
tetleyi (Powell & Bartrum, 1929). Po.
(*Amplicolpus*) Marwick, 1971.
cavershamensis (Harris, 1897). Pl (Po-Pl).
gittosinus (Powell & Bartrum, 1929). Po (Lw-Po).
healyi Marwick, 1971. Ld. **Pl. 14k.**
mataensis (Finlay & Marwick, 1937). D.
ruakiensis Marwick, 1971. Lwh.
wellmani Marwick, 1971. Ab.
- Zeacolpus* Finlay, 1926.
awamoensis Marwick, 1971. Pl.
flemingi Marwick, 1971. Lw.
fyfei Marwick, 1931. Sl-Sw (Sl-Sw).
gagei Marwick, 1971. Ab.
greggi Marwick, 1971. Lw.
kanieriensis (Harris, 1897). Tk (Tk-Wp?). **Pl. 36n.**
keari Marwick, 1971. Ld (Lwh?-Ld).
lawi Marwick, 1971. Pl? (Po-Pl).
lornensis (Marwick, 1926). Ak (Ak-Lwh?).
luteolapis (Marwick, 1931). Sc (Pl?-Sc).
- nisseni* Marwick, 1971. Sw.
opoitus opoitus Marwick, 1965. Wo.
opoitus takapauensis Marwick, 1965. Wp.
peteri Marwick, 1971. Tt (Tt-Tk).
pukeuriensis Marwick, 1934. Pl (Pl-Sl). **Pl. 20a.**
taranakiensis Marwick, 1965. Tt (Sw?-Tt). **Pl. 29h.**
vittatus (Hutton, 1873). R (Wo?-R). **Pl. 47f.**
wharekuriensis Marwick, 1971. Ld (Lwh-Ld).
willettii Marwick, 1971. Sc (Sc-Sw).
woodhouseae Marwick, 1971. Po (Lw-Po).
(*Leptocolpus*) Finlay & Marwick, 1937.
semiconcavus (Suter, 1911). Mw. **Pl. 2b.**
- FAMILY VERMETIDAE**
Agathirses Montfort, 1808.
senex (Marwick, 1926). Ak.
- Serpulorbis* Sacco, 1827.
lornensis Marwick, 1927. Ak.
ophioides (Marshall & Murdoch, 1921). Pl (Ld?-Pl).
zelandicus (Quoy & Gaimard, 1834). R (Pl?-R).
- Stephopoma* Mörch, 1860.
roseum (Quoy & Gaimard, 1834). R (Pl?-R).
- FAMILY SILIQUARIIDAE**
Siliquaria Bruguière, 1789.
weldii (Tenison Woods, 1876). R (Pl?-R).
- SUPERFAMILY STROMBACEA**
FAMILY APORRHAIIDAE
Dicroloma (sensu lato) Gabb, 1868.
zelandica Marshall, 1919. Ab (Ab-Ak). **Pl. 6g.**
- Drepanocheilus* Meek, 1864.
(*Tulochilus*) Finlay & Marwick, 1937.
benoni Finlay & Marwick, 1937. Mw. **Pl. 2e.**
- Hemichenopus* Steinmann & Wilckens, 1908.
thomsoni (Allan, 1926). Ab.
- Struthioptera* Finlay & Marwick, 1937.
osiris Finlay & Marwick, 1937. Mw.
- FAMILY STRUTHIOLARIIDAE**
Conchothyra Hutton, 1877.
australis (Marshall, 1916). Mw. **Pl. 2g, h.**
expedita Finlay & Marwick, 1937. Mw.
- Monalaria* Marwick, 1924.
concinna (Suter, 1917). Ab. **Pl. 6a, b.**
gracilis gracilis Finlay & Marwick, 1937. Dp?.
gracilis filata Marwick, 1960. Dp?.
- Perissodonta* Martens, 1878.
minor (Marshall, 1917). Mw.
mortoni Marwick, 1960. Dp?
- Pellicaria* Gray, 1847.
acuminata (Marwick, 1924). Wn (Wm-Wn) **Pl. 42e.**
canaliculata (Zittel, 1864). Wp. **Pl. 36q.**
cestata Marwick, 1965. Wp.
clarki (Neef, 1970). Wm.
convexa (Marwick, 1924). Wn. **Pl. 42b.**
fossa (Marwick, 1924). Wn. **Pl. 42a.**
incrassata (Powell, 1931). Wp. **Pl. 36o.**
lacera (Marwick, 1931). Tk.
marima (Neef, 1970). Wm.
monilifera (Suter, 1914). Wp.
nana (Marwick, 1926). Tt. **Pl. 29g.**
parva (Suter, 1915). Wo.
procanalis Beu, 1970. Wo (Tk?-Wo).
pseudovermis (Bartrum & Powell, 1928). Wo.
rugosa (Marwick, 1924). Wn. **Pl. 42c.**
vermis vermis (Martyn, 1784). R (Wc-R). **Pl. 47u.**
vermis flemingi (Neef, 1970). R (Wc-R).
vermis grahami (Neef, 1970). R (Wc-R).
zelandiae (Marshall & Murdoch, 1920). Wp (Wo?; Wp) **Pl. 36p.**
- Struthiolaria* Lamarck, 1816.
calcar Hutton, 1886. Pl (Ld?; Lw-Sw; Sw?). **Pl. 20g, h.**

cincta Hutton, 1873. Tk? (Tr?-Tk).
cingulata Zittel, 1864. Wo? (Tk?-Wo?).
dolorosa King, 1934. Wo. **Pl. 36k.**
errata Marwick, 1924. Wp.
firthi Marwick, 1948. Wp.
frazieri Hector in Hutton, 1885. Wn. **Pl. 42f.**
illepida Bartrum & Powell, 1928. Wo.
lawsi Powell & Bartrum, 1929. Po.
nexa Marwick, 1931. Tk.
papulosa (Martyn, 1784). R (Wn-R). **Pl. 47r.**
praenuntia Marwick, 1926. Tt. **Pl. 29i.**
prior Finlay, 1926. Ld. **Pl. 15a.**
(Callusaria) Finlay, 1926.
arthritica Bartrum & Powell, 1928. Wo (Tk?-Wo).
callosa Marwick, 1924. Tt (Sc-Tt). **Pl. 29d, e.**
obesa Hutton, 1885. Wo? (up.Tr?-Tk-Wo). **Pl. 36i.**
otaioica Laws, 1935. Po.
spinifera Marwick, 1924. Pl.
spinosa Hector, 1886. Pl (Pl-Sw). **Pl. 20b.**
tuberculata Hutton, 1873. Pl. **Pl. 20c, d.**

SUPERFAMILY HIPPONICACEA

FAMILY FOSSARIDAE

Korovina Iredale, 1918.

accelerans Marwick, 1928. Wp.
dupliangulata Laws, 1940. Wo.

Micreschara Cossmann, 1891.

(Naridista) Laws, 1939.

(?)esculenta (Laws, 1944). Po.
jocelynae (Laws, 1939). Po-Pl.

Radinista Finlay, 1926.

concinna (Marshall & Murdoch, 1921). Pl.
exilis (Murdoch, 1900). Wc.
viviennae (Laws, 1939). Po.

Zeradina Finlay, 1926.

aculeata Laws, 1939. Po.
costellata (Hutton, 1885). Wc.
(?)obliquecostata (Marshall & Murdoch, 1920). Ab.
odhneri Powell, 1927. R (Wc-R).

FAMILY HIPPONICIDAE

Hipponix Defrance, 1819.

centrifugalis Marwick, 1931. Sl (Pl-Sl).

SUPERFAMILY CALYPTRAEACEA

FAMILY CALYPTRAEIDAE

Cheilea Modeer, 1793.

janitrix Maxwell, 1966. Ak.
plumea Laws, 1932. Sl.
postera Laws, 1936. Wo (Wo-Wp).

Crepidula Lamarck, 1799.

costata Sowerby, 1824. R (Wc-R).
densistria Suter, 1917. Pl.
haliotoidea Marwick, 1926. Tt.
monoxyla (Lesson, 1830). R (Po?-R).
opuraensis (Bartrum & Powell, 1928). Wo.
profunda (Hutton, 1873). Wc (Wc?-R).
radiata (Hutton, 1873). Tk? (Ld?-Wn?). **Pl. 14b, e; Pl. 29j.**
salebrosa (Marwick, 1929). Ld (Ld-Lw).
turnialis (Bartrum & Powell, 1928). Wo. (Wo-Wn?).

Sigapatella Lesson, 1830.

maccoyi (Suter, 1917). Pl. **Pl. 20i.**
mapalia Marwick, 1929. Ld (Dp?-Ld).
novaezelandiae (Lesson, 1830). R (Pl?-R).
otamatea Laws, 1944. Pl (Po-Pl).
patulosa Powell & Bartrum, 1929. Po.
perampla (Powell & Bartrum, 1929). Po.
subvaricosa Powell & Bartrum, 1929. Po.
vertex Marwick, 1926. Ak.
(Spirogalerus) Finlay & Marwick, 1937.
lamellaria (Finlay & Marwick, 1937). Mw. **Pl. 2c, d.**

Zegalerus Finlay, 1926.

crater Finlay, 1926. Wn (Wp-R).
giganteus Beu, 1970. Tt.
tenuis (Gray, 1867). R (Wn-R).

FAMILY CAPULIDAE

Capulus Montfort, 1810.

uncinatus (Hutton, 1873). Wq. **Pl. 47j, n.**

Malluvium Melvill, 1906.

calcareum (Suter, 1909). R (Wc-R).

Neojanacus Suter, 1907.

perplexus Suter, 1907. R (Sw-R).
wharekuriensis Laws, 1935. Ld.

"*Neojanacus*"

kaawaensis Bartrum & Powell, 1928. Wo.

FAMILY TRICHOTROPIDAE

Dalliella Cossmann, 1895.

(?)neozelanica Laws, 1944. Po.

Miplioderma Laws, 1940.

finlayi (Laws, 1935). Lw.
reticulatum (Suter, 1917). Pl.
mangawera (Laws, 1940). Wm (Wp-Wm).
waihuanum (Marwick, 1965). Wp.
(Eosirius) Maxwell, 1966.
admeteforme (Maxwell, 1966). Ak.

Trichosirius Finlay, 1926.

cavatoctocarinatus (Laws, 1940). R (Wm-R).
inornatus (Hutton, 1873). R (Wn-R).
octocarinatus Powell, 1931. R (Wq-R).

Zelippistes Finlay, 1926.

benhami perornatus (Marshall & Murdoch, 1923). Wc.

FAMILY XENOPHORIDAE

Xenophora Fischer, 1807.

flemingi Beu, 1977. Pl (Po-Sl?).
neozelanica Suter, 1908. R (Wo-R).
prognata (Finlay, 1926). Ld (Ak?-Sl). **Pl. 14m, n.**

SUPERFAMILY LAMELLARIACEA

FAMILY TRIVIIDAE

SUBFAMILY ERATOINAE

Archierato Schilder, 1932.

accola (Laws, 1935). Ak.
antiqua (Marshall, 1919). Ab (Ab-Ak).
(?)auklandica (Dell, 1950). Po.
simulacrum Laws, 1939. Po (Po-Pl).
zeyrulata Laws, 1939. Po (Po-Pl).

"*Hespererato* Schilder, 1932".

pukeuriensis (Laws, 1935). Pl.
sepositum (Laws, 1935). Ak.
tenuilabrum (Laws, 1935). Sc (Pl-Sl).
zevitellina Laws, 1941. Po (Po-Pl).

Lachryma Sowerby, 1832.

clifdenensis (Laws, 1935). Sl.
marshalli (Marwick, 1929). Ld.
senectus (Murdoch, 1924). Pl.
submorosa (Laws, 1935). Pl.
vulcania (Marwick, 1926). Ak (Ak-Ar).
waitakiensis (Laws, 1935). Lw.

Proterato Schilder, 1927.

awamoana Schilder, 1933. Pl.
(?)dubia (Hutton, 1873). Ld.
neozelanica (Suter, 1917). Pl (Lw-Pl). **Pl. 20j.**
(?)ptiocenica Fleming, 1943. Wo (Wo-Wp).
waiauensis (Laws, 1935). Sc (Pl-Sl).

Willungia Powell, 1938.

erro (Laws, 1941). Po.
fracta (Tomlin, 1916). Ld.
maoria Powell, 1938. Pl (Po-Sc). **Pl. 24g.**

SUBFAMILY TRIVIINAE

Trivia (sensu lato) Gray, 1837.

aequiflora Laws, 1941. Po.
flora Marwick, 1928. Wp.
kaiparaensis Laws, 1939. Po.

merces (Iredale, 1924). R (Wn-R).
pinguior Marwick, 1926. Ak. **Pl. 7o**, p.
zealandica Kirk, 1882. Wn (Wn-Wc). **Pl. 47m**, q.

SUPERFAMILY CYPRAEACEA

FAMILY CYPRAEIDAE

Bernaya Jousseume, 1884.
chathamensis Cernohorsky, 1971. Dw.
zoiloides Schilder, 1958. Ab.

Cypraea (sensu lato) Linné, 1758.
ficoides (Hutton, 1873). Lwh?
(Notadusta) Schilder, 1935.
clifdenensis (Cernohorsky, 1971). Pl (Po-Tk). **Pl. 24e**, f.
trellisickensis (Suter, 1917). Ld.

FAMILY OVULIDAE

Eocypraea Cossmann, 1903.
novaezealandiae (Schilder, 1941). Ab.

SUPERFAMILY NATICACEA

FAMILY NATICIDAE

SUBFAMILY GLOBISININAE

Globisium Marwick, 1924.
crassiliratum Finlay, 1926. Lw (Ld-Lw). **Pl. 15h**.
drewi (Murdoch, 1899). Wc (Wo-R). **Pl. 47i**.
elegans (Suter, 1917). Ak? (Ab-Ak).
miocaenicum (Suter, 1917). Pl (Lw-Pl).
spirale (Marshall, 1917). Mw. **Pl. 2f**.

SUBFAMILY NATICINAE

Carinacca Marwick, 1924.
allani (Marwick, 1924). Ab (Ab-Ak?). **Pl. 6h**.
waihaoensis (Suter, 1917). Ak (Ab-Ak). **Pl. 8c**.

Magnatica Marwick, 1924.
approximata (Suter, 1917). Ld?
fons Finlay, 1930. Ab.
nuda (Marwick, 1924). Tt.
planispira (Suter, 1917). Po (Ld-Pl). **Pl. 15f**.
(Spelaenacca) Finlay, 1930.
clifdenensis Finlay, 1926. Pl.
firma (Marwick, 1924). Mw.
harrisensis (Marwick, 1924). Pl.
parilis Finlay, 1930. Ak.
procera Finlay, 1930. Ak.
rectilatera Finlay, 1926. Pl.
sutherlandi (Marwick, 1924). Ld. **Pl. 15i**.
waitemataensis Powell, 1938. Po.

Proxiuber Powell, 1933.
anteaustrale Powell, 1938. Wn (Wo-Wn).
australe (Hutton, 1873). R (Wn-R).
kaawaense kaawaense (Marwick, 1924). Wo.
kaawaense astrictum Marwick, 1965. Wo.
platamodes Finlay & Marwick, 1937. D.

Tanea Marwick, 1931.
consortis (Finlay, 1924). Pl. (Pl-Wo). **Pl. 20i**.
inexpectata (Finlay, 1924). Sl.
pittensis (Marwick, 1928). Wp.
praeconsors (Finlay, 1924). Ak.
sublata (Marwick, 1924). Pl.
zelandica (Quoy & Gaimard, 1832). R (Wn-R). **Pl. 47o**.

Taniella Finlay & Marwick, 1937.
bacca (Marwick, 1924). Ab.
mima Maxwell, 1988. Sw (Sc-Sw).
motutaraensis (Powell, 1935). Pl.
notocenia (Finlay, 1924). Pl (Ld-Wo). **Pl. 20f**.
planisuturalis (Marwick, 1924). Wn (Wo-Wc). **Pl. 41n**.
poliniciiformis Beu, 1970. Tt.
tantilla Marwick, 1960. Dp?
(Pristinacca) Finlay & Marwick, 1937.
senisculus (Marwick, 1924). Mw.

SUBFAMILY POLINICEINAE

Amauropsona Finlay & Marwick, 1937.
major (Marshall, 1917). Mw.
teres (Marwick, 1924). Mw.

Eunaticina Fischer, 1885.
linnaeana (Récluz, 1843). (Wq-R?). **Pl. 47s**.

Falsilunatia Powell, 1951.
ambigua (Suter, 1913). Wn (Wn-R?).

Friginatica Hedley, 1916.
compressa (Marwick, 1924). Sl-Sw?
marshalli Marwick, 1931. Wp (Tk-Wp).
marwicki Beu, 1970. Tt.
prisca (Marwick, 1924). Ab.
suturalis (Hutton, 1877). Ak? (Ak). **Pl. 8e**.
vaughani (Marwick, 1924). Pl (Ld-Tt).

Lunatia Gray, 1847.
fyfei (Marwick, 1924). Mw. **Pl. 2i**.
lateaperta (Marwick, 1924). Mw.

Neverita Risso, 1826.
pontis (Marwick, 1924). Ak. **Pl. 8d**.

Polinices Montfort, 1810.

chattonensis (Marwick, 1924). Ld.
huttoni Ihering, 1907. Pl. (Pl-Sl?). **Pl. 20k**.
intracassus Finlay, 1924. Sw-Tt? (Sl-Sw; Tt?).
laxus (Finlay, 1926). Sw.
lobatus (Marwick, 1924). Pl (Lw-Sl).
mackayi Marwick, 1931. Tk? (Sw?-Wo).
mucronatus (Marwick, 1924). Tt (Sl?-Wo).
oneroaensis Powell & Bartrum, 1929. Po.
otaioensis Marwick, 1960. Dp?
parki Finlay & Marwick, 1937. Mw.
propeovatus (Marwick, 1924). Tt (Sw-Wo). **Pl. 29i**.
sagenus Suter, 1917. Pl.
unisulcatus (Marwick, 1924). Tt.
waipaensis (Marwick, 1924). Lwh-Ld.
waipipiensis (Marwick, 1924). Wp (Wo?-Wm). **Pl. 37f**.
(Polinella) Marwick, 1931.
blaesius Marwick, 1929. Ld.
creper Marwick, 1965. Tt.
esdailei (Marwick, 1924). Ar (Ak-Ar). **Pl. 8a**.
finlayi (Marwick, 1924). Mw. **Pl. 2j**, k.
fryei Laws, 1933. Pl.
gradisuturalis Marwick, 1932. Sw (Sw-Tt).
incertus (Marwick, 1924). Pl (Po-Pl).
modestus (Marwick, 1924). Pl.
obstructus (Marwick, 1924). Tk-Wo? (Pl-Wp). **Pl. 37i**.
scalptus (Marwick, 1924). Tt (Sw-Tt; Tk?). **Pl. 29k**.

Propesinum Iredale, 1929.
auriforme (Marwick, 1924). Mw.
fornicatum (Suter, 1917). Ab? (Dp?-Ab). **Pl. 6d**, e.

Uberella Finlay, 1928.
barrierensis (Marwick, 1924). R (Wo-R).
cicatricella Marwick, 1965. Wo (Wo-Wm).
cicatrix Marwick, 1931. Sc? (Po-Tt; Tk?). **Pl. 27g**, h.
denticulifera (Marwick, 1924). Wc (Wn-R).
keyesi Marwick, 1965. Wn.
maesta (Marwick, 1924). Tt.
pseudovitrea (Finlay, 1924). Pl.
pukeuriensis (Marwick, 1924). Pl.
vitrea (Hutton, 1873). R (Wc-R).

"Uberella"

acerva Laws, 1933. Po.
haasti (Marwick, 1924). Ak (Ab-Ak). **Pl. 8b**.

SUBFAMILY SININAE

Sinum Röding, 1798.
infirmum Marwick, 1924. Pl (Pl-Tt).
marwicki Laws, 1930. Pl (Pl-Wp?).

SUPERFAMILY TONNACEA

FAMILY CASSIDAE

SUBFAMILY CASSINAE

Galeodea Link, 1807.
apodemetes Marwick, 1934. Pl (Ld-Pl). **Pl. 20q**.
geniculosa Marwick, 1942. Ab (Ab-Ak?).
modesta (Suter, 1917). Ab. **Pl. 6l**.

(?)*senex* (Hutton, 1873). ?
triganceae Dell, 1953. R (Wp-R).
(Galeocorys) Kuroda & Habe, 1957.
 *(6)*flemingi* Beu and Maxwell, nom. nov. Tk.
sulcata (Hutton, 1873). Wp (Tk-Wp; Wc-R?). **Pl. 48b.**
wylliei Marwick, 1931. Pl?
(Taieria) Finlay & Marwick, 1937.
allani (Finlay & Marwick, 1937). Mw. **Pl. 2 l, s.**

SUBFAMILY PHALIINAE

Echinophoria Sacco, 1890.
emilyae (Laws, 1932). Pl.
grangei (Marwick, 1926). Tt.
oconnori (Dell, 1952). Tt.
oneroensis (Powell, 1938). Po.
pollens (Finlay, 1926). Pl (Po-Sc). **Pl. 24d.**
toreuma (Powell, 1928). Pl (Pl-Sw).

Semicassis Mörch, 1852.

labiata (Perry, 1811). R (Wq-R).
pyrum (Lamarck, 1822). R (Wn-R). **Pl. 48a.**
(Kahua) Marwick, 1928.
fibrata (Marshall & Murdoch, 1920). Wp (Wo-Wm).
kaawaensis (Bartrum & Powell, 1928). Wo (Tk-Wo).
lilliei (Fleming, 1943). Wn.
marwicki (Fleming, 1943). Wn.
skinneri (Marwick, 1928). Wp (Wo-Wp). **Pl. 37c.**

FAMILY RANELLIDAE

SUBFAMILY RANELLINAE

Argobuccinum Herrmannsen, 1846.
pustulosum tumidum (Dunker, 1862). R (Wq-R).

Fusitriton Cossmann, 1903.

magellanicus laudandus Finlay, 1926. R (Wq-R).

Ranella Lamarck, 1816.

australasia australasia (Perry, 1811). R (Tt-Tk; Wq-R).
kaiparaensis (Finlay, 1924). Po.

SUBFAMILY CYMATIINAE

Cabestana Röding, 1798.
manawatuna Fleming, 1943. Wn (Tt-Wn).
spengleri (Perry, 1811). R (Wc-R).
tabulata (Menke, 1843). R (Wn-R). **Pl. 48d.**
tetleyi (Powell & Bartrum, 1929). Po (Lw-Po).

Charonia Gistel, 1848.

lampas rubicunda (Perry, 1811). (Tk?; Wq-R).

Cymatium Röding, 1798.

(Monoplex) Perry, 1811.
parthenopeum parthenopeum (Salis, 1793). R (Wc-R). **Pl. 48g.**
(Turritriton) Dall, 1904.
exaratum exaratum (Reeve, 1844). R (Wq-R).

Linatella Gray, 1857.

caudata (Gmelin, 1791). R (Wc-R). **Pl. 48c.**

Sassia Bellardi, 1873.

arthritica (Powell & Bartrum, 1929). Po (Lw-Po).
cyphoides (Finlay, 1924). Ar (Ak-Ar).
decagonia (Finlay, 1924). Ab.
jobbernsi (King, 1933). Wm-Wn? (Wm-Wn).
maoria (Finlay, 1924). Pl (Ld-Pl). **Pl. 20o.**
 *(7)*minima* (Hutton, 1873). Ld (Ld-Lw)
neozelanica (Marshall & Murdoch, 1923). Pl (Pl-Sl?). **Pl. 24i.**
pahaoensis (Vella, 1954). Tt (Sc-Tt).
palmeri (Powell, 1976). R (Tt-R).
parkinsonia (Perry, 1811). R (Wq-R). **Pl. 48f.**
pusulosa (Marwick, 1965). Wp (Wo-Wn).
tortirostris (Tate, 1888). (Po?; Pl-Sw). **Pl. 24j.**
zealta (Laws, 1939). Po-Pl? (Po-Sc). **Pl. 24j.**
(Haurokoa) Fleming, 1955.
bartrumi (Powell, 1938). Po (Ld?-Po).
marwicki (Finlay, 1924). Ak (Ak-Ar). **Pl. 7u.**
woodi (Fleming, 1955). Tk (Sw-Wo). **Pl. 30b.**

FAMILY PERSONIDAE

Kotakaia Beu, 1988
simplex Beu, 1988. Dt. **Pl. 4p.**

Personopsis Beu, 1988.
beui (Maxwell, 1968). Ak.

FAMILY TONNIDAE

Eudolium Dall, 1889.
aoteanum Beu, 1970. Po-Pl? (Po-Pl).

Tonna Brunnich, 1772.

olearium (Linné, 1758). R (Wn-R).

FAMILY FICIDAE

Ficus Röding, 1798.
imperfecta Marshall & Murdoch, 1919. Pl.
parva Suter, 1917. Lwh? (Ak-Lwh?).

Priscoficus Conrad, 1866.

alectodens Marwick, 1942. Ab. **Pl. 6j.**
allani Marwick, 1960. Dp?
obtusa (Marshall, 1917). Mw. **Pl. 2w.**

SUPERFAMILY CERITHIOPSACEA

FAMILY CERITHIELLIDAE

Cerithiella Verrill, 1882.
 (?)*infelix* (Marwick, 1931). Pl-Sc.
 (?)*paroaensis* Maxwell, 1988. Sw.
 (?)*propria* (Laws, 1941). Po.
tricincta Marshall, 1919. Ab (Ab-Ak).

Gothicispira Maxwell, 1988.

marshalli Maxwell, 1988. Sw.

Miopila Finlay, 1926.

fidicula (Suter, 1917). Pl.

FAMILY CERITHIOPSIDAE

Ataxocerithium Tate, 1894.
huttoni (Cossmann, 1895). Wc (Wc-R).
kaawaense Laws, 1936. Wo.
pyramidale Finlay, 1924. Pl.
simplex Marwick, 1928. Wn (Wp-Wn).
tricingulatum Marwick, 1924. Wn (Wm-Wn).

Cerithiopsis Forbes & Hanley, 1850.

(?)*aequicincta* Suter, 1917. Pl.
 (?)*mucro* (Laws, 1939). Po.
powelli Marshall, 1978. R (Wq-R).
 (?)*saepa* (Marwick, 1931). Pl.
 (?)*simulator* (Laws, 1939). Po.
 (?)*temperans* (Marwick, 1931). Sl.

Horologica Laseron, 1956.

violator (Laws, 1944). Po.

Joculator Hedley, 1909.

decapitatus Grant-Mackie & Chapman-Smith, 1971. Wq.

Seila A. Adams, 1861.

(Hebeseila) Finlay, 1926.
bulbosa Suter, 1908. R (Wc-R).
(Lyroseila) Finlay, 1928.
cincta (Hutton, 1886). Wn? (Wn-R). **Pl. 55 a,d.**
(Notoseila) Finlay, 1926.
attenuissima Marshall & Murdoch, 1920. Ab (Ab-Ak).
clifdenensis (Laws, 1941). Pl.
kaiparaensis (Laws, 1941). Po.
terebelloides (Hutton, 1873). R (Wn-R).

Retilaskeya Marshall, 1978.

zelandica Marshall, 1978. R (Wc-R).

Specula Finlay, 1926.

retifera (Suter, 1908). R (Wm-R).
styliformis (Suter, 1908). R (Wn-R).

Zaclys Finlay, 1926.

sarissa (Murdoch, 1905). R (Wn-R).
spiculum Laws, 1940. Wo.

SUPERFAMILY TRIPHORACEA

FAMILY TRIPHORIDAE

- Bouchettriphora* Marshall, 1983.
pallida (Pease, 1870). R (Wo-R).
 (?)*tepikiensis* (Powell, 1934). Wq.

- Cautotriphora* Laws, 1940.
simulans Laws, 1940. Wn (Wm-Wn).

- Inella* Bayle, 1879.
aoteaensis (Marshall & Murdoch, 1920). Ab (Ab-Ak).
zeattenuata Beu, 1970. Tt.
zespina (Laws, 1939). Po.

- Monophorus* Grillo, 1877.
fascelinus (Suter, 1908). R (Wc-R).
 (?)*insertus* (Marwick, 1928). Wp.

- Nototriphora* Marshall, 1983.
kaawaensis (Laws, 1940). Wo.

- Socienna* Finlay, 1926.
maoria Finlay, 1930. R (Wn-R).

- Triforis* (sensu lato) Deshayes, 1834.
neozelanicus (Laws, 1939). Po-Pl.
zecollatus (Laws, 1941). Po.

SUPERFAMILY EULIMACEA

FAMILY ACLIDIDAE

- Aclis* Lovén, 1846.
planostoma (Hutton, 1885). Wn-Wc (Wo-Wc).

- Awanuia* Powell, 1927.
dilatata Powell, 1927. R (Wo-R).
tenuis Laws, 1936. Wo.

- Austrorissopsis* Ponder, 1965.
 (?)*castlecliffensis* (Finlay, 1930). Wc.
friata (Finlay, 1930). Pl.
ponderi Grant-Mackie & Chapman-Smith, 1971. Wq.

- Rissopsetia* Dell, 1956.
nukumaruensis (Laws, 1940). Wn.

- Scaloronoba* Powell, 1927.
chemnitzia Laws, 1944. Po.
costata Powell, 1927. R (Wo-R).
pristina Laws, 1941. Po.

- Graphis* Jeffreys, 1867.
neozelanica Laws, 1939. Po.
problanda Laws, 1944. Po.

FAMILY EULIMIDAE

- Eulima* (sensu lato) Risso, 1826.
aoteaensis Marshall & Murdoch, 1921. Pl.
christyi Marwick, 1924. Wn. Pl. 41h.
hampdenensis Laws, 1935. Ab.
incondita Marwick, 1931. Pl?
obliqua (Hutton, 1885). Wn.
otaioensis Laws, 1933. Po.
treadwelli Hutton, 1885. Wc.
waihaoensis Allan, 1926. Ak (Ak-Ar). Pl. 7s.

- Fusceulima* Laseron, 1955.
murdochi (Hedley, 1904). R (Wq-R).

- Hypermastus* Pilsbry, 1899.
bulbula (Murdoch & Suter, 1906). R (Wq-R).

- Melanella* Bowdich, 1822.
badenia (Laws, 1939). Po (Po-Pl).
collator (Laws, 1944). Po (Po-Pl).
geoffreyi (Laws, 1936). Wo.
kaiparaensis (Laws, 1939). Po-Pl.
lautiodes Finlay and Marwick, 1937. Mw.
lentocontracta (Laws, 1941). Po.
patutahiensis Marwick, 1931. Sl.
tutamoensis Marwick, 1931. Sl.
waikomitica (Laws, 1939). Po (Po-Pl).
waiaotea (Laws, 1941). Po.

- Niso* Risso, 1826.

- basiglobosa* Marwick, 1942. Ab.
neozelanica Suter, 1917. Ld (Ak-Ld).
putata Finlay & Marwick, 1937. Dp?

FAMILY STILIFERIDAE

- Venustylifer* Powell, 1939.
bountyensis (Powell, 1933). R (Wq-R).

SUPERFAMILY EPITONIACEA

FAMILY EPITONIIDAE

- Acrilla* A. Adams, 1860.
elata (Suter, 1917). Po.
kaiparaensis Laws, 1944. Pl.

- Cirsotrema* Mörch, 1852.
angulatum Marwick, 1926. Tt (Sc-Tt).
caelicola Finlay, 1926. Pl.
chathamense Marwick, 1928. Wo.
firmatum Laws, 1939. Po-Pl.
gagei Maxwell, 1978. Lwh. Pl. 9m.
kuriense Marwick, 1942. Ab. Pl. 6c.
lyratum (Zittel, 1864). Ld (Lwh-Ld, ?Lw). Pl. 14l.
parvulum Marwick, 1928. Wo.
propelyratum Marwick, 1928. Wo.
zelebori (Dunker, 1866). R (Wo-R).
 (Tioria) Marwick, 1928.
 (?)*marshalli* Laws, 1935. Ab.
youngi Marwick, 1928. Dw. Pl. 4n.

- Clathroscala* Boury, 1889.
derelecta Marwick, 1965. Wo.
tricincta (Marshall, 1918). Pl?

- Epitonium* Röding, 1798.
mackayi (Marwick, 1943). Lw.
 (Hyaloscala) Boury, 1889.
bucknilli Powell, 1924. R (Wq-R).
jukesianum (Forbes, 1852). R (Wc-R).
muricatum (Laws, 1933). Pl.

- Funiscala* Boury, 1891.
nympha (Hutton, 1885). Wn (Wm-Wn).

- Goniscala* Marwick, 1943.
diurna Marwick, 1943. Pl.

- Notacirsa* Finlay, 1926.
awamoensis (Marshall & Murdoch, 1921). Pl.
gracillima (Suter, 1917). Ld.
oamarutica (Suter, 1917). Pl.
prisca (Suter, 1917). Po.
subnodulosa Maxwell, 1988. Sw.

- Opalia* H. & A. Adams, 1853.
tenuispiralis (Marshall, 1919). Ab.

- Pliciscala* Boury, 1887.
komitica Laws, 1944. Po-Pl.

- Proscala* Cossmann, 1912.
 (?)*parvicostata* (Marshall, 1917). Mw.

- Turriscala* Boury, 1889.
 (?)*cylindrella* (Suter, 1917). Ld.
kaiparaensis Laws, 1939. Po.
marginata (Hutton, 1885). Lw.
 (Kapua) Marwick, 1931.
powelli Marwick, 1931. Wo.

FAMILY JANTHINIDAE

- Hartungia* Bronn, 1861.
chavani Ludbrook, 1978. (Wm-Wn).
typica Bronn, 1861. (Tk-Wp). Pl. 37a, b.

ORDER NEOGASTROPODA

SUPERFAMILY MURICACEA

FAMILY BUCCINIDAE

- Aeneator* Finlay, 1926.
attenuatus Powell, 1927. R (Wc-R).
comptus (Finlay, 1924). R (Wq-R).

- delicatus* Powell, 1929. Wc. **Pl. 48o**.
elegans (Suter, 1917). Wn (Wm-R). **Pl. 37n**.
huttoni Finlay, 1930. Tk.
imperator King, 1933. Wn (Wm?-Wn).
marshalli marshalli (Murdoch, 1924). Wc (Wn-Wc). **Pl. 48p**.
nothopanax Fleming, 1954. ?Wn.
 (?)*problematicus* Fleming, 1943. Wp.
thomsoni (Marwick, 1924). Wn.
 (*Ellicea*) Finlay, 1928.
antorbitus (Fleming, 1955). Tk.
conformatus (Marwick, 1931). Tt?
henchmani (Marwick, 1926). Tt.
orbitus (Hutton, 1885). Wm? (Wm-Wn).
perobtus (Fleming, 1943). Wo.
validus (Marwick, 1928). Wp. **Pl. 37j**.
wairoanus Marwick, 1965. Wn.
willetti (Fleming, 1955). Tk(Tt-Tk). **Pl. 27i**.
- Austrofusus* Kobelt, 1879.
acuticostatus (Suter, 1917). Ab. **Pl. 6m**.
affiliatus Finlay, 1926. Lw. **Pl. 15d**.
allani King, 1934. Wp (Wo?-Wp).
bicarinatus (Suter, 1917). Lwh (Ak-Lwh).
chathamensis Finlay, 1928. R (Wn?-R).
clavicus King, 1933. Wm.
coerulescens (Finlay, 1930). Tk. **Pl. 30e**.
conoideus (Zittel, 1864). Tk.
cottoni King, 1933. Wn.
glans (Röding, 1798). R (Wn?; Wc-R). **Pl. 49c**.
 (?)*latecostatus* (Suter, 1917). Pl.
magnificus Finlay, 1926. Sc (Pl-Sl). **Pl. 25a**.
marshalli King, 1933. Wn.
pagoda (Finlay, 1924). Wp? (Wo-Wm). **Pl. 37g**.
pliocenicus (Powell, 1931). Wp (Wo-Wm). **Pl. 37d**.
precursor Finlay, 1926. Ld.
solitarius Dell, 1950. Po.
spiniferus (Finlay & McDowall, 1923). Pl. **Pl. 21k**.
taitae (Marwick, 1924). Wn. **Pl. 42k**.
valedictus King, 1935. Tt (Sw-Tk). **Pl. 30f**.
 (*Neocola*) Finlay, 1926.
alpha Finlay, 1926. Pl. **Pl. 25b**.
apudalpha Finlay, 1926. Lw (Lw-Po). **Pl. 21j**.
beta Finlay, 1926. Pl. **Pl. 25c**.
cliftonensis (Marwick, 1926). Tt.
demissus Marwick, 1931. Sw (Sl-Sw). **Pl. 30g**.
flexuosus (Marshall, 1918). Pl? (Po-Pl). **Pl. 25g**.
gamma Finlay, 1926. Sc (Sc-Sl; Tt?). **Pl. 25d**.
marwicki King, 1933. Tt.
ngatuturaensis Bartrum & Powell, 1928. Wo. **Pl. 37l**.
oneroaensis Powell & Bartrum, 1929. Po.
 (?)*zitteli* (Suter, 1914). Lwh.
- Buccinum* Deshayes, 1830.
caudatum Powell, 1929. Wc. **Pl. 49b**.
compactum compactum (Suter, 1917). Pl.
compactum tetleyi Powell & Bartrum, 1929. Po.
grindleyi Marwick, 1965. Wm.
medium (Hutton, 1885). W?
linea linea (Martyn, 1784). R (Wn-R).
linea flexicostatum Dell, 1956. R (Wm-R).
longicollis Powell, 1929. Pl.
pallidum pallidum Finlay, 1928. R (Wc-R).
pallidum powelli Ponder, 1971. R (Wn?-R).
 (?)*pangoides* Beu, 1973. Wp. **Pl. 37s**.
pertinax finlayi Powell, 1929. R (Wn-R).
pertinax pansum Marwick, 1965. Wm.
protensum Powell, 1929. Pl. **Pl. 21b**.
rigidum Powell, 1929. Lw.
tuberculatum Powell, 1929. Pl.
vittatum vittatum (Quoy & Gaimard, 1833). R (Wm-R).
vittatum littorinoides (Reeve, 1846). R (Wq-R).
vittatum tepikiensis Grant-Mackie & Chapman-Smith, 1971. Wq.
wairarapaensis Powell, 1938. Wn (Wn-Wq).
- Cantharus* Röding, 1798.
 (*Zeapollia*) Finlay, 1926.
acuticingulatus (Suter, 1917). Pl. **Pl. 21a**.
- Colubraria* Schumacher, 1817.
neozelanica Maxwell, 1966. Ak.
sutherlandi Beu, 1973. Lw (Lw-Po).
- Cominella* Gray, 1850.
adpersa (Bruguière, 1789). R (Wc-R).
crassinodosa Marwick, 1931. Sl (Pl-Tt).
dingleyi Marwick, 1948. Wp.
errata Finlay, 1924. Pl.
excoriata (Finlay, 1926). Wn. **Pl. 42h**.
facinerosa Bartrum & Powell, 1928. Wo.
hendersoni Marwick, 1926. Tt (Pl?-Tt). **Pl. 30h**.
kereruensis Laws, 1932. Wn (Wm-Wn).
maculosa (Martyn, 1784). R (Wn?-R).
ridicula (Finlay, 1926). Sc (Sc-Sl).
scirifer Laws, 1933. Pl.
 (*Eucominia*) Finlay, 1926.
alertae (Dell, 1956). R (Wn-R).
bauckei Marwick, 1928. Wp.
cingulata (Hutton, 1885). Wm?
elegantula (Finlay, 1926). Wc. (Wn?-R). **Pl. 49e**.
hamiltoni (Hutton, 1885). Wn. **Pl. 42g**.
intermedia (Suter, 1917). Pl.
incisa (Hutton, 1885). Wm?
marshalli (Laws, 1932). Po.
mirabilis cantuariensis (Dell, 1951). R (Wn-R).
mirabilis powelli (Fleming, 1948). R (Wc-R).
nana (Finlay, 1926). Lw.
nassoides ellisoni Marwick, 1928. Wn.
nassoides otakaui Powell, 1946. R (Wm?; Wn-R). **Pl. 42d**.
onokeana (King, 1933). Wn? (Wm?-Wn).
purchasi (Suter, 1917). Wn?
tuturawa (Fleming, 1943). Wo.
 (*Josepha*) Tenison Woods, 1878.
altispira Marwick, 1948. Wp.
chattonensis (Finlay, 1926). Ld. **Pl. 15e**.
chorista Dell, 1952. Tt.
compacta Marwick, 1926. Tt.
glandiformis (Reeve, 1847). R (Wn-R).
gramei Wells, 1986. Tt.
obsoleta (Finlay, 1926). Wn.
putangirua (King, 1933). Tt.
quoyana quoyana A. Adams, 1855. R (Wq-R).
quoyana acuminata Hutton, 1885. Wc (Wc-R).
virgata virgata H. & A. Adams, 1853. R (Wm-R).
 (*Procominula*) Finlay, 1926.
denselirata (Finlay, 1926). Lw. **Pl. 15j**.
exsculpta (Suter, 1917). Po?
praecox (Finlay, 1926). Ld.
propinqua (Finlay, 1926). Ld.
pukeuriensis (Finlay, 1926). Pl. **Pl. 21c**.
pulchra (Suter, 1917). Po.
- Egotistica* Marwick, 1934.
scirrhoma Marwick, 1934. Po. **Pl. 21d**.
- Euthrenopsis* Powell, 1929.
otagoensis Powell, 1929. R (Wn-R).
venusta Powell, 1929. R (Wm-R).
- Iredalula* Finlay, 1926.
striata (Hutton, 1873). Wc (Wm-R). **Pl. 49f**.
venusta Powell, 1934. R (Wm-R).
- Kaiparanura* Laws, 1944.
spiralis (Marshall, 1918). Po-Pl.
- Nassaria* Link, 1807.
 (*Microfusus*) Dall, 1916.
incerta (King, 1933). Wm.
- Nassicola* Finlay, 1924.
 (?)*cingulifer* (Marwick, 1931). Sc.
 (?)*compacta* (Suter, 1917). Pl.
contracta (Finlay, 1926). Sl (Sl-Sw).
finlayi Beu & Maxwell, nom.nov. Pl. **Pl. 21m**.
nassa (Finlay, 1926). Pl.
speighti (Marwick, 1932). Sw.
sublurida (Marshall, 1917). Mw.
ultima Beu, 1973. Wp (Tt-Wp). **Pl. 37m**.

(?) *Pangoa* Marwick, 1931.
mira Marwick, 1931. Sl.

Paracominia Powell & Bartrum, 1929.
ferrari (Marwick, 1934). Po.
finlayi (Powell & Bartrum, 1929). Po.
lignaria (Powell & Bartrum, 1929). Po. **Pl. 25e.**
macphersoni (Marwick, 1931). Po?

Penion Fischer, 1885.
affixus (Finlay, 1930). Sc (Pl-Sc).
asper (Marwick, 1928). Wp.
bartrumi (Laws, 1941). Pl. **Pl. 25h.**
benthicolus Dell, 1956. R (Wn-R).
brazieri Fleming, 1955. Tk.
clifdenensis (Finlay, 1930). Sc (Pl-Sl).
crawfordi (Hutton, 1873). Tt (Sc?; Sl-Tt). **Pl. 30j.**
cuvierianus (Powell, 1927). R (Wc-R).
exoptatus (Powell & Bartrum, 1929). Po.
fairfieldae (Powell, 1947). R (Wn-R).
finlayi (Laws, 1930). Po.
gauli (Marwick, 1948). Wp.
haweraensis (Powell, 1931). Wp.
hiatulus (Powell, 1947). Po.
huttoni (King, 1934). Tk?-Wo.
imperfectus (Powell, 1947). Pl.
interjunctus (Finlay, 1930). Sw (Sl-Sw).
koruahinensis (Bartrum & Powell, 1928). Wo.
marwicki (Finlay, 1930). Pl. **Pl. 20m.**
parans (Finlay 1930). Pl (Pl-Sl?).
proavitus (Finlay & Marwick, 1937). Mw.
sulcatus (Lamarck, 1816). R (Wm-R). **Pl. 49a.**
winthropi Marwick, 1965. Wp.

Pomahakia Finlay, 1927.
aberrans Finlay, 1927. Ld? **Pl. 9v, w.**

Pseudofax Finlay & Marwick, 1937.
filius Finlay & Marwick, 1937. Dp?
ordinarius (Marshall, 1917). Mw. **Pl. 2t.**
sinusiger Finlay & Marwick, 1937. Dp?

Zelandiella Finlay, 1926.
(?)*cancellaria* Finlay & Marwick, 1937. Mw.
calcarata Marwick, 1931. Tt (Sl-Tt).
fatua Finlay, 1926. Sw (Sw-Tt?). **Pl. 30c, d.**
(?)*imitatrix* Finlay & Marwick, 1937. Mw.
propenodosa (Bartrum, 1919). Wo.
robinsoni (Zittel, 1864). Lwh.
subnodosa (Hutton, 1877). Pl (Pl-Sw). **Pl. 21i.**

FAMILY NASSARIIDAE

Nassarius Dumeril, 1805.
(*Alectrion*) Montfort, 1810.
aoteanus Finlay, 1926. R (Wq-R).
(*Hima*) Leach in Gray, 1852.
karoroensis Maxwell, 1988. Sw.
separabilis (Laws, 1939). Po (Po-Pl?).
socialis (Hutton, 1886). Pl. **Pl. 21g.**

FAMILY FASCIOLARIIDAE

Falsiculus Finlay, 1930.
allani Finlay, 1930. Ld.
alta (Marshall, 1919). Ab.
benisoni (Allan, 1926). Ab. **Pl. 6i.**
corrugata (Marshall, 1918). Pl? (Po-Pl).
ectypa (Marwick, 1931). Sl.
eoaffinis Finlay, 1930. Pl.
excellens Finlay, 1930. Sc.
gemmata Powell, 1935. Pl. **Pl. 25i.**
inurbana Laws, 1932. Sc (Pl-Sl). **Pl. 25q.**
kaiparaensis (Suter, 1917). Po-Pl (Po-Pl).
levata Finlay, 1930. Lw (Ld-Pl).
obruta Finlay, 1930. Ak.
orientalis Marwick, 1931. Tk.
semilevigata Laws, 1932. Pl.
solida (Suter, 1917). Ak? (Ak).
tangituensis (Marwick, 1926). Tt (Sw-Tt). **Pl. 27n.**
teuriensis Fleming, 1943. Sl.

Fusinus Rafinesque, 1815.
(?)*waihaoicus* Laws, 1935. Ak.

Glaphyrina Finlay, 1926.
caudata caudata (Quoy & Gaimard, 1833). R (Wc?-R). **Pl. 49j,k.**
caudata progenitor Finlay, 1926. Wc.
excelsa (Suter, 1917). Pl.
paucispiralis Beu, 1967. Wm (Wm-Wn?).
plicata Powell, 1929. R (Wn-R). **Pl. 42m.**

Latirofuscus Cossmann, 1889.
(?)*optatus* Marshall & Murdoch, 1923. Ak.

Latirogona Laws, 1944.
ornata (Marshall, 1918). Pl. **Pl. 25s.**

"*Pleia* Finlay, 1930."
cryptocarinata Dell, 1956. R (Wm-R).
otaioensis Finlay, 1930. Po (Lw?-Po). **Pl. 21l.**

Taron Hutton, 1883.
dubius (Hutton, 1878). R (Wc-R).
scottae (Marwick, 1965). Wo.

FAMILY TAIOMIDAE (?)

Taioma Finlay & Marwick, 1937.
tricarinata Finlay & Marwick, 1937. Mw. **Pl. 2n, o.**

FAMILY MELONGINIDAE

Fascioplex Marwick, 1934.
browni Marwick, 1942. Ab.
liraecostata (Suter, 1917). Ab. **Pl. 6o.**
neozelanica (Suter, 1917). Ab (Dp?-Ab).

FAMILY COLUMBELLIDAE

Anachis H. & A. Adams, 1853.
(*Costoanachis*) Sacco, 1890.
problematica Laws, 1944. Po.

Antizafra Finlay, 1926.
cancellaria (Hutton, 1885). Wn.
(?)*jobsoleta* Fleming, 1943. Wn.
(?)*obtusa* Fleming, 1943. Wn.
pisanopsis (Hutton, 1885). Wn. **Pl. 42s.**
speighti (Marwick, 1924). Wn.
(?)*wairarapa* King, 1933. Tt.

Liratilia Finlay, 1926.
compta Powell, 1930. R (Wq-R).
conquisita conquisita (Suter, 1907). R (Wc-R).
conquisita angulata (Suter, 1908). R (Wc-R).

Macrozafra Finlay, 1926.
(?)*formosa* Marwick, 1943. Pl.
nodicincta (Suter, 1899). R (Wq-R).
pliocenica Fleming, 1943. Wn.

Mitrella Risso, 1826.
inconspicua Marshall, 1918. Po-Pl (Lw-Pl).

Paxula Finlay, 1926.
leptalea (Suter, 1908). R (Wn-R).
transitans (Murdoch, 1905). R (Wc?-R).

Retizafra Hedley, 1912.
toreuma Maxwell, 1988. Sw.

"*Zafra* A. Adams, 1860."
impedita Laws, 1940. Wm (Wp-Wn).
opihiensis Laws, 1933. Pl.

Zemitrella Finlay, 1926.
benthicola elongata Beu, 1967. Wm.
choava (Reeve, 1859). R (Wn-R).
contigua Powell, 1934. Wc.
haroldi Laws, 1935. Pl. **Pl. 21f.**
(?)*mackayi* (Suter, 1917). Ab (Ab-Ak).
mahoenuica Laws, 1935. Po.
pseudomarginata (Suter, 1908). R (Wq-R).
rosea (Hutton, 1873). R (Wn?-R).
stephanophora (Suter, 1908). R (Wn?-R).
subsuturalis Fleming, 1943. Wn.

sulcata (Hutton, 1873). R (Wn-R).
websteri (Suter, 1913). R (?Wm-R).

FAMILY TURBINELLIDAE
SUBFAMILY CALLIOTECTINAE

Pakaurangia Finlay, 1926.
waitaraensis (Marwick, 1926). Tt (Sc?-Tt).

SUBFAMILY COLUMBARIINAE

Columbarium (sensu lato) Martens, 1881.
pataka Maxwell, 1978. Ab.
vulneratum (Finlay & Marwick, 1937). Mw.

Coluzea Finlay in Allan, 1926.
climacota (Suter, 1917). Ak? (Ak).
dentata (Hutton, 1877). Pl. (Po-Pl). Pl. 21h.
kiosk Finlay, 1930. Pl (Pl-Sc). Pl. 25m.
macrior Finlay, 1930. Pl.
maoria (Marshall & Murdoch, 1919). Ld.
mariae Powell, 1952. R (Wp-R).
paucispinosa Finlay, 1930. Lw.
spectabilis Powell, 1931. Wp (Wp-Wm).
spiralis (A. Adams, 1856). R (Wn-R). Pl. 49h.

SUBFAMILY PTYCHATRACTINAE

Egestas Finlay, 1926.
fenestrata (Suter, 1917). Pl.
(?)*tricordata* (Beu, 1970). Tt.

Exilia Conrad, 1860.
crassicosata Suter, 1917. Ak?
dalli Suter, 1907. Po (Lw-Po). Pl. 21e.
hampdenensis (Marwick, 1942). Ab.
leachi (Marwick, 1931). Sl.
nodulifera (Marwick, 1931). Sl.
vixcostata (Finlay & Marwick, 1937). Mw.
waihaoensis Suter, 1917. Ak. Pl. 8s.
wellmani Maxwell, 1988. Sw.
(?)*zelandica* (Marshall, 1917). Po-Pl.

Latiromitra Locard, 1897.
problematica (Ponder, 1968). R (Wn?-R).

Paleopsephea Wade, 1926.
neozelanica Finlay & Marwick, 1937. Mw.

SUBFAMILY VASINAE

Fyfea Finlay & Marwick, 1937.
lirata Finlay & Marwick, 1937. Mw. Pl. 2u, v.
tuberculata Finlay & Marwick, 1937. Mw.

Heteroterma Gabb, 1869.
zelandica Marshall, 1917. Mw. Pl. 2p.

Microfulgur Finlay & Marwick, 1937.
longirostris (Marshall, 1917). Mw. Pl. 2q, r.

Tudicilana Finlay & Marwick, 1937.
simulator Finlay & Marwick, 1937. Mw. Pl. 2m.

FAMILY MURICIDAE

SUBFAMILY MURICINAE

Chicoreus Montfort, 1810.
(*Siratus*) Jousseaume, 1879.
komiticus (Suter, 1917). Po-Pl (Po-Pl). Pl. 24k.
lawsi (Maxwell, 1971). Po?
syngenes Finlay, 1930. Sc (Pl?-Sc).

Murexsul Iredale, 1915.
(?)*clifdenensis* Finlay, 1930. Sc.
dilucidus Marwick, 1931. Wo.
echinophorus Powell & Bartrum, 1929. Po.
espinosus (Hutton, 1886). Wn (Wm-Wn).
mariae Finlay, 1930. R (Wq-R).
marwicki Maxwell, 1971. Pl.
octogonus (Quoy & Gaimard, 1833). R (Wc-R). Pl. 48l.
(?)*praegressus* Finlay, 1930. Pl.
proavitus Laws, 1935. Pl.
progenitor Laws, 1935. Pl.
scobinus Finlay, 1930. Pl. Pl. 24m.

Poirieria Jousseaume, 1879.
delli Maxwell, 1971. Pl (Lw?-Pl). Pl. 20p.
denticulifera Maxwell, 1971. Ak (Ab-Lwh?). Pl. 8g.
parva Maxwell, 1971. Pl (Po?-Pl).
primigena Finlay, 1930. Lw (Ld-Wo).
zelandica (Quoy & Gaimard, 1833). R (Wo-R). Pl. 48k.

Pterotyphis Jousseaume, 1880.
(*Prototyphis*) Ponder, 1972.
allani (Maxwell, 1971). Po (Lw?-Po).
angasi powelli (Fleming, 1962). Wc (Wn?-R?). Pl. 48j.
awamoanus (Finlay, 1930). Pl. Pl. 20s.
tahuensis (Maxwell, 1971). Ak.
(*Ponderia*) Houart, 1986.
zealandicus (Hutton, 1873). Wc (Wc-R). Pl. 48i.

Pterynotus Swainson, 1833.
flemingi (Beu, 1970). Wm (Wm-R).
kaiparaensis Fleming, 1962. Po? (Po).
laetificus Finlay, 1930. Sw (Ak?, Lw-Tk). Pl. 30a.
waiareka (Beu, 1970). Ak.

SUBFAMILY TYPHINAE

Rugotyphis Vella, 1961.
francescae (Finlay, 1924). Pl.
secundus Vella, 1961. Pl (Pl-SI?).
vellai (Maxwell, 1971). Pl. Pl. 25o.

Siphonochelus Jousseaume, 1880.
(*Laevityphis*) Cossmann, 1903.
tepingai (Fleming, 1943). Wp (Wo-Wp). Pl. 37e.

Typhis Montfort, 1810.
aculeatus Vella, 1961. Sc? (Pl-SI).
adventus Vella, 1961. Lw (Ld-Po).
chattonensis Maxwell, 1971. Ld.
clifdenensis Vella, 1961. Pl.
hebetatus Hutton, 1877. Pl (Lw-Pl). Pl. 20r.
planus Vella, 1961. Pl.
(*Hirtotyphis*) Jousseaume, 1880.
aoteanus Vella, 1961. Tt.
panoplus Maxwell, 1971. Lw. Pl. 15c, g.

SUBFAMILY TROPHONINAE

Bedeva Iredale, 1936.
bartrumi (Marwick, 1948). Wp. Pl. 37h.

Comptella Finlay, 1926.
crassa Beu, 1967. Wm (Wm-R?).
curta (Murdoch, 1905). R (Wq-R).
devia (Suter, 1908). R (Wc?-R).

Pagodula Monterosato, 1884.
delli (Beu, 1967). Wm (Wm-R?).
vegrandis Marshall & Murdoch, 1923. Pl.
waitemataensis (Powell & Bartrum, 1929). Po.

Paratrophon Finlay, 1926.
patens patens (Hombron & Jacquinet, 1854). R (Wn-R).
patens exsculptus Powell, 1933. R (Wq-R).
quoyi quoyi (Reeve, 1846). R (Wn-R).
quoyi cheesemani (Hutton, 1882). R (Wm-R).

Peritrophon Marwick, 1931.
decoratus Marwick, 1931. Sc.

Terefundus Finlay, 1926.
cuvierensis (Mestayer, 1919). R (Wq-R).
lamelliferus Maxwell, 1988. Sw.
murdochi (Marwick, 1924). Wn (Wm-R?).
quadricinctus (Suter, 1908). R (Wc?-R).

Trophon Montfort, 1810.
(?)*munitus* Marwick, 1934. Wm.

Uttleya Marwick, 1934.
arcana Marwick, 1934. Wc.
crenata Marwick, 1934. Wn.
paucispiralis Beu, 1970. Wc.
subcarinata Grant-Mackie & Chapman-Smith, 1971. Wq.
williamsi Powell, 1952. R (Wq-R).

Vesanula Finlay, 1926.
chaskanon Finlay, 1926. Pl.
tegens (Hutton, 1877). Pl. **Pl. 20t.**

Xymene Iredale, 1915.
ambiguus (Philippi, 1844). R (Wm-R).
apipagoda Ponder, 1972. Ak.
aucklandicus (E.A. Smith, 1902). R (Wm-R).
bonneti bonneti (Cossmann, 1903). Wc (Wn?-Wc). **Pl. 48m.**
bonneti lassus (Marwick, 1928). Wp (Pl-Wn).
chattonensis Ponder, 1972. Ld (Ld-Pl).
expansus (Hutton, 1883). Wc (Wn-Wc). **Pl. 48e.**
huttoni (Murdoch, 1900). Wc.
inambitosus (Marwick, 1929). Ld.
lepidus (Suter, 1917). Pl.
minutissimus (Suter, 1917). Pl.
mortenseni caudatinus (Finlay, 1930). R (Wm-R).
perornatus (Marwick, 1931). Sl?
plebeius plebeius (Hutton, 1873). R (Wc-R).
plebeius moniliferus (Hutton, 1885). Wo? (Sw-Wn).
protocarinatus (Laws, 1941). Po (Po-Sw?).
** (8) pusillus* (Suter, 1907). R (Wn-R).

SUBFAMILY THAIDINAE

Agnewia Tenison Woods, 1878.
kempae Powell, 1934. Wq. **Pl. 48h.**

"*Concholepas* Lamarck, 1801".
pehuensis (Marwick, 1926). Tt.

Cronia H. & A. Adams, 1853.
tengawaica Laws, 1933. Pl.

Haustrum Perry, 1811.
haustorium (Gmelin, 1791). R (Wq-R).

Lepsiella Iredale, 1912.
intermedia Powell & Bartrum, 1929. Po (Lw-Po).
maxima Powell & Bartrum, 1929. Po (Po-Tk?).
scobina (Quoy & Gaimard, 1833). R (Wc-R).

Lepsithais Finlay, 1928.
lacunosus (Bruguière, 1789). R (Wn-R).

Morula Schumacher, 1817.
(Neothais) Iredale, 1912.
lassa (Marwick, 1948). Wp.

Thais Röding, 1798.
orbata (Gmelin, 1791). R (Wo-R).

SUBFAMILY CORALLIOPHILINAE

Coralliophila H. & A. Adams, 1853.
kaiparaensis (Marshall, 1918). Po-Pl.
lividorupis (Laws, 1935). Po.
sertata (Hedley, 1903). R (Wq-R). **Pl. 48n.**
turneri Laws, 1941. Po-Pl. **Pl. 25r.**

FAMILY MITRIDAE

Clifdenia Laws, 1932.
(?) hectori (Hutton, 1905). Ab? (Ab-Ak).
(?) mystica (Suter, 1917). Ab.
turneri turneri Laws, 1932. Pl (Pl-Sl). **Pl. 25p.**
turneri inflata Grant-Mackie, 1965. Pl.

Eumitra Tate, 1889.
(?) calcar (Marshall, 1918). Po-Pl.
nitens (Marshall, 1918). Po-Pl (Lw-Pl). **Pl. 25f.**
waitemataensis (Powell & Bartrum, 1929). Po.

Nebularia Swainson, 1840.
elator (Finlay, 1924). Sc.
eusulcata (Finlay, 1924). Pl.

FAMILY COSTELLARIIDAE

Austromitra Finlay, 1926.
ambulacrum (Marwick, 1926). Tt.
angulata (Suter, 1908). R (?Wc-R).
planata (Hutton, 1885). Wc (Wm?-Wc).
rubiginosa (Hutton, 1873). R (Wc-R).

Uromitra Bellardi, 1887.
(?) caudata (Marwick, 1931). Wo.
etremoides Finlay, 1924. Pl.
neozelanica Laws, 1939. Po. **Pl. 25l.**

FAMILY VOLUTOMITRIDAE

Microvoluta Angas, 1877.
balteata (Marwick, 1931). Pl-Sc?
fracta (Marwick, 1926). Tt.
marginata (Hutton, 1885). Wc (Wo-R).
marwicki (Vella, 1954). Tt. **Pl. 27o.**
nodulata Maxwell, 1988. Sw.
wainuioruensis (Vella, 1954). Tt.
Peculator Iredale, 1924.
clifdenensis (Finlay, 1930). Sl.
hedleyi (Murdoch, 1905). R (Wo-R).
(Parvimitra) Finlay, 1930.
paucinoda (Finlay, 1930). Po.
plicatellus (Marshall & Murdoch, 1923). Ak. **Pl. 8j.**
(?) pliciferus (Marwick, 1928). Wp.
pukeuriensis (Finlay, 1930). Pl. **Pl. 21p.**

Proximitra Finlay, 1926.
apicalis (Hutton, 1873). Pl. **Pl. 21n.**
costulosa Marwick, 1965. Wo.
enavata Marwick, 1931. Wo.
enysi (Hutton, 1873). Ld.
parki (Allan, 1926). Ak.
partinoda Finlay, 1930. Po.
rutidoloma (Suter, 1917). Po (Po-Pl). **Pl. 21o.**

Volutomitra H. & A. Adams, 1853.
banksi (Dell, 1951). R (Sw-R). **Pl. 27k.**
(Waimatea) Finlay, 1926.
amplexa (Finlay, 1930). Ab.
incisa (Marwick, 1942). Ab.
inconspicua (Hutton, 1885). Ak. **Pl. 8i.**
lornensis (Marwick, 1926). Ak.
othoniana (Finlay, 1924). Pl.
transilis (Finlay, 1930). Lw.

FAMILY MARGINELLIDAE

Carinaginella Laseron, 1957.
(?) totangiensis (Marwick, 1931). Tt?
Deviginella Laseron, 1957.
(?) coxi (Marwick, 1928). Wp.
(?) harrisi (Cossmann, 1899). Pl. (Lw-Pl). **Pl. 22a.**

Haluginella Laseron, 1957.
hectori (Kirk, 1882). Wn.
maoriana (Powell, 1932). R (Wc-R).
marwicki (Finlay, 1927). Wn.
mustellina (Angas, 1871). R (Wq-R).

Hiwia Marwick, 1931.
amplificata (Marwick, 1931). Pl-Sc (Po-Tt). **Pl. 27j.**

Protopinella Laseron, 1957.
(?) bellensis (Beu, 1970). Tt (Tt-?Wo). **Pl. 27l.**
bembix Maxwell, 1988. Sw.
conica (Harris, 1897). Pl. **Pl. 22b.**
(?) opoitia (Marwick, 1965). Wo (Wo-Wn?).
(?) whitecliffensis (Marwick, 1926). Tt.
(Ataginella) Laseron, 1957.
fraudulenta (Suter, 1917). Pl.
labinensis Maxwell, 1988. Sw.
waikohuensis (Marwick, 1931). Tt.

Serrata Jousseaume, 1875.
flemingi Maxwell, 1988. Sw.
kirki (Marwick, 1924). Wn. **Pl. 42j.**

Sinuginella Laseron, 1957.
hesterna (Bartrum & Powell, 1928). Wo.
pygmaea (Sowerby, 1846). R (Wn-R).

Volvarinella Habe, 1951.
amoena (Suter, 1908). R (Wc-R).
aveniformis (Marshall, 1919). Ab (Ab-Ak).

(?)*floralis* (Marwick, 1928). Wp.
fusula (Murdoch & Suter, 1906). R (Wc?-R).
hakataramea (Maxwell, 1969). Lw.
 (?)*megalabra* (Beu, 1979). Wn.
subfusula (Powell, 1932). R (Wn-R).

FAMILY HARPIDAE

Eocithara Fischer, 1883.

(*Marwickara*) Laws, 1935.

waihaoensis Laws, 1935. Ab. **Pl. 6p.**

Morum Röding, 1798.

(*Oniscidia*) Mörch, 1852.

finlayi (Laws, 1932). Sl (Po?-Sl). **Pl. 25n.**

harpaforme Powell & Bartrum, 1929. Po.

FAMILY OLIVIDAE

SUBFAMILY ANCILLINAE

Amalda H. & A. Adams, 1853.

(*Alocospira*) Cossmann, 1899.

cuppedia (Olson, 1956). Lw.

electa (Marwick, 1929). Ld.

hebera (Hutton, 1873). Pl. **Pl. 22g.**

paeroa (Fleming, 1943). Wo (Wo-Wp?).

subhebera (Marwick, 1926). Tt (Tt-Wp?).

(*Baryspira*) Fischer, 1883.

australis (Sowerby, 1830). R (Wn-R).

depressa (Sowerby, 1859). R (Wn-R).

gulosa (Fleming, 1943). Wo.

macbeathi (Vella, 1954). Tt.

mucronata (Sowerby, 1830). R (Wo-R). **Pl. 49g.**

olsoni Beu, 1970. Wn.

opima (Marwick, 1924). Wn.

oraria (Olson, 1956). Wp. **Pl. 37k.**

ovalis Beu, 1970. Pl?

pristina (Olson, 1956). Ld.

platycephala (Powell & Bartrum, 1929). Po.

robusta (Marwick, 1924). Pl (Ld-Pl). **Pl. 22h.**

tirangiensis (Marwick, 1926). Tt. **Pl. 30k.**

tholiculus (Marwick, 1931). Sl (Sl-Tk?).

waikataensis (Finlay, 1926). Ld.

(*Gracilispira*) Olson, 1956.

allani (Olson, 1956). Dp?

brevicula (Marwick, 1931). Sc.

exspata (Bartrum & Powell, 1928). Wo.

gigartoides (Olson, 1956). Pl.

morgani (Allan, 1926). Ak (Ab-Ar). **Pl. 8f.**

novaezelandiae (Sowerby, 1859). R (Wo-R). **Pl. 42i.**

rimuensis (Olson, 1956). Wm.

wairarapaensis (Olson, 1956). Tt.

(*Spinaspira*) Olson, 1956.

(?)*cincta* (Marshall, 1918). Po-Pl.

cingulata (Olson, 1956). Pl (Pl-Sl).

pakaurangiensis (Olson, 1956). Po-Pl (Po-Pl).

spinigera (Marshall, 1918). Po-Pl (Po-Pl).

stortha (Olson, 1956). Pl (Pl-Sw). **Pl. 25k.**

Ancillina Bellardi, 1882.

kakano Maxwell, 1978. Ab.

wellmani Maxwell, 1978. Sc.

SUBFAMILY OLIVINAE

Lamprodomina Marwick, 1931.

neozelanica (Hutton, 1885). Wp (Sl-Wn). **Pl. 37q.**

FAMILY VOLUTIDAE

SUBFAMILY ATHLETINAE

Athleta Conrad, 1853.

necopinata Suter, 1917. Ab. **Pl. 6q.**

lata (Marwick, 1926). Dp?

SUBFAMILY LYRIINAE

Lyria Gray, 1847.

zelandica Finlay, 1924. Sc (Pl-Sc; Sw?). **Pl. 26c.**

SUBFAMILY ZIDONINAE

Alcithoe H. & A. Adams, 1858.

arabica (Gmelin, 1791). R (Wn-R). **Pl. 49d.**

arabica Marwick, 1926. Wo.

bartrumi King, 1933. Wn (Wm?-Wn).

bulbus (Marwick, 1931). Wo (Wo-Wp).

callaghani (King, 1931). Tk?

cylindrica Marwick, 1926. Pl.

dilatata Marwick, 1926. Tt.

firma (Marwick, 1926). Pl.

haweraensis Marwick, 1926. Wp (Wo-Wp). **Pl. 37p.**

hurupiensis Marwick, 1926. Tt. **Pl. 30i.**

irregularis Marwick, 1946. Tk?

larochi Marwick, 1926. R (Wc?-R).

marlburiana King, 1934. Tk.

murdochi (Marwick, 1926). Pl.

parva Marwick, 1926. Wo.

pinguella (Marwick, 1931). Tk?

powelli (Laws, 1936). Wo.

regularis Finlay, 1926. Sw.

renwicki (Marwick, 1928). Wp.

turrita (Suter, 1917). Po (Po-Pl). **Pl. 21s.**

uptonensis King, 1934. Tk.

whakinoensis Marwick, 1926. Wp.

(*Leporemax*) Iredale, 1937.

bathgatei Finlay, 1926. Pl. **Pl. 26b.**

bacchanalia King, 1934. Tk (Tt-Tk).

brevis Marwick, 1926. Wn (Wm-Wn). **Pl. 42n.**

concisa Marwick, 1931. Wo.

dyscrita Finlay, 1926. Sc.

exigua Marwick, 1926. Wn.

finlayi Marwick, 1926. Pl.

fuscus fuscus (Quoy & Gaimard, 1833). R (Wn?-R). **Pl. 49i.**

fuscus resolutionis Fleming, 1954. Wn?

gatesi Marwick, 1926. Wp (Wp-Wm?). **Pl. 37o.**

gravicostata King, 1931. Tk.

lepida Marwick, 1926. Pl (Po-Pl). **Pl. 21t.**

phymatias Finlay, 1926. Pl (Pl-Sc?). **Pl. 26a.**

rugosa (Marwick, 1926). Tt.

scopi Marwick, 1926. Pl.

solida Marwick, 1926. Tt (Tt-Tk).

Iredalina Finlay, 1926.

mirabilis Finlay, 1926. R (Wm-R).

Mauira Marwick, 1943.

angusta (Suter, 1917). Ab.

biconica (Suter, 1917). Ab. **Pl. 6k.**

chesteri (Marwick, 1931). Sl?

huttoni (Suter, 1914). Pl.

maoriana (Suter, 1914). Ab.

oliveri (Marwick, 1926). Sw.

pseudorarisipina (Suter, 1915). Pl.

waihaoensis (Laws, 1935). Ab.

washburnei (Marwick, 1931). Sl (Sl-Tt).

Mauithoe Finlay, 1930.

insignis (Marwick, 1926). Sw. **Pl. 27p.**

strongi (Marwick, 1931). Tt.

Metamelon Marwick, 1926.

clifdenensis (Finlay, 1926). Pl (Pl-Sl). **Pl. 26d.**

inermis (Finlay, 1926). Lw (Ld?-Lw).

informis Laws, 1932. Pl.

marshalli Marwick, 1926. Ld.

minima Marwick, 1926. Pl (Lw-Pl).

patruelis Laws, 1932. Pl.

prominima Laws, 1932. Pl.

reverta (Finlay, 1926). Pl.

Pachymelon Marwick, 1926.

amoriaformis (Marwick, 1926). Pl. **Pl. 21u.**

Spinomelon Marwick, 1926.

awaterensis King, 1934. Wp.

benitens (Finlay, 1926). Lw (Lw-Pl).

elimatus Marwick, 1931. Wo.

enysi Marwick, 1926. Ld.

henryi Laws, 1933. Pl.

kingi Marwick, 1965. Wp.

mira Marwick, 1926. Po (Po-Pl).

parki (Suter, 1907). Po (Po-Pl). **Pl. 21q.**

residua (Finlay, 1926). Lw.
speighti Marwick, 1926. Pl.

Teremelon Marwick, 1926.
cognata (Finlay, 1926). Pl.
elegantissima (Suter, 1917). Pl.
knoxii Dell, 1956. R (Tt-R).
pretiosa (Finlay, 1926). Pl (Pl-Sc).
striata (Laws, 1935). Ab.
tumidior (Finlay, 1926). Lw (Ld-Pl). Pl. 21r.
waitakiensis (Marwick, 1926). Ld.

Waihaioia Marwick, 1926.
(?)*aculeata* (Hutton, 1885). ?
allani Marwick, 1926. Ak. Pl. 8p.
confusa Marwick, 1926). Ab.
formosa Laws, 1935. Ar.
(?)*nodulifera* Laws, 1935. Ld.
(?)*scitula* Marwick, 1926. Pl.
superstes Marwick, 1926. Pl.
suteri Marwick, 1926. Ab.
thomsoni Marwick, 1926. Ab. Pl. 6n.

SUPERFAMILY CONACEA

FAMILY CONIDAE

Conilithes Swainson, 1840.
brockenensis (Vella, 1954). Sc-Sl.
lyratus (Marshall, 1918). Po-Pl.
oliveri (Marwick, 1931). Sc.
rivertonensis (Finlay, 1926). Pl?
suteri (Cossmann, 1918). Sw?
tahuensis (Allan, 1926). Ak.
wollastoni Maxwell, 1978. Pl. Pl. 22v.

Conus (sensu lato) Linné, 1758.
abruptus Marshall, 1918. Po-Pl.
armoricus Suter, 1917. Po-Pl (Po-Pl). Pl. 26o.
fusellinus Suter, 1917. Sw?
hendersoni Marwick, 1931. Tk (Tt-Tk). Pl. 30m.
huttoni (Tate, 1890). Pl.
pseudoarmoricus Marshall & Murdoch, 1920. Ab (Ab-Ak).
thorae Finlay, 1926. Po-Pl.
trigonicus Tomlin, 1937. Ak. Pl. 8o, t.

FAMILY TEREBRIDAE

Duplicaria Dall, 1909.

(*Pervicacia*) Iredale, 1924.
angulifera (Marwick, 1931). Sl.
benesulcata (Bartrum, 1919). Wo.
flexicostata (Suter, 1909). R (Wc?-R).
omahuensis (Marwick, 1926). Tt.
timida (Marwick, 1931). Sc.
tristis (Deshayes, 1859). R (Wo-R).

Gemmaterebra Cotton, 1952.
bicorona (Hutton, 1885). ? (Sc?-Wp; Wm?). Pl. 30o.

Kaweka Marwick, 1931.
bartrumi Laws, 1936. Wo.
exilis Marwick, 1931. Tt?
fulva Marwick, 1931. Wo. Pl. 37t.

Zeacuminia Finlay, 1930.
biplex (Hutton, 1885). Po. Pl. 22u.
cantuariensis Laws, 1933. Pl.
fluctuosa Laws, 1941. Po (Po-Pl).
murdochi Powell, 1931. Wp (Wo-Wm).
orycta (Suter, 1913). Sw (Pl-Tt). Pl. 30n.
pareoraensis (Suter, 1917). Pl.
parva Laws, 1936. Wo.
planitas Laws, 1940. Wp (Wo-Wn). Pl. 37z.
subtilissima (Bartrum & Powell, 1928). Wo.
suteri (Marwick, 1929). Ld.
tahuia Finlay, 1930. Ab (Ab-Ak). Pl. 8y.
tantula Marwick, 1931. Sc.
transitorsa (Marwick, 1929). Ld.
turpicula Marwick, 1931. Sl.
viapollentia Maxwell, 1988. Sw.

FAMILY SPEIGHTIIDAE

Speightia Finlay, 1926.
spinosa (Suter, 1917). Ab. Pl. 6s.

FAMILY TURRIDAE

SUBFAMILY PSEUDOTOMINAE

Austrotoma Finlay, 1924.
ampla Powell, 1942. Wp.
clifdenica Powell, 1942. Pl (Pl-Sc). Pl. 26e.
cryptoconoidea Powell, 1942. Sc-Sl.
deducta Marwick, 1931. Tt?
echinata Powell, 1942. Sc (Sc-Sl). Pl. 26l.
excavata (Suter, 1917). Pl? (Po-Pl). Pl. 26h.
eximia (Suter, 1917). Lw.
finlayi Powell, 1938. Po (Lw-Po).
gemmulata Powell, 1942. Sl-Sw.
gracilicostata (Zittel, 1864). Lwh.
hurupiensis Dell, 1952. Tt.
inaequabilis Marwick, 1929. Ld. Pl. 15p.
(?)*indiscreta* Finlay & Marwick, 1937. Mw.
kaiparaensis Powell, 1942. Po-Pl (Po-Pl).
lawsi Powell, 1942. Po. Pl. 22l.
minor (Finlay, 1924). Pl.
molinei Marwick, 1931. Sc (Pl-Sl).
neozelanica (Suter, 1913). Sw.
nervosa Powell, 1942. Pl. Pl. 22k.
obsoleta Finlay, 1926. Sw. Pl. 30l.
prolixa Laws, 1940. Wp.
suteri Cossmann, 1916. Pl.
toreuma Marwick, 1929. Ld.

Marshallaria Finlay & Marwick, 1937.
(?)*esdailei* (Marwick, 1926). Ak.
(?)*formosa* (Allan, 1926). Ak.
multicincta Marshall, 1917). Mw.
senta Powell, 1942. Pl.
senilis (Marshall & Murdoch, 1920). Ab.
serotina (Suter, 1917). Ab.
spiralis (Allan, 1926). Ak. Pl. 8x.
uttleyi (Allan, 1926). Dp?
waitakiensis Powell, 1942. Lw.

Marshallena Finlay in Allan, 1926.
curtata (Marwick, 1926). Tt. Pl. 27r.
neozelanica (Suter, 1917). Ak (Ab-Ak). Pl. 8v.

"*Marshallena*"

anomala Powell, 1942. Pl.
austrotomoides Powell, 1931. Wp.
carinaria Powell, 1935. Pl.
celsa Marwick, 1931. Tt?
decens Marwick, 1931. Wo.
impar Powell, 1942. Wp (Wo?-Wp). Pl. 37 x.

Notogenota Powell, 1942.
finlayi Powell, 1942. Ak. Pl. 8w.
goniodes (Suter, 1917). Ab.
pahiensis Powell, 1942. Ab.

SUBFAMILY TURRINAE

Antimelatoma Powell, 1942.
buchanani buchanani (Hutton, 1873). Wc (Wn-Wc). Pl. 49l.
buchanani maorum (Suter, 1877). R (Wq-R).

Apiotoma Cossmann, 1889.
zelandica Beu, 1970. Tt.

Campylacrum Finlay & Marwick, 1937.
debile Finlay & Marwick, 1937. Mw.
sanum Finlay & Marwick, 1937. Mw.

Cochlespira Conrad, 1865.
(*Tahusyrinx*) Powell, 1942.
maora (Marshall & Murdoch, 1923). Ak. Pl. 8q.

Comitas Finlay, 1926.
allani Powell, 1942. Wn (Wo-Wn). Pl. 42p.
abnormis King, 1933. Tt.
bilix Marwick, 1931. Wo? (Wo-Wp).
declivis Powell, 1931. Wp (Wo-Wm).

- fusiformis* (Hutton, 1877). Pl (Ld-Pl). **Pl. 22i.**
gagei Maxwell, 1988. Sw.
imperfecta King, 1933. Tt.
kaipara Laws, 1939. Po-Pl (Po-Pl).
kennetti Beu, 1970. Tk.
lutescens (Hutton, 1873). Pl.
latiaxialis (Marshall, 1918). Po-Pl (Pl). **Pl. 26n.**
nana Maxwell, 1988. Sw.
onokeana King, 1933. Wm (Wm-Wn).
subcarinapex Powell, 1942. Sc (Pl-Sc).
terrisae Vella, 1954. Tt.
williamsi Marwick, 1965. Wo.
- Cosmasyrinx* Marwick, 1931.
ardua Marwick, 1931. Sl.
latis Marwick, 1931. Sl.
marwicki Beu, 1970. Tt.
monilifera Marwick, 1931. Pl-Sc. **Pl. 27s.**
tereumera Marwick, 1931. Pl-Sc.
- Echinoturris* Powell, 1935.
finlayi (Powell, 1935). Pl.
- Eoscobinella* Powell, 1942.
tahuia Powell, 1942. Ak.
 (?)*secunda* Beu, 1970. Tt.
- Eoturris* Finlay & Marwick, 1937.
complicata (Suter, 1917). Ak (Ab-Ak). **Pl. 8n.**
multicincta (Marshall, 1917). Dp?
uttleyi (Suter, 1917). Lw. **Pl. 15t.**
- Gemmula* Weinkauff, 1875.
bimarginata (Suter, 1917). Ak. **Pl. 8r.**
clifdenensis Powell, 1942. Sc (Pl-Sc). **Pl. 26g.**
disjuncta Laws, 1936. Wo.
duplex (Suter, 1917). Ak.
kaiparaensis (Marshall, 1918). Po-Pl (Po-Pl).
lawi Powell, 1942. Po.
longwoodensis Powell, 1942. Ld.
margaritata (Marshall, 1919). Ab.
orba Marwick, 1931. Tt?
ornata (Marshall, 1918). Po-Pl (Po-Pl).
peraspera Marwick, 1931. Tt? (Tt-Wo). **Pl. 27m.**
polita (Marshall, 1919). Ab.
reticulata (Marshall, 1919). Ab. **Pl. 6t.**
waihaoensis Finlay, 1924. Ak.
- Insolentia* Finlay, 1926.
elegantula Powell, 1942. Pl.
inaequalis Marwick, 1931. Sc.
laciniata (Suter, 1917). Ab.
pareoraensis (Suter, 1917). Pl.
powelli Beu, 1970. Sc.
seminuda (Suter, 1917). Lwh?
 (?)*sertula* (Suter, 1917). Ab (Dp?-Ab). **Pl. 6r.**
- Leucosyrinx* Dall, 1889.
climoi Maxwell, 1988. Sc (Sc-Sw).
- Lucerapex* Iredale, 1936.
angustatus (Powell, 1940). R (Wn-R).
 (?)*pulcherrimus* (Vella, 1954). Tt.
- Paracomitas* Powell, 1942.
gemmea (Murdoch, 1900). Wc. **Pl. 49q.**
protransenna (Marshall & Murdoch, 1923). Wn. **Pl. 42r.**
(Macrosinus) Beu, 1970.
beui Maxwell, 1988. Sw.
flemingi (Beu, 1970). Tt.
haumuria Beu, 1979. Wn (Wn-R).
- Parasyrinx* Finlay, 1924.
alta (Harris, 1897). Pl. **Pl. 22s.**
subalta (Marshall & Murdoch, 1919). Ld (Ld-Lw). **Pl. 15q.**
(Lirasyrinx) Powell, 1942.
anomala (Powell, 1942). Ld.
- Tholitoma* Finlay & Marwick, 1937.
dolorosa Finlay & Marwick, 1937. Mw.
- Viridoturris* Powell, 1964.
powelli Maxwell, 1988. Sw.
- Zemacies* Finlay, 1926.
armata Powell, 1942. Ab.
awakinoensis Powell, 1942. Po.
climacota (Suter, 1917). Pl?
elator Finlay, 1926. Pl (Pl-Sc). **Pl. 26i.**
gravida (Marshall, 1919). Ab.
hamiltoni (Hutton, 1905). Ab?
immatura Finlay & Marwick, 1937. Mw.
lividorupis Laws, 1935. Po.
marginatis (Marshall, 1919). Ab (Ab-Ak). **Pl. 8 l.**
ordinaria (Marshall, 1918). Pl? (Po-Pl).
prendrevillei Marwick, 1928. Wp (Wo-Wp). **Pl. 37u.**
simulacrum Laws, 1935. Sl (Sc-Sl).
torticostata (Marshall, 1919). Ab.
- SUBFAMILY DRILLIINAE**
- Austroclavus* Powell, 1942.
awakinoensis Powell, 1942. Po.
clifdenensis Powell, 1942. Sc (Pl-Sc).
famelica (Marwick, 1931). Sc.
finlayi Powell, 1942. Sc (Pl-Sc).
kaipara (Laws, 1939). Po (Po-Pl).
marshalli Powell, 1942. Pl (Po-Pl). **Pl. 22o.**
nitens (Marshall, 1918). Pl?
nodulatus Laws, 1948. Po.
tenuispiralis (Marshall, 1918). Pl. **Pl. 26k.**
- Splendrillia* Hedley, 1922.
aequistriata (Hutton, 1886). Wn. **Pl. 42t.**
afflicta (Marwick, 1931). Wo.
annectens Powell, 1942. Wc. **Pl. 49n.**
anomala Powell, 1942. Wc.
aoteana Finlay, 1930. R (Wo-R).
armata Powell, 1942. R (Wo-R).
clava Powell, 1942. Wp (Wo-Wp).
clifdenensis Powell, 1942. Sl-Sw.
cristata Powell, 1942. Wn.
edita Powell, 1942. Wn (Wn-Wc).
elongata Beu, 1970. Tt.
filiculosa (Marwick, 1931). Sc (Sc-Tt?).
kingmai Marwick, 1965. Wn (Wm-Wn).
koruahinensis (Bartrum & Powell, 1928). Wo (Wo-Wp).
lincta Powell, 1942. Wo.
 (?)*majorina* Beu, 1979. Wn (Wn-R).
powelli (King, 1934). Wp.
whangaimoana Vella, 1954. Wm.
 (?)*zeobliqua* Beu, 1979. Wn (Wn-R).
(Hauturua) Powell, 1942.
bijuga (Marwick, 1931). Pl? (Pl-Sc).
exiguenscens (Marwick, 1931). Sl.
laevella (Marwick, 1931). Sc? (Pl?-Tt).
vellai Beu, 1970. Tt (Sw-Tt).
(Syntomodrillia) Woodring, 1928.
waiauensis (Powell, 1942). Sc.
(Wairarapa) Vella, 1954.
rebecca (Vella, 1954). Tt.
- SUBFAMILY CRASSISPIRINAE**
- Clavatoma* Powell, 1942.
pulchra Powell, 1942. Wp (Wo-Wm). **Pl. 37y.**
- Inquisitor* Hedley, 1918.
awamoensis (Hutton, 1873). Pl. **Pl. 22j.**
flemingi (Vella, 1954). Tt.
 (?)*fraudator* Finlay & Marwick, 1937. Mw.
hebes Marwick, 1931. Pl-Sc.
komiticus Laws, 1939. Po-Pl (Po-Pl).
powelli (Dell, 1950). Po.
 (?)*waihaoensis* Powell, 1942. Ak.
waihoraensis Marwick, 1931. Pl-Sc.
- SUBFAMILY BORSONIINAE**
- Aotadrillia* Powell, 1942.
alpha (King, 1933). Wn (Wm-Wn).
apicarinata (Marshall & Murdoch, 1923). Wn.

- asper* (Marwick, 1931). Tt.
callimorpha (Suter, 1917). Pl.
chordata (Suter, 1908). R (Wn?-R).
consequens (Laws, 1936). Wo.
exigua (Marwick, 1931). Sc? (Pl-Sc?).
finlayi Powell, 1942. Wn.
ihungia (Marwick, 1931). Sc.
thomsoni Powell, 1942. Wp.
trifida Powell, 1942. Wn.
waihuaensis Powell, 1942. Wp.
wanganuiensis (Hutton, 1873). Wc (Wn-R?). **Pl. 49p.**
- Austroturris* Laseyron, 1954.
 (?)*solitaria* (King, 1933). Wm.
- Awateria* Suter, 1917.
defossa Powell, 1942. Tt.
echinata Powell, 1942. Wo?
evanida Suter, 1917. Wp.
karakaensis Marwick, 1931. Wo?
marwicki Powell, 1942. Tt.
miocenica Vella, 1954. Tt.
retiolata King, 1933. Wm (Wm-R).
streptophora Suter, 1917. Wp (Wp-Wm?). **Pl. 37r.**
striata Vella, 1954. Tt.
thomsoni Powell, 1942. Wp.
wairoaensis Powell, 1942. Wn.
- Awheaturris* Beu, 1970.
echinata Beu, 1970. Tt.
 (?)*experta* (Laws, 1947). Po.
pahaoaensis (Vella, 1954). Tt.
- Bathytoma* Harris & Burrows, 1891.
bartrumi Laws, 1939. Po (Po-Pl). **Pl. 26j.**
coweorum Beu, 1970. Tt.
finlayi Laws, 1939. Sc (Pl-Sl).
haasti (Hutton, 1877). Pl (Po-Pl). **Pl. 22m.**
hokianga Laws, 1947. Po.
mitchelisoni Powell, 1935. Pl.
wairarapaensis Vella, 1954. Sc-Sl.
 (*Micantapex*) Iredale, 1936.
discors Powell, 1942. Wn (Tt?-Wn).
filaris (Marwick, 1931). Sl (Sl-Tt?).
fortinodosa (Marwick, 1931). Wo (Tt-Wo).
hawera (Laws, 1940). Wp.
media (Marwick, 1931). Pl (Pl-Tk).
murdochi murdochi (Finlay, 1930). Wn (Wm-Wn). **Pl. 42q.**
murdochi paucispiralis (Powell, 1942). Wn.
murdochi prior (Vella, 1954). Wn.
ngatapa (Marwick, 1931). Sl (Pl-Tk?).
pergracilis (Marwick, 1931). Pl-Sc (Pl?-Sl).
praecisa (Marwick, 1931). Pl-Sc (Pl?-Sl).
proavita (Powell, 1942). Wp.
tenuineta (Marwick, 1931). Tt (Tt-Wo).
- Borsonella* Dall, 1908.
sinelirata Marwick, 1931. Tt.
- Borsonia* Bellardi, 1839.
clifdenensis Finlay, 1930. Sc.
mitromorphoides Suter, 1917. Ld. **Pl. 15r.**
zelandica (Marshall, 1919). Ab.
- Eothesbia* Finlay & Marwick, 1937.
microtomoides Finlay & Marwick, 1937. Mw.
- Mangaoparia* Vella, 1954.
powelli Vella, 1954. Tt.
- Maoricrassus* Vella, 1954.
carinatus Vella, 1954. Tt.
- Mauidrillia* Powell, 1942.
 (?)*acuta* (Marwick, 1928). Wp.
angustata Powell, 1942. Pl.
browni Marwick, 1943. Pl.
cinctuta (Marwick, 1929). Ld.
clavicula Powell, 1942. Pl.
costifer (Suter, 1917). Pl. **Pl. 22p.**
fimbriata Laws, 1947. Po.
- imparilirata* Powell, 1942. Po.
inaequalis Powell, 1942. Lw.
incerta Beu, 1970. Tt.
occidentalis Maxwell, 1988. Sw.
praecophinodes (Suter, 1917). Pl.
supralaevis Powell, 1942. Pl.
unilirata Powell, 1942. Pl.
- Microdrillia* Casey, 1903.
pakaurangia Powell, 1942. Po.
- Mitrellatoma* Powell, 1942.
angustata (Hutton, 1886). Wn.
- Phenatoma* Finlay, 1924.
decessor Marwick, 1928. Wp. **Pl. 37w.**
lawsi Powell, 1942. Pl.
perlata (Suter, 1917). Pl.
precursor Powell, 1942. Wn (Wm-Wn).
rosea (Quoy & Gaimard, 1833). R (Wm?-R). **Pl. 49m.**
zealandica (Smith, 1877). R (Wn?-R).
- Tahudrillia* Powell, 1942.
simplex Powell, 1942. Ak.
- Tomopleura* Casey, 1904.
clifdenica Powell, 1942. Sc.
crassispiralis (Marwick, 1929). Ld.
excavata (Hutton, 1877). Pl.
finlayi Powell, 1942. Pl.
striata (Marshall, 1917). Mw.
transenna (Suter, 1917). Pl (Po-Pl) **Pl. 22r.**
waiuaensis Powell, 1942. Sw.
 (*Maoritomella*) Powell, 1942.
annosa (Powell, 1942). Lw (Ld-Lw).
maoria (Powell, 1942). Sl (Sl-Sw).
mangaoparia (Beu, 1970). Tt.
pagodula (Powell, 1942). Wp (Wo-Wp).
pukeuriensis (Powell, 1942). Pl.
robusta robusta (Powell, 1942). Wn.
robusta moderata (Marwick, 1965). Wo.
rupta (Marwick, 1931). Sl.
sola (Powell, 1942). Po (Po-Pl).
studiosorum (King, 1933). Wm.
subalbula (Murdoch, 1900). Wc (Wn-Wc).
torquatella (Marwick, 1931). Wo (Wo-Wp).
- SUBFAMILY MITROMORPHINAE**
- Cordieria* Rouault, 1848.
huttoni Finlay, 1930. Ak.
rudis (Hutton, 1885). Ak. **Pl. 8m.**
- Itia* Marwick, 1931.
clatrata Marwick, 1931. Sl.
- Mitrolumna* Bucquoy, Dautzenberg & Dollfus, 1883.
brachyspira (Suter, 1917). Pl.
formosa (Marwick, 1931). Wo.
granum (Marwick, 1928). Wp. **Pl. 37v.**
sutherlandica (Powell, 1942). Pl.
waitakiensis (Powell, 1942). Lw.
- Scrinium* Hedley, 1922.
blandiatum (Suter, 1917). Lw. **Pl. 15s.**
callimorphum (Suter, 1917). Ld.
finlayi Powell, 1942. Pl.
ordinatum (Hutton, 1877). Pl.
strophorum (Suter, 1917). Pl.
strongi Marwick, 1931. Tt? (Sl?-Tt).
thomsoni Powell, 1942. Wp.
- Vexithara* Finlay, 1926.
magna Maxwell, 1969. Lw.
nodosolirata (Suter, 1917). Po. **Pl. 22n.**
vexilliformis (Marshall & Murdoch, 1923). Pl.
- SUBFAMILY CLATHURELLINAE**
- Etrema* Hedley, 1918.
kaipara Powell, 1942. Pl.
- Etrempsopsis* Powell, 1942.
aequisculpta Powell, 1942. Pl.
carinapex Powell, 1942. Pl.

clifdenica Powell, 1942. Sc (Pl-Sw).
compta Powell, 1942. Sc-Sl.
disposita Laws, 1944. Pl (Po-Pl).
duospiralis Laws, 1944. Pl (Po-Pl).
elata Powell, 1942. Pl.
erecta Powell, 1942. Sc (Sc-Sw).
haroldi Powell, 1942. Pl. **Pl.55k, l.**
imperfecta (Suter, 1917). Pl.
latiapex Powell, 1942. Pl.
oamarutica Powell, 1942. Pl.
quadrspiralis Powell, 1942. Pl.

SUBFAMILY MANGELIINAE

Anacithara Hedley, 1922.
axialis (Marshall, 1918). Pl. **Pl. 26m.**
clifdenica Powell, 1942. Pl.
errabunda Powell, 1942. Sc?
finlayi Powell, 1942. Sl-Sw.
nana Powell, 1942. Sl.

Antiguraleus Powell, 1942.
abnormis (Hutton, 1885). Wn (Wm-Wn). **Pl. 42o.**
deceptus Powell, 1942. Wn.
(?)depressispirus (Beu, 1969). Wm.
fusiformis Dell, 1956. R (Wn-R).
makaraensis Vella, 1954. Wn.
otagoensis Powell, 1942. R (Wc-R).
rishworthi Vella, 1954. Ti.
rossianus Powell, 1942. R (Wn-R).
subtruncatus Powell, 1942. R (Wn-R).
taranakiensis (Marwick, 1926). Ti.

Heterocithara Hedley, 1922.
laterculus Marwick, 1931. Wo.
marwicki Maxwell, 1988. Sw.

Liracraea Odhner, 1924.
dictyota (Hutton, 1885). Wn.
odhneri Powell, 1942. R (Wc-R).
titirangiensis Marwick, 1928. Wn.

Neoguraleus Powell, 1939.
amoenus (Smith, 1884). R (Wc-R).
benthiculus Powell, 1942. R (Wq-R).
deceptus Powell, 1942. Pl.
finlayi Powell, 1942. R (Wc-R).
hautotaraensis Vella, 1954. Wn.
interruptus Powell, 1942. R (Wc?-R).
lineatus (Marwick, 1928). Wp.
lyallensis (Murdoch, 1905). R (Wn-R).
murdochi (Finlay, 1924). Wc (Wn-R).
morgani (Marwick, 1924). Wn.
ngatuturaensis (Bartrum & Powell, 1928). Wo.
nukumaruensis Powell, 1942. Wn.
protensus (Hutton, 1885). Wn (Wn-Wc).
sinclairi (Smith, 1884). R (Wo-R).
waihuaensis Powell, 1942. Wp.
(Fusiguraleus) Powell, 1942.
angustatus Powell, 1942. Sw.
exsculptus Powell, 1942. Sc.
flexicostatus Powell, 1942. Po. **Pl. 22t.**
gracilentus (Suter, 1917). Pl.
gracilicostus Beu, 1979. Wn.
granulatus Powell, 1942. Pl.
lawsi Powell, 1942. Pl.
leptosoma (Hutton, 1885). Pl.
major Powell, 1942. Pl.
mancus Powell, 1942. Pl.
marwicki Powell, 1942. Sl.
nutans Powell, 1942. Lw.
platycostatus Powell, 1942. Sc.
plenecomptus Grant-Mackie & Chapman-Smith, 1971. Wq.
porrectus Powell, 1942. Pl.
powelli Marwick, 1965. Wp.
raricostatus Powell, 1942. Pl.
rigidus Powell, 1942. Sc.
satanicus Beu, 1965. Wn.
satus (Laws, 1936). Wo (Wo-Wp).

subobsoletus Powell, 1942. Pl.
sutherlandicus Powell, 1942. Pl.

Vexiguraleus Powell, 1942.
clifdenensis Powell, 1942. Pl (Pl-Sl?).

SUBFAMILY DAPHNELLINAE

Buccinaria Kittl, 1887.
(?)pusula (Laws, 1947). Po.
Cryptodaphne Powell, 1942.
pseudodrillia Powell, 1942. Po.
semilirata (Powell, 1942). Ld.
Eubela Dall, 1889.
awakinoensis Powell, 1942. Po (Po-Sw?). **Pl.55e, i.**
monile Marwick, 1931. Sc? (Pl-Sc).

Hokianga Laws, 1947.
nodulata Laws, 1947. Po.

Maoridaphne Powell, 1942.
clifdenica (Laws, 1939). Sl (Pl-Sl).
haroldi Powell, 1942. Pl.
(?)kaiparica (Laws, 1939). Po (Po-Pl).

Mioawateria Vella, 1954.
aitanga Grant-Mackie & Chapman-Smith, 1971. Wq.
expallata (Laws, 1947). Po.
personata (Powell, 1942). Wo (Sw-Wo). **Pl. 27q.**

Nepotilla Hedley, 1918.
bartrumi Laws, 1939. Po (Po-Pl).

Puha Marwick, 1931.
fulgida Marwick, 1931. Pl-Sc.
hebes (Hutton, 1873). Pl?
(?)sinusigera Powell, 1942. Pl.

Rugobela Finlay, 1924.
canaliculata (Suter, 1917). Pl.
humerosa (Marwick, 1926). Ak (Ak-Ar).
infelix (Suter, 1917). Pl.
nodulosa Powell, 1942. Pl.
(?)oborni Marwick, 1960. Dp?
semilaevigata Laws, 1935. Lw.
sepebilis (Powell & Bartrum, 1929). Po.
tenuicostata Laws, 1935. Po.
tenuilirata (Suter, 1917). Pl (Pl-Sw). **Pl. 22q.**
(?)tersa (Marwick, 1931). Sl-Sw.

Taranis Jeffreys, 1870.
aliena (Marwick, 1965). Wo.
bicarinata (Suter, 1915). Wc (Wc-R).
gratiosa (Suter, 1908). R (Wc-R).
nexilis (Hutton, 1885). Wc (Wn-Wc).

Zenepos Finlay, 1928.
lacunosa (Hutton, 1885). Wc.

SUBFAMILY THATCHERIINAE

Clinura Bellardi, 1875.
(?)generosa (Marwick, 1931). Pl?

Thatcheria Angas, 1877.
liratula (Powell, 1942). Wo.
pagodula (Powell, 1942). Ti. **Pl. 27t.**
(Waitara) Marwick, 1931.
waitaraensis (Marwick, 1926). Ti.

SUPERFAMILY CANCELLARIACEA

FAMILY CANCELLARIIDAE

SUBFAMILY CANCELLARIINAE

Anapepta Finlay, 1930.
anomala (Marshall & Murdoch, 1920). Ab.
culminata (Beu, 1970). Ti.
explicata Laws, 1935. Po (Po-Pl?).
finlayi Marwick, 1931. Pl. **Pl.56a, b.**
nucleosa Marwick, 1931. Sl (Sl-Sw?).
serrata Laws, 1935. Po.
tuberculifera Laws, 1935. Sl.

- Aphera* H. & A. Adams, 1854.
scopalveus Finlay, 1926. Pl. **PI. 22d**.
- Fusiaphera* Habe, 1961.
marshalli (Allan, 1926). Ak. **PI. 8h**.
naroniformis (Finlay, 1930). Pl.
- Inglisella* Finlay, 1924.
(?)*allophyla* Maxwell, 1988. Sw.
ampla Laws, 1935. Po (Po-Pl).
awakinoensis Laws, 1935. Po.
cincta (Hutton, 1885). Pl.
(?)*delli* (Beu, 1970). Tt.
disticha Marwick, 1965. Wo.
hirta Laws, 1936. Wo.
jocosa Maxwell, 1988. Sw.
laterinensis Maxwell, 1988. Sw.
marshalli (Vignal in Cossmann, 1921). Ab.
(?)*marwicki* (Dell, 1956). R (Wm?-R).
parva Laws, 1935. Pl (Pl-Sw).
pukeuriensis (Suter, 1917). Pl. **PI. 22c**.
- Maorivetia* Finlay, 1924.
brevirostris (Hutton, 1877). Pl. **PI. 22f**.
- Oamaruia* Finlay, 1924.
cancellata Marwick, 1965. Wo.
gemmata Maxwell, 1969. Ld.
suteri (Marshall & Murdoch, 1920). Pl.
(*Zeadmete*) Finlay, 1926.
araeostyla Maxwell, 1988. Sw.
(?)*concava* Marwick, 1931. Wo.
(?)*elegantula* Beu, 1970. Tt.
(?)*gibbera* Marwick, 1931. Sl.
kumeroa (Fleming, 1943). Wn.
(?)*major* Marwick, 1965. Wo.
miocenica (Finlay, 1930). Pl.
nodus (Finlay, 1930). Lw.
pliocenica (Finlay, 1930). Wc.
teres Laws, 1940. Wn.
trailli (Hutton, 1873). R (Wq-R).
- Pristimerica* Finlay & Marwick, 1937.
dolioides Finlay & Marwick, 1937. Mw.
- Scalptia* Jousseume, 1887.
(?)*christiei* (Finlay, 1924). Ld. **PI. 15l**.
haweraensis (Laws, 1940). Wp.
kaiparaensis (Laws, 1939). Po.
maoria (Marshall & Murdoch, 1921). Pl.
pukeuriensis (Finlay, 1930). Pl.
(?)*waikaiaensis* (Finlay, 1924). Ld.
- Tatara* Fleming, 1950.
flemingi Beu & Maxwell, 1987. Lwh (Ar-Lwh). **PI. 9k**.
pahiensis (Marshall & Murdoch, 1921). Ab.
revoluta (Finlay, 1926). Ak. **PI. 8k**.
transenna (Suter, 1917). Lw (Lw-Sc?).
- Waipaoa* Marwick, 1931.
(?)*affectata* Marwick, 1931. Sl?
cristata (Marwick, 1926). Tt.
(?)*grata* Marwick, 1931. Pl-Sc.
- SUBFAMILY ADMETINAE
Antepta Finlay & Marwick, 1937.
nasuta Finlay & Marwick, 1937. Mw.
- Bonellitia* Jousseume, 1887.
fundata Marwick, 1931. Wo (Wo-Wm).
lacunosa (Hutton, 1885). Wn. **PI. 42l**.
(*Admetula*) Cossmann, 1889.
hampdenensis Marshall & Murdoch, 1923. Ab.
ovalis (Marshall, 1918). Po-Pl.
- Coptostomella* Finlay & Marwick, 1937.
pupa Finlay & Marwick, 1937. Mw.
- SUBFAMILY PLESIOTRITONINAE
Kapuatriton Beu & Maxwell, 1987.
kaitarus Beu & Maxwell, 1987. Ak.
- Turehua* Marwick, 1943.
crassispinalis Beu & Maxwell, 1987. Ak.
dubia (Marshall, 1919). Ab.
lividorupis Beu & Maxwell, 1987. Po (Lw-Po). **PI. 22e**.
poncuspidis Beu & Maxwell, 1987. Ar.
tenuispinalis Beu & Maxwell, 1987. Ld.
- SUBCLASS OPISTHOBRANCHIA
ORDER CEPHALASPIDEA
SUPERFAMILY ACTEONACEA
FAMILY ACTEONIDAE
Acteon Montfort, 1810.
articulatus Marwick, 1931. Sc.
chattonensis Marwick, 1929. Ld. **PI. 56f**.
cratericulatus Hedley, 1906. R (Wc-R).
infultus Marwick, 1931. Sc.
oneroaensis Powell & Bartrum, 1929. Po.
otamateaensis Laws, 1941. Po-Pl (Po-Pl).
procratericulatus Laws, 1939. Po (Po-Pl).
semispinalis Marshall, 1917. Mw.
wangaloa Finlay & Marwick, 1937. Mw.
- Crenilabium* Cossmann, 1889.
*(9)*starboroughense* (King, 1934). Wp (Wo-Wm?).
zelandicum Marshall, 1918. Pl? (Pl). **PI. 26r**.
- Ongleya* Finlay & Marwick, 1937.
tholispira Finlay & Marwick, 1937. Mw. **PI. 2x**.
- Pupa* Röding, 1798.
alba (Hutton, 1873). R (Wc-R).
- Tenuiactaeon* Aldrich, 1921.
ambiguus (Hutton, 1885). Wc (Wn-R). **PI. 49o**.
granulocostatus (Laws, 1939). Po-Pl?
ovalis (Hutton, 1885). Pl.
praecursorius (Suter, 1917). Pl.
- Tornatellaea* Conrad, 1860.
incompta Finlay & Marwick, 1937. Mw.
morbosa Finlay & Marwick, 1937. Mw.
saucia Finlay & Marwick, 1937. Mw.
subovalis (Marshall, 1917). Mw.
- Triploca* Tate, 1893.
waihaoensis Marshall & Murdoch, 1923. Ak. **PI. 8aa**.
- FAMILY RINGICULIDAE
Ringicula Deshayes, 1838.
castigata Marwick, 1929. Ld. **PI. 56i, j**.
marwicki Powell, 1935. Pl.
torquata Marwick, 1926. Tt.
uniplicata Hutton, 1885. Wn.
zecorpulenta Laws, 1939. Po.
(*Ringiculina*) Monterosato, 1884.
altocanalis Dell, 1952. Tt.
ngatapa Marwick, 1931. Sl (Sl-Sw).
(?)*obesior* Marwick, 1931. Sl.
tutamoensis Marwick, 1931. Sl.
- Superstes* Finlay & Marwick, 1937.
curtus (Marshall, 1916). D?
innominandus Finlay & Marwick, 1937. Mw.
marshalli Finlay & Marwick, 1937. Ab (Ab-Ak). **PI. 8z**.
paucistriatus (Marshall, 1916). D?
phoenix Finlay & Marwick, 1937. Ak.
- SUPERFAMILY PHILINACEA
FAMILY CYLICHNIDAE
Cyllichna Lovén, 1846.
theidis Hedley, 1903. R (Wo-R).
- Cyllichna* Marwick, 1931.
bartrumi Marwick, 1931. Pl? (Po-Pl). **PI. 26p**.
circumspecta Marwick, 1931. Sl.
impar Finlay & Marwick, 1937. Mw.
plana Laws, 1939. Po-Pl (Po-Pl).
putealis Finlay & Marwick, 1937. D.
- Kaitoa* Marwick, 1847.
haroldi Marwick, 1931. Pl. **PI. 22w**.

- islandica* Marwick, 1931. Sl.
recta Laws, 1939. Po-Pl (Po-Pl).
- Maoriscaphander** Dell, 1950.
manukauensis Dell, 1950. Po.
- Priscaphander** Finlay & Marwick, 1937.
cingulatus (Marshall, 1917). Mw. Pl. 2y.
- Roxania** Leach, 1847.
alpha (Mestayer, 1921). Po.
- Scaphander** Montfort, 1810.
(?)enyasi (Hutton, 1873). Ld.
flemingi Marwick, 1965. Wn.
hiulcus Laws, 1936. Wo.
komiticus Laws, 1939. Po (Po-Pl).
malleatus Marwick, 1931. Sc.
miriamae Dell, 1952. Tt.
scapha Laws, 1933. Pl.
toringa Dell, 1950. Tt.
- Taita** Laws, 1948.
callosa Laws, 1948. Po.
clatrellata (Marwick, 1931). Sl.
lawi Maxwell, 1988. Sw.
- FAMILY PHILINIDAE**
Philine Ascanius, 1772.
auriformis Suter, 1909. R (Wc-R).
powelli Rudman, 1970. R (Wc-R).
tepiakensis Rudman, 1970. Wc (Wc-Wq).
- SUPERFAMILY BULLACEA**
FAMILY HAMINOEIDAE
Atys Montfort, 1810.
maorinus Marwick, 1931. Pl-Sc.
- Haminoea** Turton, 1830.
zelandiae (Gray, 1843). R (Wp-R).
- Limulatys** Iredale, 1936.
lacrimula (Laws, 1939). Po-Pl.
- FAMILY BULLIDAE**
Bulla Linné, 1758.
quoyi Gray, 1843. R (Wq-R).
- FAMILY RETUSIDAE**
Cylichnina Monterosato, 1884.
ennucleata Powell & Bartrum, 1929. Po.
otahuensis Laws, 1950. Wp.
segnis Laws, 1940. Wo.
soror (Suter, 1917). Pl.
striata (Hutton, 1873). R (Wq-R).
- Pyrunculus** Pilsbry, 1895.
improcerus (Marwick, 1931). Sc.
- Retusa** Brown, 1827.
oruensis (Webster, 1908). R (Wn-R).
pressa Marwick, 1928. Wp.
- Volvulella** Newton, 1891.
fulmeniculum (Marwick, 1931). Sc (Pl-Sc).
marwicki (Bartrum & Powell, 1928). Wo.
reflexa (Hutton, 1886). Pl. Pl. 56h.
- ORDER ENTOMOTAENIATA**
SUPERFAMILY ARCHITECTONICACEA
FAMILY ARCHITECTONICIDAE
Architectonica Röding, 1798.
(?)spinogula Laws, 1941. Po (Po-Pl).
- Discotectonica** Marwick, 1931.
hokianga (Vella, 1954). Po (Po-Pl). Pl. 25i, j.
platyplagia (Dell, 1952). Tt.
seniscula (Marwick, 1931). Sc (Pl-Sl).
- Granosolarium** Sacco, 1892.
lawi Maxwell, 1969. Lw.
marwicki (Allan, 1926). Ab.
- Helicacus** d'Orbigny, 1841.
maorianus Powell, 1934. Wq (Wq-R).
- Philippia** Gray, 1847.
lutea (Lamarck, 1822). R (Wn-R).
- Pseudomalaxis** Fischer, 1885.
asculpturatus Maxwell, 1966. Ak.
(Spirolaxis) Monterosato, 1913.
copaerentia (Laws, 1944). Po.
- Wangaloa** Finlay, 1927.
aucklandica (Marshall, 1918). Po-Pl.
ngaparaensis (Suter, 1917). Ak. Pl. 7q, r.
plana (Marshall, 1917). Mw.
- FAMILY MATHILDIDAE**
Brooksena Finlay, 1926.
duplicincta Laws, 1939. Po. Pl. 55b.
succincta (Suter, 1908). R (Wo-R).
- Eomathilda** Finlay & Marwick, 1937.
paxilla Finlay & Marwick, 1937. Mw.
- Fimbriatella** Sacco, 1895.
kaiparaensis (Laws, 1941). Po (Po-Pl).
marwicki Maxwell, 1966. Ak.
nathani Maxwell, 1988. Sw.
prima (Laws, 1935). Ab.
- Gegania** Jeffreys, 1884.
(Tubena) Marwick, 1943.
olsoni (Maxwell, 1969). Lw (Ab-Po). Pl. 14d.
viola Marwick, 1943. Pl.
- Kaitangata** Finlay & Marwick, 1937.
hendersoni Finlay & Marwick, 1937. Mw.
- Mathilda** Semper, 1865.
(Opimilda) Iredale, 1929.
pontis (Maxwell, 1966). Ak.
- Mathildona** Iredale, 1929.
allani Maxwell, 1966. Ak.
- Veterator** Laws, 1944.
quadricinctus (Marwick, 1931). Sl (Po-Sl).
- SUPERFAMILY PYRAMIDELLACEA**
FAMILY PYRAMIDELLIDAE
SUBFAMILY ODOSTOMIINAE
Agatha A. Adams, 1860.
alexanderi (Marwick, 1929). Ld.
georgiana (Hutton, 1885). Wc (Wn-R).
otaiensis Laws, 1940. Po.
pittensis (Marwick, 1928). Wp.
- Bartrumella** Laws, 1940.
kaawaensis Laws, 1940. Wo.
waitakereensis Hayward, 1981. Pl.
- Besla** Dall & Bartsch, 1904.
lawi Grant-Mackie & Chapman-Smith, 1971. Wq.
otahua Laws, 1950. Wp.
vaga Laws, 1941. Wc (Wc-R).
- Chrysallida** A. Adams, 1864.
(?)curvicostata (Grant-Mackie and Chapman-Smith, 1971). Wq.
zecarinata Laws, 1948. Po.
- Costosyrnola** Laws, 1937.
solitaria Laws, 1937. Pl.
tabulata Laws, 1937. Pl.
waikaia Laws, 1937. Ld.
- Egila** Dall & Bartsch, 1904.
arcuata Laws, 1941. Pl.
- Elodiamea** Folin, 1884.
(?)eocenica Laws, 1941. Ak.
- Evalea** A. Adams, 1850.
huttoni (Suter, 1908). Wc.
liricincta (Suter, 1907). R (Wm-R).
obsoleta (Murdoch, 1900). Wc (Wn-Wc).

- Evelynella* Laws, 1940.
doliella Laws, 1940. Sl? (Sc-Sw).
kaawa Laws, 1940. Wo.
marginalis Laws, 1940. Wo.
sinemacula Laws, 1940. Ld.
venustas Laws, 1940. Sc (Pl-Sw). **Pl.57a, e, f.**
- Gumina* Finlay, 1928.
dolichostoma (Suter, 1908). R (Wc-R).
minor Laws, 1940. Wm (Wm-Wn).
- Levipyrulina* Laws, 1941.
marginata Laws, 1941. Pl.
sulcata Laws, 1941. Pl (Pl-Sl).
- Linopyrga* Laws, 1941.
junior Laws, 1941. Sc (Sc-Sl).
parva Laws, 1941. R (Wc-R).
rugata (Hutton, 1884). Wc (Wo-R). **Pl.57k, l.**
pseudorugata (Marshall & Murdoch, 1921). Pl.
sanguis Laws, 1941. Sl (Sl-Sw).
- Obexomia* Laws, 1941.
denselirata (Suter, 1908). R (Wq-R).
granum (Laws, 1940). Wo.
- Odostomia* Fleming, 1817.
ancisa (Marwick, 1931). Sl (Sl-Tt).
arowhana (Marwick, 1931). Sl.
awatumida Laws, 1939. Pl.
bartrumi Laws, 1939. Wo.
biangulata Laws, 1939. Pl.
castlecliffensis Laws, 1939. Wc (Wm-Wc).
chattonensis Laws, 1939. Ld.
chordata Suter, 1907. R (Wc-R).
gorensis Laws, 1939. Ld.
graviapicalis Laws, 1939. Pl.
incidata Suter, 1908. R (Wn-R).
mahoenuica Laws, 1939. Po.
obstinata Laws, 1939. Pl (Ld-Sw). **Pl.57i, m.**
ototarana Laws, 1939. Ld.
pervaga Laws, 1939. R (Wn-R).
sheriffi Hutton, 1883. Wc (Wn-Wc).
taumakiensis Suter, 1908. R (Wn-R).
turneri Laws, 1939. Wc (Wo-R).
vaga Laws, 1939. R (Wn-R).
vixornata (Marwick, 1931). Sc.
waipaoa (Marwick, 1931). Sc.
waitakiensis Laws, 1939. Lw.
whangaparaoa Grant-Mackie & Chapman-Smith, 1971. Wq.
zecorpulenta Laws, 1939. Wn (Wm-Wn).
- Parodostomia* Laseyron, 1959.
southlandica (Laws, 1940). Sc (Pl-Sc).
- Pukeuria* Laws, 1941.
anaglypta Laws, 1941. Pl.
- Puposyrnola* Cossmann, 1921.
stirps Laws, 1937. Sc.
- Pyrgulina* A. Adams, 1864.
latocorrugata Laws, 1941. Pl.
- Sinuatodostomia* Nomura, 1937.
neozelanica Laws, 1940. Wo.
- Striodostomia* Laws, 1940.
kaawa Laws, 1940. Wo.
locuples Laws, 1940. Wn.
orewa Laws, 1940. R (Wq-R).
waikaia Laws, 1940. Ld.
- Syrnola* A. Adams, 1860.
aclyformis Marwick, 1929. Ld.
angulifera (Laws, 1937). Sc (Po-Sc).
finlayi (Laws, 1937). Pl. **Pl.57g.**
irrevocata Laws, 1937. Wn.
lutosa Marwick, 1931. Sc (Pl?-Sc).
otaioensis (Laws, 1937). Po.
rodatta (Laws, 1940). Wo.
- sculptilis* Laws, 1937. Pl.
sulcifera Laws, 1937. Sw (Pl-Sw).
waiauca (Laws, 1937). Pl (Pl-Sw).
wallacei Marwick, 1929. Ld.
- Tibersyrnola* Laws, 1937.
inexpectata Laws, 1937. Pl.
lawsi (Powell, 1934). Wq.
pupaformis Grant-Mackie & Chapman-Smith, 1971. Wq.
semiconcava (Marshall & Murdoch, 1923). Pl.
tepikiensis (Powell, 1934). Wq.
- Waikura* Marwick, 1931.
circumdata Laws, 1941. Pl.
clivosa Marwick, 1931. Pl-Sc.
davidi Marwick, 1943. Pl.
elevata Maxwell, 1988. Sw.
finlayi Laws, 1941. Wn (Wm-Wn).
hawera Laws, 1941. Wp.
teres Marwick, 1965. Wo.
torques Marwick, 1931. Sl (Pl?-Sl).
- SUBFAMILY TURBONILLINAE**
- Chemnitzia* Orbigny, 1839.
brevisutura Laws, 1937. Po.
eruita Laws, 1950. Wp.
granti Laws, 1937. Pl (Po-Pl).
haugrandis (Marwick, 1931). Sl.
jactura Laws, 1937. R (Wq-R).
kaawa Laws, 1937. Wo.
kereruensis Laws, 1937. Wn.
ngatutura Laws, 1940. Wo.
petaneana Laws, 1937. Wn (Wm-Wc).
pliocena Laws, 1937. Wq (Wc-Wq). **Pl.57c, h.**
quadruplator Laws, 1940. Wo.
raptor Laws, 1937. Wc.
sycophanta Laws, 1937. Sw?
zealandica Hutton, 1873. R (Wc-R).
- Eulimella* Jeffreys, 1847.
alpha Laws, 1938. Ab.
awamoensis (Marshall & Murdoch, 1921). Pl.
beta Laws, 1938. Ab.
coxi Laws, 1938. Pl.
deplexa Hutton, 1885. Wc (Wm-Wc).
imitator Laws, 1939. Po (Po-Pl).
kaawaensis Laws, 1940. Wo.
kempi Grant-Mackie & Chapman-Smith, 1971. Wq. **Pl. 57d.**
komitica Laws, 1939. Po.
larga Laws, 1938. Pl.
levilirata Murdoch & Suter, 1906. R (Wm-R).
media (Hutton, 1885). Wc.
mestayerae (Marwick, 1931). Pl? (Pl?-Sc).
parlimbata Laws, 1939. Po (Po-Pl).
waihoraensis (Marwick, 1931). Pl-Sc.
- Gispyrella* Laws, 1937.
finlayi Laws, 1937. Pl.
hemiorysta Laws, 1937. Pl.
spatha Laws, 1937. Pl.
- "*Mormula* A. Adams, 1864."
awakinoensis Laws, 1937. Po.
laevigata Laws, 1937. Pl.
locuples Laws, 1937. Pl (Po-Pl).
tutamoensis Laws, 1937. Sl.
- Planpyrgiscus* Laws, 1937.
disparilis Laws, 1940. Wo.
extenuata (Marwick, 1931). Sl.
- Pyrgiscilla* Laws, 1937
adepts Laws, 1937. Ab.
chattonensis (Marwick, 1929). Ld.
festiva Marwick, 1943. Pl.
hampdenensis (Allan, 1926). Ab.
otoconsors Laws, 1937. Ld.
- Pyrgiscus* Philippi, 1841.
abjunctus Laws, 1937. Pl (Pl-Sl).

- (?)*discors* Maxwell, 1988. Sw.
intextus (Marwick, 1931). Sc.
macphersoni (Marwick, 1931). Sl.
- Pyrgolampros* Sacco, 1892.
albolapis Laws, 1937. Pl.
evelynae Laws, 1937. Sl?
pakaurangiensis Laws, 1939. Po.
semilaevigata Laws, 1937. Pl.
- Terelimella* Laws, 1938.
hutchinsoniana Laws, 1938. Pl.
kaawa Laws, 1940. Wo.
larochi Laws, 1938. R (Wc-R).
levianguilata Laws, 1950. Wp.
monstrosa Laws, 1950. Wp.
ototarana Laws, 1938. Ld.
 (?)*pravitas* Laws, 1941. Po.
- Turbonilla* Risso, 1826.
arcana Laws, 1937. Ab.
asperdolata Laws, 1940. Wo.
awamoana Laws, 1937. Pl (Po?-Pl).
awasimulans Laws, 1937. Pl.
bexleyana Laws, 1937. Po.
clifdenica Laws, 1937. Sc.
comitas Laws, 1937. Pl.
crebricostata Marwick, 1931. Pl-Sc.
duplicaria Marwick, 1931. Wo? (Wo-Wn).
erratica Laws, 1937. Pl.
komitica Laws, 1937. Po.
koruahina Laws, 1937. Wo.
macies Laws, 1937. Pl.
natales Laws, 1937. Sc (Sc-Sl). **Pl. 57b.**
ngatapa Marwick, 1931. Sl.
oamarua Laws, 1937. Pl.
paleogenica Corgan, 1969. Ak.
praegravata Laws, 1940. Wo.
pukeuriensis Laws, 1937. Pl.
separabilis Laws, 1937. Pl.
speighti Laws, 1937. Po.
stoneleighana Laws, 1937. Wn (Wm?-Wn).
tahuensis Laws, 1937. Ak.
waikura Marwick, 1931. Sl.
zesulcata Maxwell, 1988. Sw.
- ORDER THECOSOMATA
 FAMILY CAVOLINIIDAE
 SUBFAMILY CAVOLINIINAE
Cavolinia Abildgaard, 1791.
tridentata (Niebuhr, 1775). R (Wc-R).
- SUBFAMILY CLIONAE
Hyalocylis Fol, 1875.
annulata (Tate, 1887). (Ab-Ar). **Pl. 8u.**
- FAMILY CUVIERINIDAE
Vaginella Daudin, 1802.
aucklandica Clarke, 1905. Po.
inflata Hayward, 1981. Pl.
torpedo Marshall, 1918. Po-Pl (Po-Pl). **Pl. 26s, t.**
urenuensis (Suter, 1917). P?
- FAMILY SPIRATELLIDAE
Lornia Marwick, 1926.
limata Marwick, 1926. Ak (Dw-Ar).
 (?)*marwicki* Powell, 1935. Pl.
- Spiratella* Blainville, 1817.
atypica Laws, 1944. Po (Po-Pl).
ferax Laws, 1944. Po (Po-Pl). **Pl. 56d, e.**
- SUBCLASS PULMONATA
 ORDER BASOMMATOPHORA
 SUPERFAMILY SIPHONARIACEA
 FAMILY SIPHONARIIDAE
Benhamina Finlay, 1926.
obliquata (Sowerby, 1825). R (Wq-R).
- Siphonaria* Sowerby, 1825.
australis Quoy & Gaimard, 1833. R (Wq-R).
- Williamia* Monterosato, 1884.
maxwelli Marshall, 1981. Ld-Lw (Ld?-Po).
- FAMILY TRIMUSCULIDAE
Gadinalia Iredale, 1940.
conica (Angas, 1867). R (Hol-R).
- SUPERFAMILY AMPHIBOLACEA
 FAMILY AMPHIBOLIDAE
Amphibola Schumacher, 1817.
crenata (Gmelin, 1791). R (Wn-R).
- Salinator* Hedley, 1900.
neozelanica Laws, 1950. Wp.
- SUPERFAMILY ELLOBIACEA
 FAMILY ELLOBIIDAE
Leuconopsis Hutton, 1884.
putealis Laws, 1950. Wp.
- Ophicardelus* Beck, 1837.
costellaris (H. & A. Adams, 1854). R (Wq-R).
- CLASS SCAPHOPODA
 ORDER DENTALIIDA
 SUPERFAMILY DENTALIACEA
 FAMILY DENTALIIDAE
Antalis H. & A. Adams, 1854.
multistricta (Finlay & Marwick, 1937). Mw.
nana (Hutton, 1873). Wc (Pl?-R). **Pl. 41l.**
pareorensis (Pilsbry & Sharp, 1897). Tk-Wp.
- Dentalium* Linné, 1758.
centenniale Marwick, 1942. Ab.
ihungia Marwick, 1931. Sc.
irregulare Hutton, 1873. Tk-Wp?
mantelli Zittel, 1864. Lwh.
otamaringaense Marwick, 1926. Tt.
- Fissidentalium* Fischer, 1885.
solidum Hutton, 1873). Tt?
zelandicum (Sowerby, 1860). R (Tk-R).
- FAMILY LAEVIDENTALIIDAE
Laevidentalium Cossmann, 1888.
fodinense Maxwell, 1988. Sw.
waihoraense Emerson, 1954. Pl-Sc.
- ORDER GADILOIDA
 SUPERFAMILY GADILACEA
 FAMILY GADILIDAE
Cadulus (sensu lato) Philippi, 1844.
atavus Finlay & Marwick, 1937. D.
delicatus Suter, 1913. R (Pl?-R).
hurupiensis Dell, 1952. Tt.
 (*Gadila*) Gray, 1847.
zecaninus Laws, 1939. Po-Pl.
- Striocadulus* Emerson, 1962.
delli (Marwick, 1965). Wn.
prosperus (Marwick, 1931). Tt (Pl?-Wo).
- CLASS POLYPLACOPHORA
 ORDER NEOLORICATA
 SUBORDER LEPIDOPLEURINA
 FAMILY LEPIDOPLEURIDAE
Leptochiton Gray, 1847.
clifdenensis (Ashby, 1929). Pl.
finlayi (Ashby, 1929). R (Wm-R). **Pl. 43a, c, e.**
inquinatus (Reeve, 1847). R (Pl-R).
otagoensis (Iredale & Hull, 1929). R (Wq-R).
- SUBORDER ISCHNOCHITONINA
 FAMILY ISCHONCHITONIDAE
Ischnochiton Gray, 1847.
circumvallatus (Reeve, 1847). R. (Wq-R).

maorianus Iredale, 1914. R (Wc-R).
vetustus Powell & Bartrum, 1929. Po.

FAMILY CALLOCHITONIDAE

Callochiton Gray, 1847.
chattonensis Ashby, 1929. Ld.
empleurus (Hutton, 1872). R (Wq-R).

Eudoxochiton Shuttleworth, 1853.
nobilis (Gray, 1843). R (Wq-R).

FAMILY MOPALIIDAE

Plaxiphora Gray, 1847.
caelata (Reeve, 1847). R (Wc-R).
(*Fremblya*) H. Adams, 1866.
egregia (H. Adams, 1866). R (Wq-R).
(*Guildingia*) Pilsbry, 1893.
obtecta Pilsbry, 1893. R (Wq-R).
tutamoensis (Bucknill, 1928). Sc?

FAMILY SCHIZOCHITONIDAE

Lorica H. & A. Adams, 1852.
haurakiensis Mestayer, 1921. R (Wp-R). **Pl. 43b, d.**

FAMILY CHITONIDAE

Chiton Linné, 1758.
glaucus Gray, 1828. R (Wq-R).
pelliserpentis Quoy & Gaimard, 1835. R (Wc-R).
Onithochiton Gray, 1847.
neglectus neglectus Rochebrune, 1881. R (Wm-R). **Pl. 43f, h, k.**
Rhyssoplax Thiele, 1893.
aerea (Reeve, 1847). R (Wq-R).
allanthomsoni Mestayer, 1929. Ld.
canaliculata (Quoy & Gaimard, 1835). R (Wn-R). **Pl. 43i.**

SUBORDER ACANTHOCHITONINA

FAMILY ACANTHOCHITONIDAE

Acanthochitona Gray, 1821.
febilis Laws, 1950. Wp. **Pl. 31f, i, j.**
zelandica (Quoy & Gaimard, 1835). R (Wc-R). **Pl. 43g.**
(*Notoplax*) H. Adams, 1861.
ashbyi (Laws, 1932). Ld. **Pl. 10b.**
mariae (Webster, 1908). R (Wp?; Wn-R). **Pl. 44a, d, h.**
rubiginosa (Hutton, 1872). R (Wn-R). **Pl. 38a-c.**

Cryptoconchus Blainville in Burrow, 1815.
marwicki Bucknill, 1928. Wc. **Pl. 43j, l.**
porosus (Burrow, 1815). R (Wq-R).

CLASS CEPHALOPODA

SUBCLASS NAUTILOIDEA

FAMILY ATURIIDAE

Aturia Bronn, 1838.
coxi Miller, 1947. (Sc-Tt).
cubaensis (Lea, 1841). (Po-Tk). **Pl. 26q.**
mackayi Fleming, 1945. D (D-Ab).

FAMILY HERCOGLOSSIDAE

Cimomia Conrad, 1866.
zelandica Johnston, 1970. Up. Cret. (Up. Cret.-Lwh?).
Hercoglossa Conrad, 1866.
(?)*innominanda* Fleming, 1945. Ab.

FAMILY NAUTILIDAE

Eutrephoceras Hyatt, 1894.
allani (Fleming, 1945). Dw.

SUBCLASS DIBRANCHIATA

FAMILY ARGONAUTIDAE

Argonauta Linné, 1758.
oweri Fleming, 1945. Wo-Wp.
Izumonauta Kobayashi, 1954.
lata Kobayashi, 1954 (?). (Tk).

APPENDIX:

Some nomenclatural and taxonomic notes on name changes.

Most changes in our checklist of Cenozoic Mollusca from those used by Fleming (1966b) are either explained in the descriptive text, or follow automatically from publications cited in the bibliography. The following nine cases require separate explanations. The notes are numbered where they bear *asterisks in the checklist.

(1) *Nemocardium (Pratulium) marwicki* nom. nov.: We propose this as a replacement name for *Nemocardium diversum* Marwick (1928, p. 472), as it is a junior secondary homonym of *Nemocardium diversum* (Conrad, 1948) (Dockery 1982, p. 72, pl. 33, fig. 1-12).

(2) *Maetra murchisoni* Deshayes in Reeve, 1854: The name *Maetra murchisoni* has been attributed to Deshayes (1855a, p. 64) in recent publications (Climo 1972; Powell 1979). Although Deshayes's paper has often been assigned a date of 1854, the list of dates of publication of "Proceedings of the Zoological Society of London" (Sclater 1893) demonstrates that it appeared on 10 January 1855. The name was therefore published earlier in Reeve's monograph of *Maetra* in "Conchologia Iconica" (Reeve 1854, pl. 15, fig. 76), as Reeve's caption to pl. 15 bears the date "May 1854". As Reeve clearly attributed the name to Deshayes, in "Proc. Zool. Soc. 1854", and was not intending to anticipate Deshayes's publication, the name should be attributed to "Deshayes in Reeve". Reeve's figured specimen (Climo 1972, fig. 1 a, c, e) is the holotype of *Maetra murchisoni* Deshayes in Reeve, 1854. The authorship change will apply to several other names in Maetridae.

(3) *Spisula (Crassula) aequilatera* (Deshayes in Reeve, 1854): this is almost an exact repeat of the *Maetra murchisoni* case, above; the publication of Reeve's monograph of *Maetra* (1854, pl. 4, fig. 14) is earlier than Deshayes's (1855a) paper. Reeve's pl. 4 is dated "March 1854". In this case there is a slight name change, from the well known *S. aequilateralis* to *S. aequilatera*. Again, Reeve (1854) clearly attributed the name to Deshayes, in "Proc. Zool. Soc. 1854", and it should be attributed to "Deshayes in Reeve"; and Reeve's figured specimen is the holotype of *Maetra aequilatera* Deshayes in Reeve, 1854.

(4) *Hiatula* Modeer, 1793: in most reference works (eg., Moore 1969, p. N691), *Hiatula* Modeer is listed as a synonym of *Mya* Linné, 1758. However, Rehder (1967, p. 27) and Habe (1977, p. 223) pointed out a type designation for *Hiatula* Modeer by Stoliczka (1871, p. 114), much earlier than that usually cited; Stoliczka designated *Solen diphos* Linné, 1771 as type species of *Hiatula*. Rehder also pointed out that *S. diphos* Linné is an earlier name for *Soletellina radiata* Blainville, 1824, type species of *Soletellina* Blainville, 1824. *Hiatula* Modeer, 1793 is therefore an earlier objective synonym of *Soletellina* Blainville, 1824. Rehder (1967, p. 27) listed several correct earlier usages of *Hiatula*, as early as H. and A. Adams (1856, p. 392).

(5) *Bembicium hokianga* (Laws, 1948): Unfortunately, we realised during the preparation of this book, and after Reid's (1988) monograph of *Bembicium* appeared, that the formerly enigmatic little shell named *Astraea (Astraliium) hokianga* by Laws (1948, p. 146) is an earlier name for the species from a nearby locality named *Bembicium discoideum* by Reid (1988, p. 141). Comparison of the two holotypes confirmed the synonymy (holotype of *A. hokianga*: NZGS, TM1553; holotype of *B. discoideum*: NZGS, TM6665).

(6) *Galeodea (Galeocorys) flemingi* nom. nov.: We propose this as a replacement name for *Galeocorys allani* Fleming (1966a, p. 433). Now that we regard both *Galeocorys* Kuroda and Habe, 1957 and *Taieria* Finlay and Marwick, 1937 as subgenera of *Galeodea* Link, 1807, *G. allani* Fleming is a junior secondary homonym of *Galeodea (Taieria) allani* (Finlay and Marwick, 1937).

(7) *Sassia (Sassia) minima* (Hutton, 1873): Hutton (1873b, p. 5) proposed *Triton minimus* for shells from "Awamoa" and "Broken River (L)" (ie., the lower (Duntroonian) beds, or "fan coral bed", at Broken River, Castle Hill Basin, Canterbury). Finlay (1924b, p. 454-5) regarded the Broken River specimen (in NZGS) as the "holotype" of *Triton minimus*, presumably because Hutton's Awamoa syntype was missing by then, and provided the common species at Awamoa with the name *Austrotriton maurium*. We regard Finlay's action as the designation of Hutton's Broken River syntype as the lectotype of *Triton minimus*.

Finlay (1931a, p. 10) later renamed the species *Austrosassia procera*, thinking it was preoccupied by *Triton minimus* Giebel, 1847. Examination of Giebel's (1847, p. 188) book showed that *Triton minimum* Giebel is a species in *Triton* Laurenti, 1768 (Vertebrata), not *Triton* Montfort, 1810 (Mollusca). The Code of Zoological Nomenclature (1985 ed., Article 57(h) i) states that homonymy between species-group names proposed in homonymous generic-group names applying to different groups of animals "is to be ignored"; the cited example is a precise parallel of the present case. *Triton minimus* Hutton was never to be regarded as a homonym, and must be reinstated.

The lectotype of *Triton minimus* Hutton is a small, poorly preserved specimen (Finlay 1924b, pl. 48, fig. 5), but clearly belongs in a very tall-spined, prominently shouldered species of *Sassia (Sassia)* closely related to *S. zealta* (Laws) (Pl. 24j). We can see no differences from a reasonably common, "giant", tall-spined species of *Sassia (Sassia)*, reaching at least 150 mm in height, occurring at several South Island Duntroonian and Waitakian localities (Wharekuri, Waitaki Valley, Duntroonian; Wharekuri Greensand, head of Lake Waitaki, Duntroonian; Otekaike Limestone, Sister's Creek, Hakataramea Valley, Waitakian; Brother's Stream, Hakataramea Valley, Waitakian) and the name *Sassia minima* (Hutton) appears to apply to this species. Through a complex history, *Sassia minima* (Hutton) applies to the largest world species of *Sassia* we are aware of.

(8) *Xymene pusillus* (Suter): Finlay (1927b, p. 511-512) and Ponder (1972a, p. 478-479) disagreed with Marwick's (1924c, p. 199) action in providing the new species *Xymene oliveri* for the New Zealand Pliocene to living species previously known as *Trophon crispus* (Gould), as Cossman (1903, p. 54, footnote) stated that it was "the New Zealand species" that must receive the new name *Trophon gouldi*. However, Cossman's action constitutes the nomenclatural replacement of a preoccupied name, *Trophon crispus* (Gould), and although Cossman replaced the name for incorrect reasons, Finlay (1927b, p. 511) showed that it nevertheless is preoccupied (*Fusus crispus* "Couthouy" Gould, 1849 (Johnston 1964, p. 62), not *Fusus crispus* Borsson, 1821) and Cossman's action must stand. Cossman was not proposing a new species from New Zealand, and his usage of "New Zealand" merely implies that he learnt of the name from Hutton (1893) rather than from a South American monograph. Cossman's replacement name applies to the South American species named by Gould, and another name must be found for the New Zealand species. Ponder's (1972a) synonymy shows the earliest name to be *Trophon pusillus* Suter (1907d, p. 253) and we adopt it here (= *Cymatium suteri* Marshall and Murdoch, 1921; = *Xymene oliveri* Marwick, 1924).

(9) *Crenilabium starboroughense* (King): King's (1934, p. 27, pl. 1, fig. 5) holotype (his only specimen) of *Pupa starboroughensis* is a large but incomplete, chalky specimen, which in our opinion, is the species later named *Crenilabium obsoletum* by Marwick (1965, p. 46, pl. 11, fig. 19, 20, 26).

The following Pliocene material of *Crenilabium* has been compared in NZGS: (1) holotype of *Pupa starboroughensis*, from "Brown sands, Starborough Creek, Awatere Valley, Marlborough" (Waipipian); (2) holotype and two paratypes of *C. obsoletum*, from GS1564, sandstone, Waihua River, Wairoa (Waipipian), all rather poorly preserved specimens with apertural characters scarcely visible; and (3) Kaawa Creek, coast south of Waikato Heads, South Auckland (Opoitian), one excellent, fresh specimen. All these specimens have the same elongate shape, very long last whorl, tall, gradually tapered spire, fine spiral sculpture (low, wide, closely spaced, flat-topped cords, with exceedingly fine axial threads in the interspaces, on the Kaawa Creek shell), and almost evenly rounded anterior end with a prominently margined, thickened inner lip (weakly but clearly notched at the base of the columella to form a slight siphonal spout on the Kaawa Creek shell). The Kaawa Creek specimen bears many low, rounded, closely spaced transverse ridges on the inner area of the inner lip, slightly finer and more numerous than those of *C. zelandicum* Marshall (Pl. 26r), confirming the generic position. In our opinion, all these specimens are conspecific; the earliest name is *C. starboroughense* (King). At least one unnamed species (Late Miocene) is present in NZGS.

LIST OF NEW SYNONYMIES AND NEW COMBINATIONS IN THIS WORK

NEW SYNONYMIES

SYNONYM

NAME ACCEPTED HERE

Genus-group Taxa:

<i>Tuangia</i> Marwick, 1927	<i>Protothaca</i> Dall, 1902
<i>Proficus</i> Finlay and Marwick, 1937	<i>Priscoficus</i> Conrad, 1866
<i>Mauicassis</i> Fleming, 1943	<i>Kahua</i> Marwick, 1928
<i>Otahua</i> Marwick, 1948	<i>Bedevea</i> Iredale, 1924
<i>Pittella</i> Marwick, 1928	<i>Ellicea</i> Finlay, 1928
<i>Finlayola</i> Laws, 1937	<i>Syrnola</i> A. Adams, 1860

Species-group Taxa:

<i>Pecten benedictus tepungai</i> Fleming, 1957	<i>P. benedictus marwicki</i> (Finlay, 1930)
<i>P. benedictus zeehanai</i> Fleming, 1957	<i>P. novaezelandiae</i> (Reeve, 1853)
<i>P. tainui aotea</i> Fleming, 1953	<i>P. tainui</i> (Finlay, 1930)
<i>P. (Patinopecten) marshalli</i> Suter, 1913	<i>Athlopecten athleta</i> (Zittel, 1864)
<i>P. dieffenbachii</i> Gray, 1843 }	<i>Chlamys zelandiae</i> (Gray, 1843)
<i>P. zealandonus</i> Hertlein, 1931 }	
<i>Lima mestayerae</i> Marwick, 1924	<i>L. zealandica</i> Sowerby, 1876
<i>Divaricella notocenica</i> King, 1933	<i>D. (Divalucina) huttoniana</i> (Vanatta, 1901)
<i>Miltha dosiniiformis</i> Marshall and Murdoch, 1921	<i>M. neozelanica</i> Marshall and Murdoch, 1921
<i>Venericardia caelebs</i> Marwick, 1929	<i>Megacardita ponderosa</i> (Suter, 1913)
<i>Marama (Marama) murdochi marwicki</i> Beu, 1970	<i>M. (Marama) murdochi</i> Marwick, 1927
<i>Notocallista (Striacallista) multistriata ovalina</i> Marwick, 1938	<i>N. (Striacallista) multistriata</i> (Sowerby, 1851)
<i>Imperator anthropophagus</i> Marwick, 1928	<i>Astraea heliotropium</i> (Martyn, 1784)
<i>Bembicium discoideum</i> Reid, 1988	<i>B. hokianga</i> (Laws, 1948)
<i>Nozeba candida</i> var. <i>effusa</i> Finlay, 1924	<i>N. candida</i> Finlay, 1924
<i>Natica haweraensis</i> Marwick, 1924	<i>Taniella planisuturalis</i> (Marwick, 1924)
<i>Magnatica powelli</i> Laws, 1932	<i>M. (Magnatica) planispira</i> (Suter, 1917)
<i>Uber pateaeis</i> Marwick, 1924 }	<i>Polinices (Polinices) waipipiensis</i> (Marwick, 1924)
<i>Polinices stanleyi</i> Marwick, 1948 }	
<i>Sigaretotrema insociale</i> Marwick, 1960	<i>Propesinum fornicatum</i> (Suter, 1917)
<i>Sigaretus (Naticina) cinctus</i> Hutton, 1885	<i>Eunaticina linnaeana</i> (Récluz, 1843)
<i>Struthiolaria subspinosa</i> Marwick, 1924	<i>S. (Struthiolaria) calcar</i> Hutton, 1886
<i>S. tasmani</i> King, 1933	<i>S. (Struthiolaria) papulosa</i> (Martyn, 1784)
<i>S. fortis</i> Marwick, 1924 }	<i>S. (Callusaria) callosa</i> Marwick, 1924
<i>S. armata</i> Marwick, 1924 }	
<i>S. media</i> Marwick, 1924 }	
<i>S. (Pellicaria) wellmani</i> Neef, 1970 }	<i>Pellicaria acuminata</i> (Marwick, 1924)
<i>Pellicaria mangaoparia</i> Vella, 1953 }	
<i>P. rotunda</i> Vella, 1953 }	
<i>Phalium (Echinophoria) hectori</i> Abbott, 1968	<i>Echinophoria pollens</i> (Finlay, 1926)
<i>Euspinacassis multinodosa</i> Powell, 1928	<i>Echinophoria toreuma</i> (Powell, 1928)
<i>Cabestana debilior</i> Finlay, 1930 }	<i>Cabestana tabulata</i> (Menke, 1843)
<i>C. otagoensis</i> Powell, 1954 }	
<i>Cymatium octoserratum</i> Finlay, 1924 }	<i>Sassia (Sassia) tortirostris</i> (Tate, 1888)
<i>Austrosassia morgani</i> Marwick, 1931 }	
<i>Austrosassia procera</i> Finlay, 1931	<i>S. (Sassia) minima</i> (Hutton, 1873)
<i>Charonia clifdenensis</i> Finlay, 1924	<i>S. (Sassia) neozelanica</i> (Marshall & Murdoch, 1923)
<i>Cymatium sculpturatum</i> Finlay, 1924	<i>S. (Haurokoa) marwicki</i> (Finlay, 1924)
<i>Aeneator drewi</i> Fleming, 1943	<i>A. marshalli</i> (Murdoch, 1924)
<i>Cominula attenuata</i> Fleming, 1943	<i>Cominella (Eucominia) hamiltoni</i> (Hutton, 1885)
<i>Cominella drewi</i> Hutton, 1883	<i>Xymene expansus</i> (Hutton, 1883)
<i>Austrosipho (Verconella) latispinifer</i> Marwick, 1932 }	<i>Penion crawfordi</i> (Hutton, 1873)
<i>A. masoni</i> Fleming, 1943 }	
<i>A. takapauensis</i> Fleming, 1943 }	
<i>A. (Verconella) edita</i> Powell, 1934 }	<i>P. sulcatus</i> (Lamarck, 1816)
<i>Verconella accipitris</i> Finlay, 1930 }	
<i>V. allani</i> Finlay, 1930 }	
<i>V. falsa</i> Finlay, 1930 }	
<i>Phos conicus</i> Marshall, 1917	<i>Pseudofax ordinarius</i> (Marshall, 1917)
<i>Glaphyrina marwicki</i> Beu, 1965	<i>G. plicata</i> Powell, 1929
<i>Coluzea espinosa</i> Finlay, 1930	<i>C. spiralis</i> (A. Adams, 1856)
<i>Zexilia tenuilirata</i> Laws, 1935 }	<i>Exilia waihaoensis</i> Suter, 1917
<i>Z. submarginata</i> Laws, 1935 }	
<i>Murexsul tepikiensis</i> Powell, 1934	<i>Coralliophila sertata</i> (Hedley, 1903)
<i>Mitra (Cancilla) armorica</i> Suter, 1917	<i>Proximitra rutidolomum</i> (Suter, 1917)
<i>Proximitra tumens</i> Finlay, 1930	<i>P. apicalis</i> (Hutton, 1873)

<i>Alcithoe familiaris</i> Marwick, 1926	<i>Alcithoe (Alcithoe) turrita</i> (Suter, 1917)
<i>Alcithoe wekaensis</i> Marwick, 1926	} <i>A. (Alcithoe) cylindrica</i> Marwick, 1926
<i>A. compressa</i> Marwick, 1926		
<i>A. armigera</i> Marwick, 1926		
<i>A. robusta</i> Marwick, 1926		
<i>A. sequax</i> Marwick, 1926	} <i>A. (Leporemax) lepida</i> Marwick, 1926
<i>A. reflexa</i> Marwick, 1926		
<i>A. neglecta</i> Marwick, 1926		
<i>A. separabilis</i> Laws, 1932		
<i>A. swainsoni</i> Marwick, 1926	} <i>A. (Alcithoe) arabica</i> (Gmelin, 1791)
<i>A. lutea</i> Marwick, 1926		
<i>A. detrita</i> Marwick, 1926		
<i>A. transformis</i> Marwick, 1926		
<i>A. acuta</i> Marwick, 1926	} <i>A. (Leporemax) fusus hedleyi</i> (Murdoch and Suter, 1908)
<i>Fulgoraria turrita</i> var. <i>nukumaruensis</i> Marshall and Murdoch, 1920		
<i>A. (Leporemax) fusus haurakiensis</i> Dell, 1956		
<i>Spinomelon otaiensis</i> Laws, 1932		
<i>S. evelynae</i> Laws, 1933	} <i>S. parki</i> (Suter, 1907)
<i>Waihaoia (Teremelon) awamoensis</i> Marwick, 1926		
<i>Mauia curvispina</i> Marwick, 1926	<i>Teremelon tumidior</i> (Finlay, 1926)
<i>Turris neglectus</i> Suter, 1917	<i>Mauira biconica</i> (Suter, 1917)
<i>Cordieria haasti</i> Finlay, 1930	<i>Eoturris complicata</i> (Suter, 1917)
<i>C. verrucosa</i> Finlay, 1930	} <i>C. rudis</i> (Hutton, 1885)
<i>Pseudoinquisitor problematicus</i> Powell, 1942		
<i>Chiton clavatus</i> Suter, 1907	<i>Inquisitor awamoensis</i> (Hutton, 1873)
<i>C. huttoni</i> Suter, 1906	} <i>Rhyssoplax aerea</i> (Reeve, 1847)
<i>C. suteri</i> Iredale, 1910		
<i>Rhyssoplax oliveri</i> Mestayer, 1921		

NEW COMBINATIONS

(Original generic locations are in square brackets. List does not include infrageneric changes (i.e. from one subgenus to another within a genus) or changes resulting from elevation in rank of subgenus to genus or vice versa).

Ennucula (?) *waikuraensis* (Marwick, 1931) [*Nucula*]
Sarepta constricta (Marwick, 1942) [*Ovaleda*]
Quadrilatera januaria (Marwick, 1926) [*Fossularca*]
Lissarca inusitata (Laws, 1944) [*Austrosarepta*]
L. obsoleta (Laws, 1944) [*Austrosarepta*]
Tucetona aucklandica (Powell, 1938) [*Glycymeris (Grandaxinea)*]
T. chambersi (Marshall and Browne, 1909) [*Glycymeris*]
T. finlayi (Laws, 1939) [*Glycymeris (Grandaxinea)*]
T. laticostata (Quoy and Gaimard, 1835) [*Pectunculus*]
T. lornensis (Marwick, 1923) [*Glycymeris*]
T. monadusta (Marwick, 1932) [*Glycymeris*]
T. traversi (Hutton, 1873) [*Pectunculus*]
T. wairarapaensis (Powell, 1938) [*Glycymeris (Grandaxinea)*]
Hormomya (?) *willeysi* (Marwick, 1928) [*Mytilus (Aulacomya)*]
Xenostrobus altijugatus (Marwick, 1931) [*Modiolus*]
Duplipecten (?) *devinctus* (Suter, 1917) [*Pecten (Chlamys, Aequipecten)*]
D. parki (Marwick, 1942) [*Lentipecten*]
Eburneopecten (?) *imperfectus* (Marwick, 1928) [*Lentipecten (Duplipecten)*]
Sectipecten mariae (Finlay, 1927) [*Pallium*]
Limea (?) *inconspicua* (Marwick, 1926) [*Mantellum*]
Crenostrea cannoni (Marwick, 1928) [*Ostrea*]
Crenostrea (?) *nelsoniana* (Zittel, 1864) [*Ostrea*]
Pycnodonte mackayi (Suter, 1917) [*Ostrea (Ostrea)*]
Flemingostrea wollastoni (Finlay, 1927) [*Ostrea*]
Borniola brevitata (Laws, 1944) [*Rochefortula*]
B. kaawaensis (Bartrum and Powell, 1928) [*Rochefortula*]
Volupicuna antiqua (Marwick, 1928) [*Cuna*]
V. awheaensis (Beu, 1970) [*Cuna*]
V. caerulea (Fleming, 1955) [*Cuna*]
V. (?) cerussata (Bartrum & Powell, 1928) [*Cuna*]
V. fictilia (Laws, 1936) [*Cuna*]
V. firma (Marwick, 1928) [*Cuna*]
V. kaupara (Laws, 1944) [*Cuna*]
V. ngatutura (Laws, 1940) [*Cuna*]
V. tuta (Marwick, 1931) [*Cuna*]
Eucrassatella australis (Hutton, 1873) [*Astarte*]
Cyclomactra (?) *altilunula* (Marwick, 1927) [*Eumarcia*]
Elliptotellina donaciformis (Marwick, 1928) [*Ascitellina*]
E. protensa (Powell, 1935) [*Ascitellina*]
E. urinatoria (Suter, 1913) [*Tellina (Tellina)*]

Moerella huttoni (Smith, 1885) [*Tellina*]
Peronaea gaimardi (Iredale, 1915) [*Tellina*]
Peronaea (?) *pahiensis* (Fleming, 1950) [*Angulus*]
Rexithaerus spenceri (Suter, 1907) [*Tellina* (*Angulus*)]
Serratina charlottae (Smith, 1885) [*Tellina* (*Tellinella*)]
S. eugonia (Suter, 1913) [*Tellina* (*Tellina*)]
S. ferrari (Marwick, 1931) [*Tellinella*]
"Tellina" robini (Finlay, 1924) [*Macoma*]
Tellinota arta (Laws, 1933) [*Angulus* (*Peronidia*)]
T. edgari (Iredale, 1915) [*Tellina*]
T. tumens (Laws, 1933) [*Angulus* (*Peronidia*)]
Hiatula nitida (Gray, 1843) [*Psammobia*]
H. siliqua (Reeve, 1857) [*Soletellina*]
H. waitemata (Marwick, 1948) [*Soletellina*]
Abra inflata (Laws, 1939) [*Angulus* (*Peronidia*)]
Abra (?) *marshalli* (Finlay, 1927) [*Pseudarcopagia* (?)]
"Parilimya" neozelanica (Suter, 1914) [*Thracia*]
"Parilimya" waitotarana (Powell, 1931) [*Pholadomya*]
"Parilimya" warrenae (Dell, 1952) [*Pholadomya*]
Asthenothaerus (?) *matauensis* (Finlay and Marwick, 1937) [*"Thraciopsis"*]
A. pusillior (Laws, 1936) [*Eximiothracia*]
Benthastelena (?) *muta* (Finlay, 1924) [*Trochus*]
Benthastelena (?) *transenna* (Suter, 1917) [*Astraea* (*Cyclocantha*)]
Calliostoma correlatum (Fleming, 1943) [*Maurea*]
C. couperi (Vella, 1954) [*Venustas*]
C. finlayi (Marwick, 1928) [*Maurea*]
C. foveauxanum (Dell, 1950) [*Venustas*]
C. granti (Powell, 1931) [*Maurea* (*Mucrinops*)]
C. waiaureka (Laws, 1935) [*Maurea* (*Mucrinops*)]
Calliotropis fenestrata (Suter 1917) [*Cantharidus*]
Spectamen carinatum (Laws, 1935) [*Zeminolia*]
S. fossa (Laws, 1932) [*Zeminolia*]
S. lene (Marwick, 1928) [*Zeminolia*]
S. ordo]Laws, 1941) [*Zeminolia*]
S. venustum (Maxwell, 1969) [*Zeminolia*]
Turbo (?) *barbara* (Marwick, 1942) [*Maurea* (*Mucrinops*)]
Turbo (?) *orycta* (Suter, 1917) [*Calliostoma*]
Cirsochilus priscus (Powell, 1935) [*Risellopsis*]
C. tricarinatus (Laws, 1939) [*Antisolarium*]
Neritoplica (?) *pomahakaensis* (Finlay, 1924) [*Nerita*]
Bembicium hokianga (Laws, 1948) [*Astraea* (*Astraliun*)]
Onoba (*Onoba*) *cryptolira* (Laws, 1950) [*Austronoba*]
O. (Onoba) obessa (Grant-Mackie and Chapman-Smith, 1971) [*Subonoba* (*Austronoba*)]
O. (Ovirissoa) gibbera (Laws, 1950) [*Estea*]
O. (Ovirissoa) zebina (Finlay, 1930) [*Badenia*]
Powellisetia (?) *bucina* (Laws, 1941) [*Notosetia*]
Chevallieria (?) *fossilis* (Finlay, 1924) [*Epigrus*]
C. pakaurangia (Laws, 1944) [*"Epigrus"*]
C. waitotarana (Laws, 1940) [*Epigrus*]
Circulus duplicarina (Marwick, 1929) [*Elachorbis*]
Circulus (?) *edomitus* (Marwick, 1931) [*Elachorbis*]
Pterolabrella (?) *hawera* (Laws, 1940) [*Elachorbis*]
Batillaria hectori (Harris, 1897) [*Cerithium*]
Gazameda grindleyi (Marwick, 1971) [*Zeacolpus*]
Crepidula opuraensis (Bartrum and Powell, 1928) [*Crypta*]
C. profunda (Hutton, 1873) [*Crypta*]
C. radiata (Hutton, 1873) [*Pilaeopsis*]
C. salebroso (Marwick, 1929) [*Maoricrypta*]
C. turnialis (Bartrum and Powell, 1928) [*Crypta*]
Archierato (?) *aucklandica* (Dell, 1950) [*Closia* (?)]
"Hespererato" pukeuriensis (Laws, 1935) [*Erato*]
"Hespererato" sepositum (Laws, 1935) [*Erato*]
"Hespererato" tenuilabrum (Laws, 1935) [*Erato*]
Proterato (?) *dubia* (Hutton, 1873) [*Marginella*]
Propesinum auriforme (Marwick, 1924) [*Micreschara* (*Macromphalina*)]
P. fornicatum (Suter, 1917) [*Sinum*]
Uberella (?) *haasti* (Marwick, 1924) [*Natica* (*Carinacca*)]
Semicassis (*Kahua*) *fibrata* (Marshall and Murdoch, 1920) [*Phalium*]
S. (Kahua) kaawaensis (Bartrum and Powell, 1928) [*Xenophalium*]
S. (Kahua) lilliei (Fleming, 1943) [*Xenophalium* (*Mauicassis*)]
S. (Kahua) marwicki (Fleming, 1943) [*Xenophalium* (*Mauicassis*)]
Sassia (*Sassia*) *arthritica* (Powell & Bartrum, 1929) [*Charonia* (*Charoniella*)]
S. (Sassia) cyphoides (Finlay, 1924) [*Austrotriton*]
S. (Sassia) decagonia (Finlay, 1924) [*Cymatium*]
S. (Sassia) jobbernsi (King, 1933) [*Cymatium*]
S. (Sassia) maoria (Finlay, 1934) [*Austrotriton*]
S. (Sassia) minima (Hutton, 1873) [*Triton*]
S. (Sassia) neozelanica (Marshall & Murdoch, 1923) [*Austrotriton*]

S. (Sassia) pahaoaensis (Vella, 1954) [*Austrosassia*]
S. (Sassia) pusulosa (Marwick, 1965) [*Austrosassia*]
S. (Sassia) tortirostris (Tate, 1888) [*Triton*]
S. (Sassia) zealta (Laws, 1939) [*Austrosassia*]
S. (Haurokoa) bartrumi (Powell, 1938) [*Mayena*]
S. (Haurokoa) marwicki (Finlay, 1924) [*Cymatium*]
S. (Haurokoa) woodi (Fleming, 1955) [*Argobuccinum (Haurokoa)*]
Priscoficus obtusa (Marshall, 1917) [*Perissolax*]
Cerithiella(?) propria (Laws, 1941) [*Zaclys*]
Cerithiopsis(?) mucro (Laws, 1939) [*Zaclys (Miopila)*]
Cerithiopsis(?) saepta (Marwick, 1931) [*Miopila*]
Cerithiopsis(?) simulator (Laws, 1939) [*Zaclys (Miopila)*]
Cerithiopsis(?) temperans (Marwick, 1931) [*Miopila*]
Horologica violator (Laws, 1944) [*Zaclys*]
Bouchettriphora(?) tepikiensis (Powell, 1934) [*Notosinister*]
Nototriphora kaawaensis (Laws, 1940) [*Notosinister*]
Inella aoteaensis (Marshall and Murdoch, 1920) [*Triphora*]
I. zespina (Laws, 1939) [*Notosinister*]
Melanella badenia (Laws, 1939) [*Balcis*]
M. collator (Laws, 1944) [*Balcis*]
M. geoffreyi (Laws, 1936) [*Balcis*]
M. kaiparaensis (Laws, 1939) [*Balcis*]
M. lentocontracta (Laws, 1941) [*Balcis*]
M. waikomitica (Laws, 1939) [*Balcis*]
M. waiaotea (Laws, 1941) [*Balcis (Vitreolina)*]
Opalia tenuispiralis (Marshall, 1919) [*Epitonium*]
Austrofusus(?) latecostatus (Suter, 1917) [*Alectrion (Tritia)*]
A. pliocenicus (Powell, 1931) [*Zelandiella*]
Exilia hampdenensis (Marwick, 1942) [*Zexilia*]
E. vixcostata (Finlay and Marwick, 1937) [*Zexilia*]
Exilia(?) zelandica (Marshall 1917) [*Coptochetus*]
Pterotyphis (Prototyphis) allani (Maxwell, 1971) [*Pterochelus*]
P. (Prototyphis) awamoanus (Finlay, 1930) [*Pteronotus (Pterochelus)*]
P. (Prototyphis) tahuensis (Maxwell, 1971) [*Pterochelus*]
Bedeve bartrumi (Marwick, 1948) [*Otahua*]
Pagodula delli (Beu, 1967) [*Vesanula*]
P. waitemataensis (Powell and Bartrum, 1929) [*Vesanula*]
Coralliophila lividorupis (Laws, 1935) [*Murexsul*]
Clifdenia(?) mystica (Suter, 1917) [*Euthria (Dennantia?)*]
Uromitra(?) caudata (Marwick, 1931) [*Austromitra*]
Carinaginella(?) totangiensis (Marwick, 1931) [*Marginella*]
Deviginella(?) coxi (Marwick, 1928) [*Marginella*]
Deviginella(?) harrisi (Cossmann, 1899) [*Marginella*]
Haluginella hectori (Kirk, 1882) [*Marginella*]
H. marwicki (Finlay, 1927) [*Marginella*]
Protophina(?) bellensis (Beu, 1970) [*Euliginella*]
Protophina(?) opoitia (Marwick, 1965) [*Triginella*]
Protophina(?) whitecliffensis (Marwick, 1926) [*Marginella*]
Sinuginella hesterna (Bartrum and Powell, 1928) [*Marginella*]
Volvarinella(?) floralis (Marwick, 1928) [*Marginella*]
V. hakataramea (Maxwell, 1969) [*Longinella*]
Volvarinella(?) megalabra (Beu, 1979) [*Mesoginella (Sinuginella)*]
Alcithoe (Alicithoe) bartrumi (King, 1933) [*Pachymelon*]
A. (Alcithoe) bulbosus (Marwick, 1931) [*Waihaoia (Pachymelon)*]
A. (Alcithoe) callaghani (King, 1931) [*Pachymelon*]
A. (Alcithoe) firma (Marwick, 1926) [*Waihaoia (Pachymelon)*]
A. (Alcithoe) murdochi (Marwick, 1926) [*Waihaoia (Pachymelon)*]
A. (Alcithoe) pinguella (Marwick, 1931) [*Waihaoia (Pachymelon)*]
A. (Alcithoe) powelli (Laws, 1936) [*Pachymelon (Palomelon)*]
A. (Alcithoe) renwicki (Marwick, 1928) [*Waihaoia (Pachymelon)*]
A. (Alcithoe) uptonensis King, 1934 [*Pachymelon*]
Gemmaterebra bicorona (Hutton, 1885) [*Cerithium*]
Marshallaria(?) esdailei (Marwick, 1926) [*Turricula*]
M. serotina (Suter, 1917) [*Surcula*]
Austroclavus famelica (Marwick, 1931) [*Insolentia*]
Austroturris(?) solitaria (King, 1933) [*Insolentia*]
Mitrolumna brachyspira (Suter, 1917) [*Borsonia (Mitromorpha)*]
M. granum (Marwick, 1928) [*Mitrihara*]
M. formosa (Marwick, 1931) [*Mitrihara*]
M. sutherlandica (Powell, 1942) [*Mitrihara*]
M. waitakiensis (Powell, 1942) [*Mitrihara*]
Cryptodaphne semilirata (Powell, 1942) [*Cosmasyrinx*]
Fusiaphera marshalli (Allan, 1926) [*Uxia*]
F. naroniformis (Finlay, 1930) [*Uxia*]
Inglisella marshalli (Vignal in Cossmann, 1921) [*Cerithidea*]
Scalptia(?) christiei (Finlay, 1924) [*Trigonostoma*]
S. haweraensis (Laws, 1940) [*Merica*]
S. kaiparaensis (Laws, 1939) [*Merica*]

S. maoria (Marshall and Murdoch, 1921) [*Admete*]
S. pukeuriensis (Finlay, 1930) [*Merica*]
Scalptia(?) *waikaiaensis* (Finlay, 1924) [*Trigonostoma*]
Crenilabium starboroughense (King, 1934) [*Pupa*]
Tenuiactaeon ambiguus (Hutton, 1885) [*Admete*(?)]
T. granulocostatus (Laws, 1939) [*Leucotina*]
T. ovalis (Hutton, 1885) [*Tornatellina*]
T. praecursorius (Suter, 1917) [*Acteon*]
Scaphander(?) *enysi* (Hutton, 1873) [*Cylichna*]
Volvulella fulmeniculum (Marwick, 1931) [*Rhizorus*]
V. marwicki (Bartrum and Powell, 1928) [*Rhizorus*]
Chrysallida(?) *curvicostata* (Grant-Mackie and Chapman-Smith, 1971) [*Rissoa* (*Haurakia*)]
Syrnola angulifera (Laws, 1937) [*Finlayola*]
S. finlayi (Laws, 1937) [*Finlayola*]
S. otaioensis (Laws, 1937) [*Finlayola*]
S. waiauaica (Laws, 1937) [*Finlayola*]
Vaginella urenuensis (Suter, 1917) [*Clio* (*Creseis*)]
Striocadulus delli (Marwick, 1965) [*Cadulus*]
S. prosperus (Marwick, 1931) [*Cadulus*]

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- (1) the original reference to the publication of every species name included in the "Checklist of New Zealand Cenozoic Mollusca";
- (2) references included in synonymies or discussions in the main descriptive text, or in the introduction to each age period; and
- (3) many other references to important family revisions, etc, mentioning or affecting New Zealand taxa, or that we have followed in arriving at our classification.

References to generic names can be found from Neave's invaluable "Nomenclator Zoologicus" (Zoological Society of London, 1939-1940; supplements 1950, 1966, 1975); most generic names proposed by New Zealand workers will be found in the following bibliography. We have not cited the number of illustrations for most entries, but they have been included for a few rare works, for which we had difficulty determining full bibliographic details.

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In the Index to Beu & Maxwell (1990), the third column on page 494 was partly misprinted in the original. An errata slip with the following corrections was pasted into some copies.

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