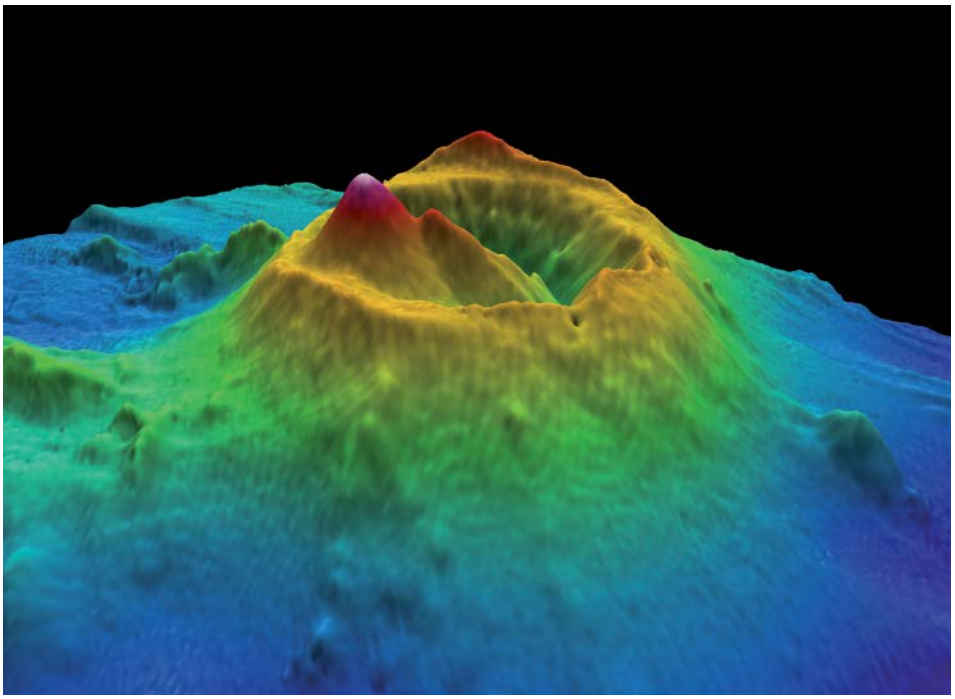
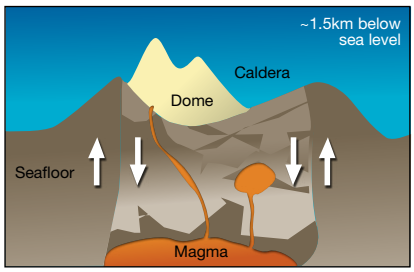
Volcano Fact Sheet

Brothers Volcano

Description

- This is a submarine (undersea) volcano in the Kermadec Arc, 400km north east of White Island.
- Brothers is three times bigger than White Island.
- It has an oval shape approx 13 km long and 8 km wide.
- It has a 3km wide summit caldera with walls 300-500m high.
- The caldera walls are very steep and there is evidence of landslides.
- A dome rises 350m from the caldera floor.
- The caldera floor is 1850m below sea level.





▲A computer generated 3D image of Brothers Volcano.

◄Brothers is a submarine **caldera volcano** - a volcano that has collapsed into itself, forming a large ring crater.

►Black smoker chimneys form when hydrothermal fluid jets react with cold sea water.

Features

- Brothers Volcano Currently has more hydrothermal activity than any other volcano in the Kermadec Arc.
- The hydrothermal vents (hot springs)on the caldera wall have formed a large field of 'black smoker' chimneys up to 8m high.

When hot hydrothermal fluid jets out of a vent, it mixes with cold sea water and a chemical reaction occurs. This causes metals in the fluid to precipitate out of the solution. The plumes of black 'smoke' created by this reaction settle and form deposits of metallic minerals on the crater floor. As this reaction occurs it can also build 'chimneys' rich in metals above the vents.

- The dome inside the caldera also has active hydrothermal vents.
- Plumes of hot water from the vents can rise 750 m through the ocean above.
- The area around the hydrothermal vents has unique forms of marine life such as tubeworms, and bacteria which use the hydrothermal fluids as an energy source.

Type

- This is an active submarine caldera.

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate.

Eruptive history

- This is unknown at present.

Eruptive material

- The crater walls reveal layers of dacite lava flows. Dacite is between rhyolite and andesite in viscosity.

Last eruptive activity

- Unknown.

Monitoring

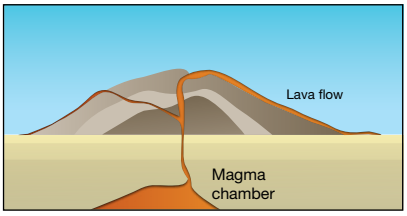
- Undersea volcanoes are not monitored, however they are a focus of current exploration. The minerals and marine life found around active undersea volcanoes may have economic and biotechnology benefits for NZ

Volcano Fact Sheet

Dunedin Volcano

Description

• This long extinct volcano was probably around 1000m high but has been eroded down over millions of years. The highest point today is Mt Cargill at 700m.



▲ Dunedin harbour and peninsula are remnants of the now extinct Dunedin volcano.

◄ It was a **shield volcano** - a broad volcano that is built up from fluid lava flowing down its gently sloping sides.

Features

• The Dunedin City area, Portobello Peninsula and Otago Harbour are all part of the volcano.

• The hills surrounding Dunedin (Mt Cargill, Flagstaff, Saddle Hill, Signal Hill and Harbour Cone) are remnants of the volcanic crater.

• The sea has drowned the lower slopes of the volcano.

• The area between Port Chalmers and Portobello was the vent of the volcano and is now part of Otago Harbour.

• Outcrops of lava and ash are visible around the city and harbour.

Type

• This is an extinct shield volcano.

Cause

• These volcanoes occur away from plate boundaries and subduction zones. They probably arise from hot spots in the mantle and produce mainly basalt magma.

Eruptive history

• It began erupting around 16 million years ago and had 3 main eruptive phases. Between phases the slopes of the volcano were forested and traces of these forests are preserved between lava flows in swamp and lake deposits.

Eruptive material

• These are pyroclastic flows, lava flows and fall deposits made mainly from basalt magma.

Last eruptive activity

• The rocks are dated at about 10 million years ago.

Monitoring

• None is necessary because the volcano is extinct.

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Volcano Fact Sheet

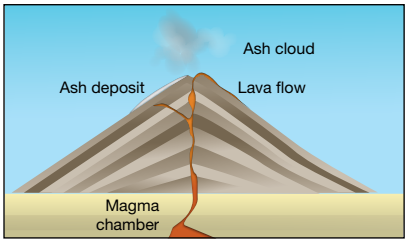
Ngauruhoe Volcano

Description

- Ngauruhoe is the largest, youngest and most active cone of the much larger Tongariro Volcano Complex.
- It lies between Tongariro to the north and Ruapehu to the south within Tongariro National Park.
- It is 2291m high (the highest point of the Tongariro complex).

►The 1975 eruption of Ngauruhoe.

▼Ngauruhoe and the entire Tongariro complex is a **stratovolcano (also called a composite cone)** - it is made up of alternating layers of ash and lava flow.



Maori name

- There are several explanations for its name. Nga-Uru-Hoe, meaning 'throwing hot stones', is the most common.

Features

- It has no vegetation on its slopes due to the steep, loose, scree slopes covered in material from recent eruptions.
- Fumaroles exist in the inner crater and on the rim of the eastern and northern outer crater. Steam is seldom visible above the crater rim.

Type

- Ngauruhoe is a stratovolcano (also called composite cone volcano).
- It is made of alternating layers of ash, scoria and andesite lava flows.

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate
- The Earth's crust is stretched and thinned in the entire Taupo Volcanic Zone by movement of the plates

Eruptive history

- Recent research suggests the cone may have appeared up to 4500 years ago, rather than the often quoted age of 2500 years.
- Maori oral history records many eruptions prior to European colonisation.
- More than 60 eruptions gave occurred since written records began in 1839.
- Most of these have been ash eruptions but a few have included lava flows.
- The last lava flow from Ngauruhoe was in 1954.
- Traditionally Ngauruhoe has erupted at least every 9 years but there has been no eruption since 1975.

Eruptive material

- Pyroclastic falls and flows, andesite lava flows, lava blocks and bombs are common.

Last eruptive activity

- In 1973 red hot blocks of lava were ejected and during 1974 and 1975 ash eruptions continued with lava blocks thrown as far as 3km away.
- During the final stage of the eruption in 1975 the eruption plume reached about 13km above the summit before collapsing and sending pyroclastic flows of ash and scoria down the mountain.
- For images and further information see:

http://www.teara.govt.nz/en/historic-volcanic-activity/3

Monitoring

- There are 4 seismographs, chemical analysis of gases, and airborne gas monitoring is done regularly. 2 continuous GPS stations, 2 web cameras facing Ngauruhoe and one microphone.

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Volcano Fact Sheet

Rangitoto Volcano

Description

• Rangitoto is a volcanic island in the Hauraki Gulf visible from most parts of Auckland City.

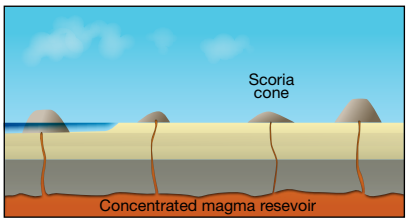
• It is the most recent, largest and least altered volcano in the Auckland Volcanic Field which is made up of around 50 small volcanoes.

• It was formed by at least 2 eruptions 600-700 years ago.

• The highest part is 260m, and it is 5.5km wide.

• The island is part of the Hauraki Gulf Maritime Park and is administered by the Department of Conservation.

• Past activities include scoria quarries, military installations and at one time it had a small permanent population.



▲ Rangitoto can be seen from most parts of Auckland City.

◄ Rangitoto is in the Auckland **volcanic field** - an area that has a concentration of lava flows, from which magma bubbles sporadically surface, creating scoria cones.

Maori Name

• *Rangitoto* means 'Bloody sky' and is thought to refer to the serious injury of a Maori chief during a battle on the island.

Features

• Roads and tracks allow visitors to walk over lava fields and through lava caves (tubes left behind by the passage of liquid lava).

• Vegetation varies from 'raw' lava fields to scrub and sparse forests including the largest pohutukawa forest in NZ.

• A moat like ring around the summit is due to subsidence of the mountaintop as underlying lava flows cooled and shrank.

Type

• It is an intra-plate or hot spot volcano, these occur away from plate boundaries and are not related to subduction.

• The volcano consists of scoria cones on top of a broad ring of lava flows.

Cause

• A mantle hot spot exists about 100 km below Auckland. When rock is melted by this extra heat it will separate from the surrounding solid rock and rise to the surface. The melted rock is basalt magma which has a low viscosity (flows easily) and may rise to the surface at speeds of up to 5 km/hour.

Eruptive history

• The Auckland Volcanic Field is monogenetic meaning each volcano usually only erupts once. Approximately 50 volcanoes have formed over the last 250.000 years. The field is still active and there is no way to predict where or when the next 'bubble' of magma will rise to the surface and create a new volcano.

• The size and length of each eruption depends on how big the 'bubble' of magma was, so Rangitoto was a comparatively large 'bubble' of magma.

Eruptive material

• If the basalt magma mixes with water (seawater or groundwater) super heated steam blows it apart. This causes a pyroclastic eruption that produces fall and flow deposits and has created the low rings of pyroclastic rock (called tuff) around the craters of many Auckland volcanoes, eg Lake Pupuke.

• When the magma has no contact with water, lava can fountain out less explosively and build a cone of tephra. Basalt tephra is called scoria so the cones are commonly called scoria cones eg, One Tree Hill.

• Rangitoto makes up nearly 60% of the total volume of material erupted by all volcanoes in the Auckland Field.

Last eruptive activity

• Rangitoto erupted 600-700 years ago over an unknown time span.

• The sequence of events was likely to have been:

- A violent pyroclastic eruption as cold sea water met molten rock, creating an explosion crater and a tuff ring.
- Ongoing fire fountaining built scoria cones once water could no longer reach the magma
- Lava flows from the base of the scoria cone

Monitoring

• 8 seismographs are operated jointly by GeoNet and the Auckland Regional Council.

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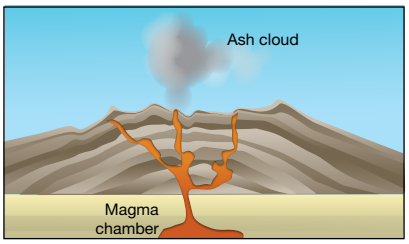
Volcano Fact Sheet

Ruapehu Volcano

Description

- Ruapehu is the largest active volcano in NZ and is located at the southern end of the Taupo Volcanic Zone in Tongariro National Park.
- At 2797m high, it is the highest peak in the North Island.
- It has the North Island's only glaciers.
- 3 summit craters have been active in the last 10,000 years, and the currently active vent is beneath the crater lake of South Crater.
- It is surrounded by a ring plain of volcanic material from lahars and landslides.



▲ The eruption of Mt Ruapehu in 1997.

► The South Crater lake.

◄ Mt Ruapehu is a **stratovolcano (also called a composite cone)** - it is made up of alternating layers of ash and lava flow.

Maori Name

- *Ruapehu* means 'pit of noise' or 'exploding pit'.

Features

- It has several peaks and a summit plateau
- The warm, acidic crater lake is fed by snow melt.
- There are two large commercial ski fields, Whakapapa and Turoa.

Type

- It is a stratovolcano, (also called composite cone volcano)
- Is is built up by a succession of layers of andesite lava and ash deposits.

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate
- The Earth's crust is stretched and thinned in the entire Taupo Volcanic Zone.
- It is believed to have a number of very small magma bodies 1-5km below the crater

Eruptive history

- Ruapehu began erupting at least 250,000 years ago
- Major eruptions in recorded history have been about 50 years apart, in 1895, 1945, and 1995.
- For dramatic images of the 95/96 eruption see: http://www.youtube.com/watch?v=h8W_sGYAQlc

http://www.swisseduc.ch/stromboli/perm/nz/rp96-en.html

- Mminor eruptions are frequent, with about 60 occurring since 1945.

Eruptive material

- Tephra ranging in size from dust (ashfall) to bombs and blocks, is produced in every eruption
- Lava flows occur from the vent (though none in historical times), lava domes in the vent (1945) and fire fountaining (sprays of liquid lava) have been witnessed.
- Pyroclastic flows are uncommon in Ruapehu's history with none in historic times.
- Usually the crater lake causes magma to cool and fragment (explode) quickly and violently leading to fine ash eruptions.

Last eruptive activity

- On 25 September 2007- an explosion of ash, rocks and water across the summit area lasted 7 minutes and produced 2 lahars but no high eruption plume.

Other Volcanic Hazards

- Frequent lahars have occurred during eruptions or later due to collapse of crater lake wall
- A 1953 lahar caused the Tangiwai disaster
- The most recent dam break lahar was on the 18 March 2007.
- Landslides (debris avalanches) are also possible.

Monitoring

- 2 web cameras, 10 seismographs and 6 microphones detect volcanic explosions,and 9 continuous GPS stations record ground deformation. Water and gas monitoring of the crater lake and airborne gas monitoring is also carried out regularly.

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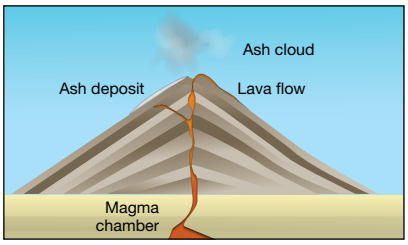
Volcano Fact Sheet

Taranaki / Egmont Volcano

Description

- This volcano has two official names Mount Egmont or Mount Taranaki.
- It is located in Egmont National Park.
- It is one of the most symmetrical volcanic cones in the world.
- There is a circular ring plain of volcanic material formed from lahars and landslides.
- At 2,518m high, it is the second highest peak in the North Island.
- It is NZ's largest mainland volcanic cone by volume.
- The summit crater is filled with ice and snow and has a lava dome in the centre.
- It is the youngest, largest and only active volcano in a chain that includes the Kaitake and Pouakai Ranges, Paritutu and the Sugar Loaves, all of which are eroded remains of what were once large volcanoes.



▲ Mt Taranaki is one of the most symmetrical volcanic cones in the world.

◄ It is a **stratovolcano (also called a composite cone)** - and is made up of alternating layers of ash and lava flow.

Maori Name

- Taranaki (tara means mountain peak and naki is thought to come from ngaki meaning shining and referring to the mountain's winter snow cover).

Features

- Volcanic ash has been weathered and mixed with the soil to produce rich, fertile farmland.
- There is a secondary cone called Fanthams Peak on the south side.
- It has a small ski field.

Type

- Taranaki is a stratovolcano (also called composite cone volcano).
- It is made of layers of mostly andesite lava flows and pyroclastic deposits (tephra).

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate. The magma is probably coming from deeper than the Taupo Volcanic Zone volcanoes as the subducting slab is deeper.

Eruptive history

- Eruptions began about 130,000 years ago
- Large eruptions occur on average every 500 years with smaller eruptions about 90 years apart.
- At least 5 eruptions have involved cone collapse. This has created the extensive ring plain, and huge landslides have reached as far as 40km from the cone.

Eruptive material

- Lava flows have reached up to 7km from the cone.
- Pyroclastic flows have travelled up to 15km.
- Tephra ranges in size from dust (ashfall) to bombs and blocks

Last eruptive activity

- An explosive medium sized ash eruption occurred around 1755 and minor volcanic events (creation of a lava dome in the crater and its collapse) occurred in the 1800's.
- The last major eruption was around 1655.
- It is considered to be a "sleeping" active volcano that is likely to erupt again

Other Volcanic Hazards

- These include lahars, debris avalanches and floods.

Monitoring

- A web camera and 9 seismographs are used.

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Volcano Fact Sheet

Tongariro Volcano

Description

• Tongariro is a massive complex of volcanic cones formed by eruptions from at least 12 vents over more than 275,000 years.

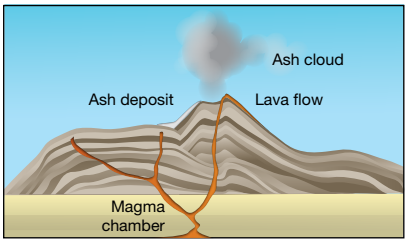
• It is located in Tongariro National Park which was given to the nation in 1887 by the Maori chief Te Heuheu Tukino IV.

• Volcanic explosions, collapse and erosion during the last Ice Age has modified the volcano.

• Ngauruhoe is the youngest cone (7000 years old) and most historically active vent, it has been frequently active in recorded times but has not erupted since 1977.

• Historic eruptions have also occured at Te Maari.

▼ The complex is a **stratovolcano (also called a composite cone)** - It is made up of alternating layers of ash and lava flow.



▲ The Tongariro volcanic complex.

▼ August 2012 eruptive vents.

Maori Name

Tongariro –fire carried away or seized by the cold south wind.

Features

• Ngauruhoe at 2291m is the highest point of the Tongariro complex and is on Tongariro's southern flank.

• Areas of mineral springs and fumaroles (steam vents) include Ketetahi Springs, Red and Te Maari craters. These are part of NZ's highest geothermal system which underlies parts of the volcano.

• Altitude, steep slopes, 'fresh' volcanic material and erosion prevent vegetation growing on most parts of the Tongariro complex.

• Some craters have filled with water to create Blue Lake and the Emerald Lakes.

Type

• It is an active stratovolcano (also called composite cone volcano).

• It is made of alternating layers of pyroclastic material (ash and rocks) and mainly andesite lava flows.

Cause

• It was created by subduction of the Pacific Plate below the Australian Plate.

• The Earth's crust is stretched and thinned in the entire Taupo Volcanic Zone by movement of the plates.

Eruptive material

• Pyroclastic ashfalls and flows, andesite lava flows, blocks and lava bombs are widespread over the complex.

Historical eruptive activity

• Ngauruhoe has erupted many times, most recently in 1977.

• Upper Te Maari crater(s) erupted in 1869, 1886, 1893, 1896–7 and 2012.

Monitoring (GeoNet)

• 4 seismographs, 1 microphone, chemical analysis of water and gases, 3 continuous GPS stations, and 3 web cameras facing Tongariro are used to observe activity.

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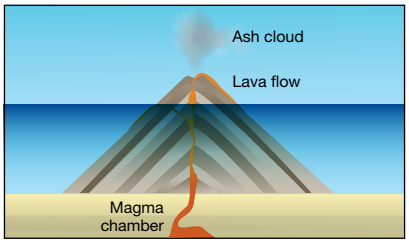
Volcano Fact Sheet

White Island Volcano

Description

- This is New Zealand's most active during the last 40 years.
- 70% of the cone is under the sea.
- It is an uninhabited island about 2 km in diameter and 48 km from the coast of the Bay of Plenty. The closest towns are Tauranga and Whakatane.
- It marks the northern end of the Taupo Volcanic Zone.
- The highest point is 321m, and the crater floor is less than 30m above sea level.
- The island is a privately owned scenic reserve, despite the harsh environment it is home to a number of bird species including a gannet colony.



▲ White Island is 48km off the coast of the North Island.

◄ The island is actually a submerged **stratovolcano (also called a composite cone)** - which is a volcano made up of alternating layers of ash and lava flow.

Maori Name

- *Te Puia o Whakaari* meaning to make visible.

Features

- Sulphur mining occurred at intervals from the 1880's until the 1930's and the remains of a factory can be seen on the island
- 11 sulphur miners were killed by a debris flow in 1914, when part of the crater rim collapsed.
- In May 2004 a dinosaur figurine (Dino from the Flintstones) was glued in front of one of the GeoNet web cameras and has been there ever since. Is he still there? Check: http://www.geonet.org.nz/volcano/activity/white-island/cameras/whiteisland-latest.html

Type

- White Island is a stratovolcano, also called composite cone volcano.
- It is made of layers of andesite lava flows and pyroclastic deposits (tephra).

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate.

Eruptive history

- White Island has been active for at least 150,000 years
- There has been continual low level activity and some small eruptions since human settlement of NZ.
- From 1975 until 2001 there were frequent small eruptions making this the island's most active period in hundreds of years. Ash and gas plumes rose as high as 10km, lava bombs and blocks were thrown into the sea and occasionally the glow of red hot rock was visible at night from the Bay of Plenty coast.

Last eruptive activity

- Previous activity occurred from March to September 2000.
- A new eruptive episode started on the island in August 2012. This followed only a few days of unrest. Eruptions have produced a tuff cone and a small amount of lava was extruded in December 2012.

Other Volcanic Hazards

- Craters and fumaroles continually produce gases which are mainly steam, carbon dioxide and sulphur dioxide. Gases dissolved in the magma escape and rise towards the surface where they mix with, and heat the groundwater beneath the crater floor. This produces the white steam/gas cloud which is usually present above White Island. This acidic cloud can sting the eyes and skin, affect breathing and damage equipment and clothes.

Monitoring

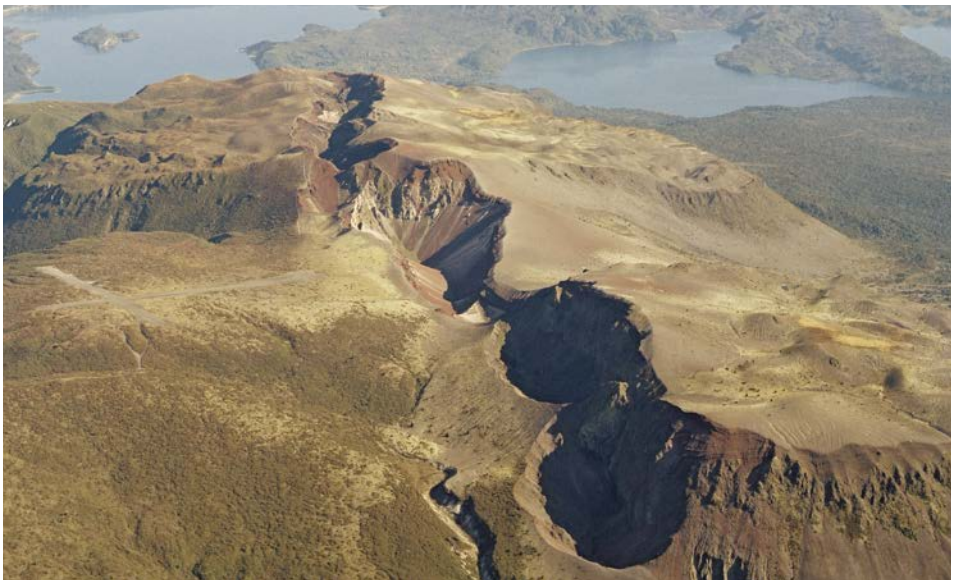
- This includes 2 web cameras on the island and one at Whakatane, 1 seismograph and a microphone to detect volcanic explosions, regular monitoring of water, gas and soil, and levelling to measure land deformation every 3 months

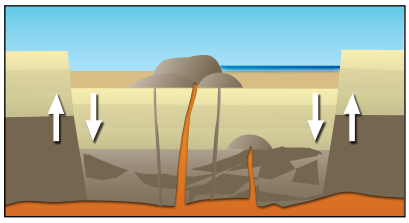
Volcano Fact Sheet

Tarawera Volcano and the Okataina Volcanic Centre

Description

- Tarawera is one of a number of dome volcanoes in the Okataina Volcanic Centre which lies east of Rotorua.
- The Okataina Volcanic Centre is a caldera which last collapsed about 64,000 years ago. Since then eruptions from many vents in the caldera floor have built dome volcanoes and partly filled in the hole left by that collapse.
- Tarawera is the site of NZ's largest eruption during the last 500 years.
- The volcano is 1111m high and is surrounded by a number of lakes created or altered by the 1886 eruption





▲ Tarawera.

◄ **Caldera volcano** - volcano that has collapsed into itself, often filling with water to form a lake.

Maori Name

- *Tarawera* means 'burnt cliff'or 'peaks'.

Features

- It has 3 dome shaped peaks with a central fissure created by the 1886 eruption.
- The 'Buried Village' of Te Wairoa has been excavated from the rocks, ash and boiling mud which buried it in 1886.

Type

- It is a dome volcano inside an active caldera

Cause

- It was created by subduction of the Pacific Plate below the Australian Plate
- The Earth's crust is stretched and thinned in the entire Taupo Volcanic Zone.

Eruptive History

- Eruptions which created Mt Tarawera began about 18,000years ago .
- The eruptions which formed the Okataina Caldera began around 400,000 years ago.
- The rhyolite lava flows which form the summit domes of Tarawera's three peaks were formed about 800 years ago.
- The time between eruptions in the Okataina Volcanic Centre is long (700 to 3000 years) but eruptions are 100 to 10,000 times larger than those of cone volcanoes.

Eruptive material from the 1886 eruption

- Thse include pyroclastic flows (scoria, mud and steam) and falls (ash).
- Caldera volcanoes usually erupt rhyolite magma very explosively but the 1886 eruption produced basalt which is less viscous.
- Basalt magma produces scoria when it explodes, scoria is darker and heavier than the pumice produced by rhyolite magma.
- When heat from the magma created superheated steam in Lake Rotomahana the lakebed rock fragmented and produced fine 'Rotomahana Mud' which spread over a wide area and was heavy enough to collapse nearby buildings.

Last eruptive activity

- The 10th June 1886, eruption began at 1.30am and lasted about 5 hours.
- The eruption blasted a 17 km long rift across the mountain top of Tarawera, through Lake Rotomahana and into the Waimangu Valley area.
- The world famous Pink and White Terraces were destroyed.
- More than 100 people were killed in villages near the mountain.
- The eruption was heard as far away as Blenheim and ash affected the atmosphere as far south as Christchurch.

Other Volcanic Hazards in the 1886 eruption include:

- earthquakes
- lightning storms and fireballs
- fissures along faultlines in the surrounding area
- strong winds
- suffocating gases and ashfall
- darkness during daylight hours as the eruption cloud moved north

Monitoring

- Okataina Caldera is monitored by 8 seismographs, 7 continuous GPS stations, lake monitoring and levelling.

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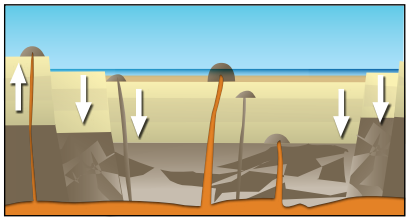
Volcano Fact Sheet

Taupo Volcano

Description

- This is a large caldera (collapsed) volcano which is partly filled by NZ's largest lake, Lake Taupo
- It can be termed a 'supervolcano' and is the most frequently active and productive rhyolite caldera in the world.



▲ Lake Taupo is a **caldera volcano** - a volcano that has collapsed into itself, often filling with water to form a lake. Lake Taupo has had at least two seperate collapses.

▶ Lake Taupo looking South.

Maori Name

- *Taupo* from *Taupo-nui-a–Tia* meaning 'the great cloak of Tia'. In Maori mythology Tia discovered the lake.

Features

- In 1998 a mini submarine called JAGO was used to explore the most recently active vent on the lakebed and found hot water jets. See:

http://www.minerals.co.nz/jago/jago_index.html

- Layered cliffs of light coloured ignimbrite rock, looser tephra (pumice and ash) and evidence of old shorelines are found around the lake.

Type

- It is an active caldera volcano created by collapse of the ground surface due to emptying of the magma chamber in huge eruptions
- It produces viscous rhyolite magma and has less frequent but more violent eruptions than cone volcanoes.

Cause

- Taupo was created by subduction of the Pacific Plate below the Australian Plate.
- The Earth's crust is stretched and thinned in the entire Taupo Volcanic Zone by movement of the plates.
- A magma chamber is located between 6 and 8 km below the lake floor.

Eruptive History

- Taupo Volcano began erupting about 300,000 years ago.
- The present day caldera was created by an eruption about 27,000 years ago called the Oruanui eruption.
- Between the Oruanui eruption (27,000 years ago) and the Taupo eruption (1800 years ago) there were at least 26 much smaller eruptions which formed lava domes and spread pumice and ash over nearby areas.

Eruptive material

- 99% of the material erupted from Taupo is pumice and ash which has exploded violently to form pyroclastic ash falls and flow deposits.
- When the flow deposits are hot enough they become re-melted to create a rock type called welded ignimbrite.
- The remaining 1% of the magma has lost enough gas to flow rather than explode and forms small lava domes such as Mt Tauhara.

Last eruptive activity

- This was about 1800 years ago, and is called the Taupo Eruption.
- It is the most violent eruption known in the world in the last 5000 years.
- The eruption plume reached 50 km into the air, all of NZ received at least 1cm of ash and areas near the lake were covered in more than 100 m of pyroclastic flow.
- The flow spread up to 90 km from the vent and flowed over all local features except Ruapehu.
- It is possible that ash from this eruption was the cause of red sunsets recorded by the Romans and Chinese.

Other Volcanic Hazards

- Strong earthquakes causing ground deformation, these will precede a big eruption.
- Lahars of loose pumice and ash deposits flowing down rivers after eruptions.
- Deposits from the Taupo eruption blocked the lake outlet, raising the lake 34m above its modern level. When this blockage failed a catastrophic flood was released down the Waikato River.
- Increased activity in geothermal areas can be expected, with steam explosions.

Monitoring

- There are 7 seismographs and 6 continuous GPS stations, and lake levelling at 22 sites.

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