TAMAKI PAENGA HIRA
AUCKLAND MUSEUM

AUCKLAND WAR MEMORIAL MUSEUM

EDUCATION KIT
VOLCANOES

BACKGROUND NOTES

EQC
EARTHQUAKE COMMISSION
KŌMIHANA RŪWHENUA

TAMAKI PAENGA HIRA
AUCKLAND MUSEUM

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Also, to the many past staff of Auckland Museum and other organisations who contributed so heavily to previous projects that have been used extensively in the assembly of this kit. In particular to Bruce Hayward and Brian Gill, for their research and expertise as authors of the original "Volcanoes and Giants" kit, without whose efforts this current kit would not have been possible.

Finally of course thanks to EQC, the Earthquake Commission, whose funding support enabled the creation of the new "Volcanoes" exhibition.

EQC
EARTHQUAKE COMMISSION
KŌMIHANA RŪWHENUA

INTRODUCTION TO THE RESOURCE:

The education resources provided by Auckland War Memorial Museum focus on specific galleries or on specific exhibitions in those galleries. There are a small number of resources that were developed for exhibitions that are no longer present but which have been maintained on the website by popular demand.

Visiting education groups may book to request the following learning opportunities:

- Self-conducted visits based on supporting resource materials.
- Gallery Introduction with a Museum Educator or trained guide (approx 15 minutes), using resource materials. Longer gallery tours and Highlights Tours are also available.
- Hands-on activity session for school groups with a Museum Educator (approx 45–50 mins), using resource materials. Students have the opportunity to handle real or replica items from museum collections,

Sessions will be tailored to suit the level and focus of the visiting group.

ABOUT THIS EDUCATION RESOURCE:

This kit has been designed to meet the needs of a wide range of education groups.

The kit is in three separate sections and includes:

1. Teacher Background Material suitable for all levels
2. Curriculum Links from Pre-school to Adult [these are still under development]
3. Pre and Post Visit Activities and Gallery Activity Sheets

Some education services at Auckland Museum are provided under a contract to the Ministry of Education under the LEOTC programme and Ministry support is gratefully acknowledged.

BOOKING INFORMATION

All education group visits must be booked.

Phone: 306 7040 Fax: 306 7075

Email: schools@aucklandmuseum.com

Service charges apply to education groups depending on the level of service required.

Numbers and Adult/Child ratios:

Pre-school	1:3 or better
Y 1–6	1:6
Y 7–8	1:10
Y 9–13	1:30

All groups including Adult groups ought to be accompanied by their teacher or educator.

Adult/child interaction is vital to maximize the value of the museum experience. Group leaders need to have some background knowledge of what the students are expected to cover and they do need to participate in the introduction process on arrival. Knowing about the expectations of the class teacher and the museum will make the visit smoother for everyone.

www.aucklandmuseum.com

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introduction

New Zealand is a land of volcanoes and earthquakes. Volcanic activity has played a major role in shaping New Zealand since its earliest origins, around 500 million years ago.

Auckland City is built on an active field of small basalt volcanoes. Forty-eight have erupted within 29km of the city centre over the last 150,000 years. The most recent eruption, 600 years ago, formed Rangitoto Island at the entrance to the harbour. Another eruption within the Auckland region is by no means impossible.

In Maori tradition volcanoes are the work of Ruaumoko, the restless unborn child of Papatuanuku, the Earth Mother. In the 21st century we're still fascinated by volcanoes' violence and beauty. They remind us of the power of our planet — a power that can create and destroy. And, in New Zealand, for better or worse, we've chosen to build our greatest city here amongst them.

LAND AND IDENTITY IN TAMAKI: A Ngati Whatua Perspective

Extracted from a lecture by I.H Kawharu delivered 13 November 2001

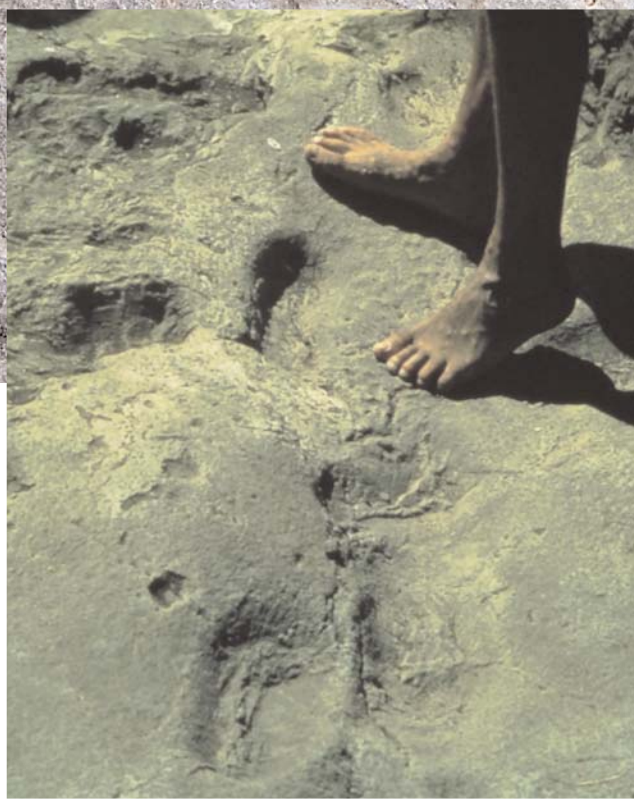
Ngati Whatua originated at an indeterminate point in time in the far north and made their way through the Hokianga down into the Kaipara. By the 16th and 17th centuries they were well established around the Kaipara harbour. In the early 18th century a serious altercation occurred in the southern Kaipara between the Waiohua of Tamaki and Ngati Whatua, which resulted in a heavy loss of life among Ngati Whatua. Honour required the account to be settled, and it was not long after that Ngati Whatua evened the score and took possession of the Tamaki Isthmus.

Following custom, Ngati Whatua invited the vanquished Waiohua to join forces with them, an invitation which was accepted and confirmed in a number of marriages. Under the leadership of Tuperiri, Ngati Whatua established themselves in the following decades throughout the isthmus, particularly along the axis between the volcanic cones Te Arapueru (Mangere Mountain) and Maungakiekie (One Tree Hill), Tuperiri's pa. Beyond this defence line Ngati Whatua managed the day-to-day control and exploitation of the whole isthmus and the adjoining harbours.

The viability of any economic organisation in pre-contact times was always likely to be dependent upon the outcome of successful political strategies. Thus Ngati Whatua had been ensuring their political control of the Tamaki Isthmus by establishing mutually beneficial alliances with the neighbouring Tainui and Ngati Paoa tribes on their southern borders.

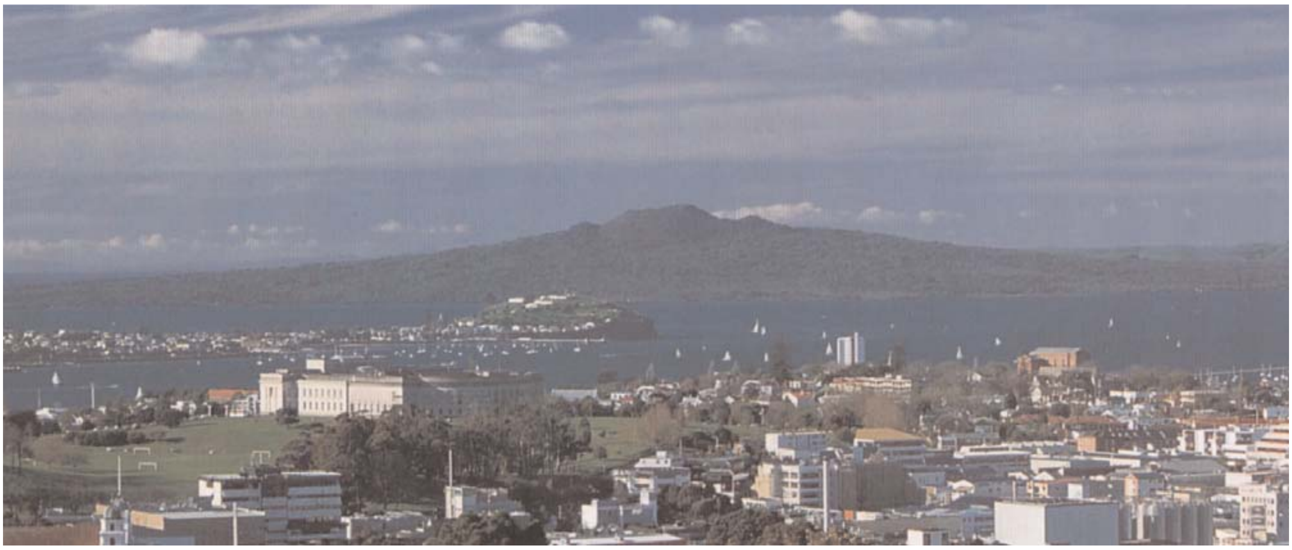
In the mid 1820's Ngati Whatua had been forced to seek refuge from the threat of their musket-armed cousins to the north, Ngapuhi, and found it with yet other kin in the northern part of the Waikato. Then when there was an evening in the balance of the musket-determined power, Ngati Whatua felt able to return to reoccupy their former settlements in the isthmus. But, of course they had incurred a substantial debt to Tainui and they settled it by the gifting of a number of blocks of land. One, for instance, was between Mount Hobson and the western slopes of Maungakiekie. They also received land from Ngati Whatua in the vicinity of Onehunga, the Orakei Basin, and Mt. Roskill.

A similar relationship to that with Tainui was also established with Ngati Paoa. Ngati Paoa, who occupied areas in the firth of Thames and Waiheke Island, received land from Ngati Whatua in something akin to a dowry, in the vicinity of the volcanic fortification, Maungarei (Mount Wellington) on the western bank of the Tamaki estuary in the late 18th century. Thus in addition to the day-to-day tactics of maintaining the internal integrity and safety of the tribe, chiefs also had to take care to maintain stable external relations by way of tuku rangatira – the granting of access to lands and associated resources to allies.



THE FOOTPRINTS

According to tradition, on the day Rangitoto erupted, 600 years ago, the people living on neighbouring Motutapu Island had gone to the mainland. When they returned, leaving these footprints in the newly fallen ash, their villages and gardens had been destroyed. Since the ash layer turned to stone it must have been many years before Motutapu was inhabitable again.

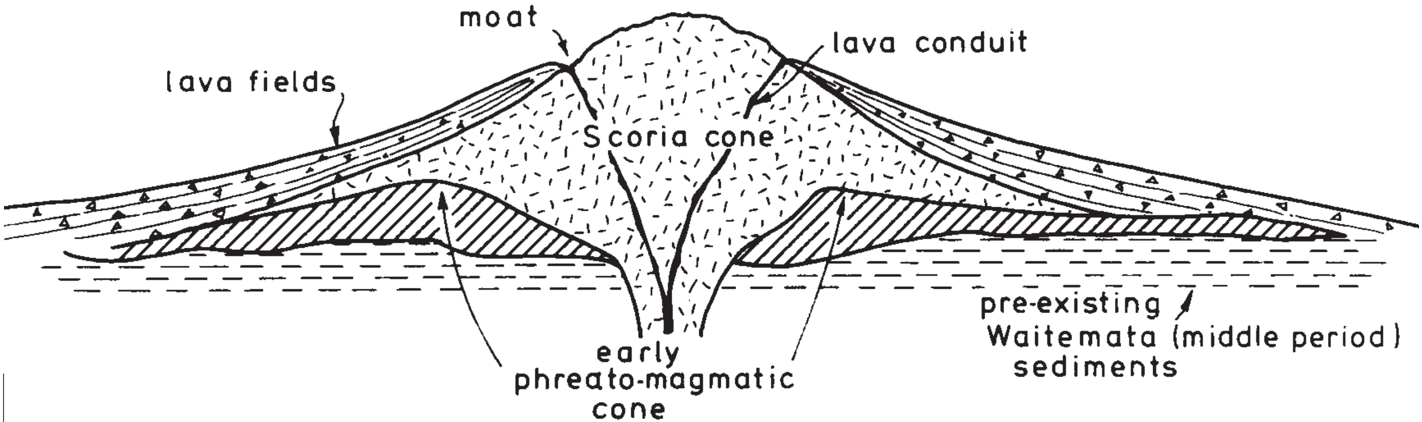


Rangitoto PHOTO: L O KERMODE

RANGITOTO — Symbol of Auckland

Rangitoto is Auckland's youngest and largest volcano. Its graceful, symmetrical shape and location in the middle of Waitemata Harbour make it Auckland's best known and most-loved volcano. The 260m high peak is a steep sided scoria cone formed by the accumulation of scoria thrown out by fire fountaining from its large central crater. The two outer hills near the summit are remnants of earlier scoria cones that have been partially buried by the younger and larger central cone. The gentle, slopes that form most of Rangitoto are composed of numerous overlapping basalt lava flows that were erupted from near the top of the island and flowed down in all directions towards the sea.

Several methods of dating indicate that Rangitoto was volcanically active during one brief period of formation around 1400 AD. At this time Maori were living on Motutapu, a neighbouring island. They must have thought that the end of the world had come as



Cross section of Rangitoto

great fountains of water, ash and steam were thrown up from an eruption centre only four kilometres away. Their island was deeply buried under a thick blanket of ash, smothering their settlements and gardens, and making Motutapu uninhabitable for a while. Footprints fossilised in the ash are part of the "Volcanoes" exhibition.

Popular folklore in Auckland has it that Rangitoto erupted more than once, the last time being less than 300 years ago. However, this is not supported by traditional Maori accounts or scientific investigations.

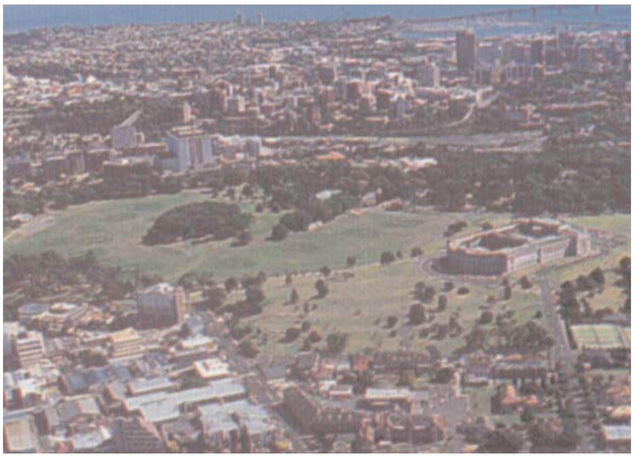
PUKEKAWA — AUCKLAND DOMAIN VOLCANO

Auckland Museum is built in the Auckland Domain on the edge of a volcano that erupted 100 000 to 150 000 years ago, making it one of Auckland's oldest volcanoes. It has a classic "castle and moat" layout. The volcano consists of a wide explosion crater containing a small central scoria cone.

The crater floor was initially a lake, that over thousands of years, filled with alluvium and plant remains to become a swamp. In European times the swampy floor has been drained and smoothed to form playing fields. A semi-circular tuff ring, formed by the accumulation of volcanic ash, surrounds the explosion crater.

The Domain duck ponds are fresh water springs, derived from ground water draining the crater lake and swamp. Water from the springs, together with overflow from the original crater lake and swamp, has, over thousands of years, eroded away the soft tuff ring rim on its northern side. The springs provided Auckland's first piped water supply in 1866. The Domain Wintergarden's fernery occupies a disused scoria quarry on the north side of the small central scoria cone.

The hospital on the opposite side of the volcano to the museum sits on the lava flow from Pukekawa.

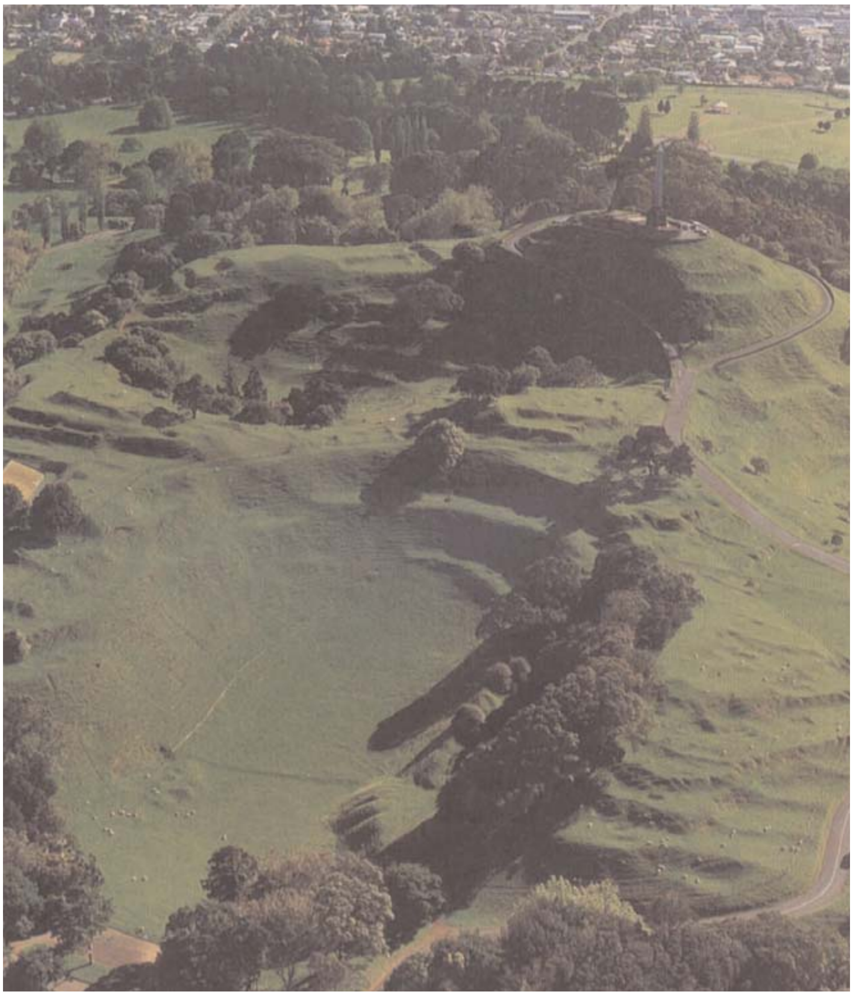


Auckland Domain Volcano PHOTO: BRUCE W HAYWARD

HUMAN OCCUPATION

Tamaki Herenga Waka ("Tamaki — desired by a hundred") is the Maori name for Auckland.

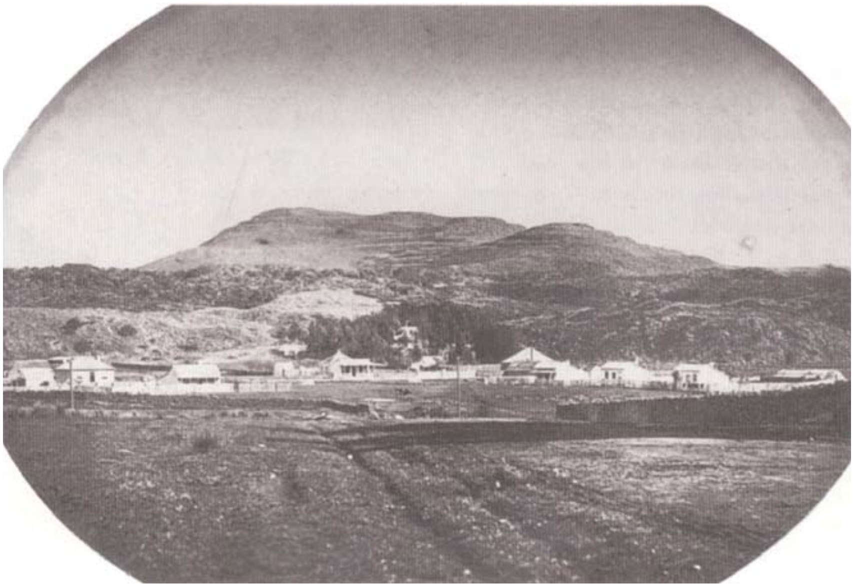
When Maori people arrived in Auckland they cleared the land for gardens, particularly choosing the fertile north-facing slopes of the volcanic cones. Later their descendants looked to more permanent settlements, so that parts of the hill slopes were terraced to provide family homes and storage pits as well as gardens. The claims for land grew stronger. Tribes and hapu sought wider occupation throughout Tamaki, its gravelly volcanic soil becoming famous for growing kumara. From about 1400 AD the higher volcanoes became defended hill forts, mostly to protect the store crops, while on the lower slopes terracing was extended to accommodate an increased population.



Maungakiekie (One Tree Hill) PHOTO: L D HOMER, GNS SCIENCE

European Use of Auckland's Volcanoes

The volcanic scoria cones and lava flows provided the only source of hard rock within easy reach of the growing settlement of Auckland. Over the years dozens of quarries have actively nibbled, bitten and gulped at our volcanic heritage to satisfy the city's endless demand for building aggregate, road metal and solid fill. Today about 20% (2 million tonnes) of New Zealand's aggregate for concrete and roads is quarried from Auckland's basalt lava flows. The largest quarry is still actively digging into



Maungawhau, 1860s (Mount Eden) PHOTO: J KINDER, 1860s, AUCKLAND MUSEUM LIBRARY several thick flows on the northwest side of Mt Wellington. In the late 19th and early 20th centuries, stone masons quarried and dressed basalt from Auckland's lava flows and used it to build houses, churches and other buildings. Many of these are still standing, such as St Paul's and St Andrew's churches in Symonds St, the Melanesian Mission Station at Mission Bay, and Kinder House at Parnell.

Kinder House PHOTO: J KINDER, 1863, AUCKLAND MUSEUM LIBRARY

AUCKLAND — City of Volcanoes

Living On A Hotspot

About 100km beneath Auckland City lies an active hotspot — an area of extra hot mantle. This hotspot creates batches of magma that rise through the crust and erupt at the surface, creating Auckland's basalt volcanic field, similar to Hawaii.

Forty eight volcanoes have erupted within 29km of Auckland Museum over the last 150 000 years. The Museum itself is built on the rim of the Domain Volcano. The most recent eruption, 600 years ago, formed Rangitoto Island at the entrance to the harbour. Another eruption within Auckland City can be expected at some time in the future.

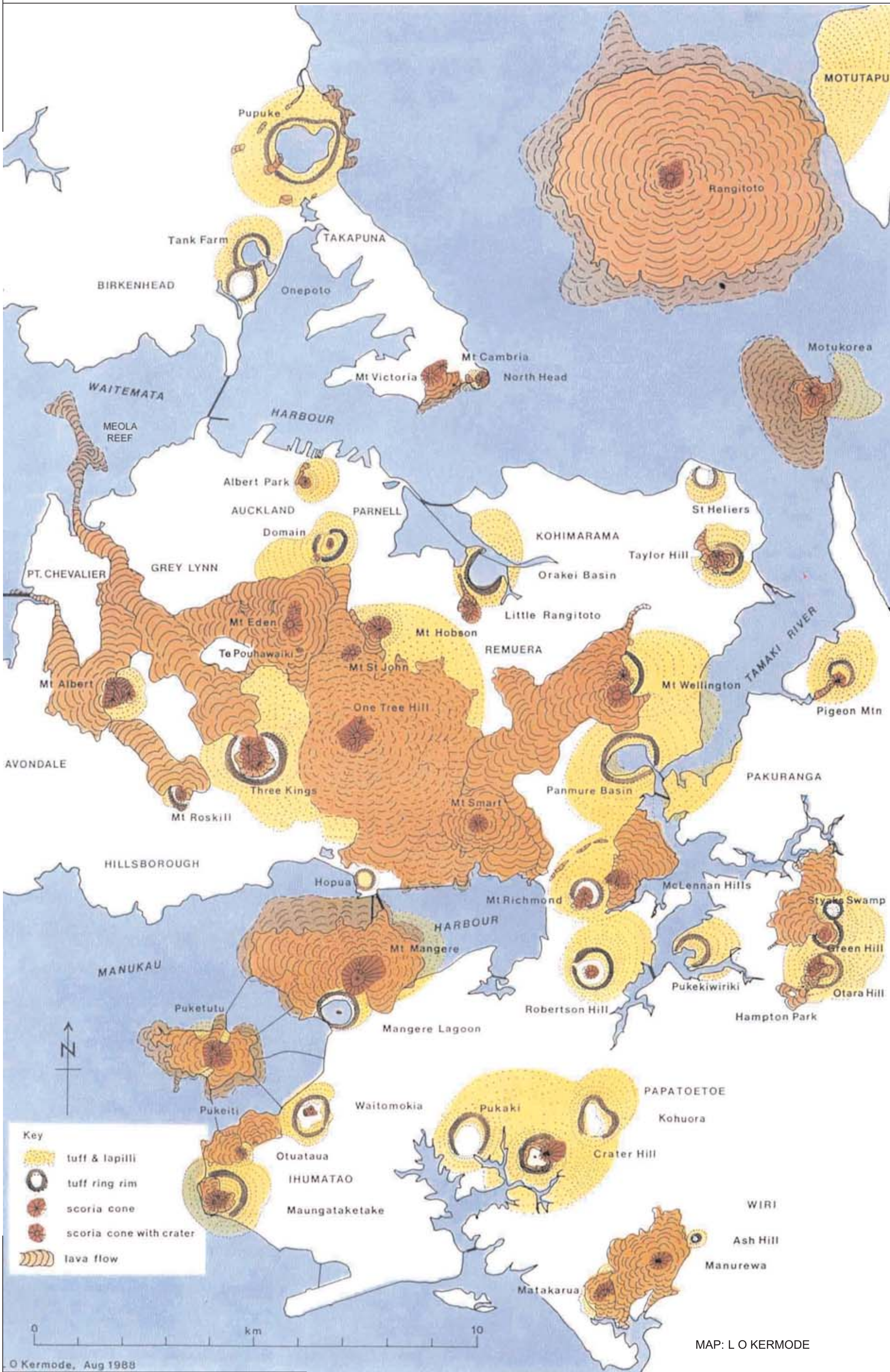
Mt Wellington Quarry PHOTO: BRUCE W HAYWARD

Protection of Auckland's Remaining Volcanoes

The scoria from Auckland's volcanic cones provides a cheap source of porous fill for construction sites, because the scoria is loosely compacted, easy to excavate, requires no crushing and is light and therefore cheap to transport.

Scoria quarrying has completely removed twenty of Auckland's forty scoria cones and almost all the rest have suffered irreparable damage. Although scoria

Scoria Quarry PHOTO: BRUCE W HAYWARD



MAP: L O KERMODE

Scoria Quarry PHOTO: BRUCE W HAYWARD

removal has now largely stopped on the isthmus and the North Shore, active quarries are still destroying our irreplaceable heritage of volcanic cones in the Manukau and Mangere areas.

Mt Smart was once a sizeable scoria cone. Nearly two million cubic meters of scoria has been removed and the whole site reshaped to form a sports stadium.

The destruction of Auckland's volcanoes has not gone unchallenged. There have always been concerned citizens and local body politicians who have fought to retain our volcanic heritage as public parks and domains.

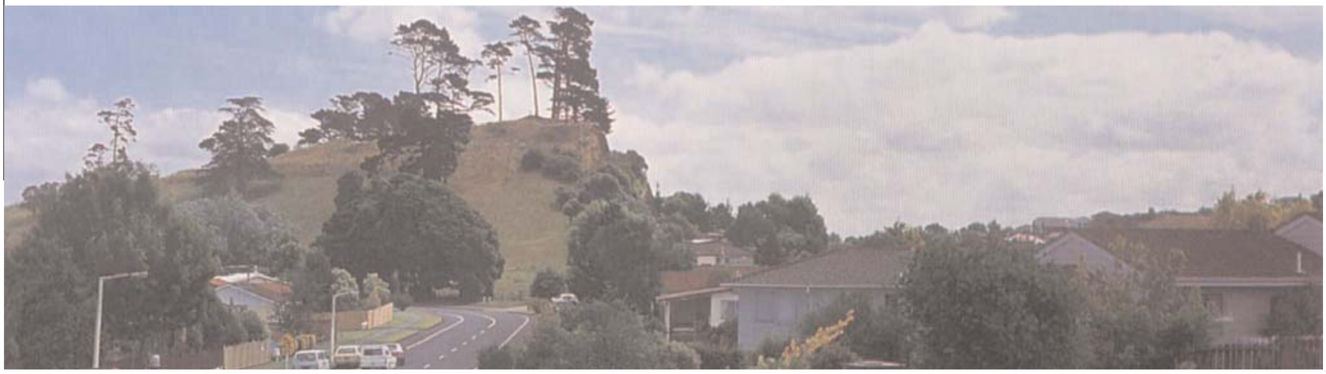
Mt Albert PHOTO: L D HOMER, GNS SCIENCE

Mt Albert is typical of many of Auckland's cones; privately-owned houses occupy one half and the other is public reserve. In recent years, the regional planning authority has strongly advocated the retention of the volcanic character of the city by imposing building height restrictions to protect important sight lines to and from our volcanic cones.

Today almost all remaining volcanic cones and craters on the North Shore and the Auckland Isthmus are protected within public reserves. Of the 18 volcanoes in the southern part of the field within Manukau City, only Mangere Mountain and the remains of Pigeon Mountain are currently protected in public reserves. Many of the remainder are now lost or soon will be.

Fossil Forests

Auckland's volcanoes erupted into a landscape of lush kauri and broadleaf forest. In the vicinity of each eruption, this forest was stripped, flattened, burned or buried. In several places today, fossilised remains of these forests tell the story of their destruction. For example, remnants of a mature forest, devastated by the explosive eruption of Maungataketake (Ellett's Mountain) volcano 27 000 years ago, are exposed near



Pigeon Mountain PHOTO: BRUCE W HAYWARD

Ihumatao, on the Manukau Harbour foreshore near Auckland Airport. Trunks and stumps of giant kauri and other trees, can be seen in the sand flats and adjacent cliffs.

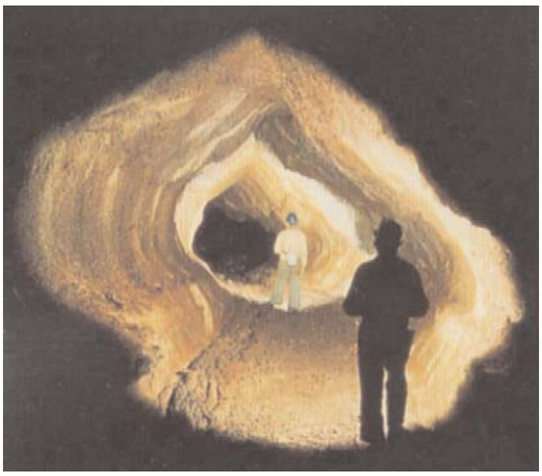
Takapuna Fossil Forest PHOTO: BRUCE W HAYWARD

The remains of an ancient forest that was engulfed by lava flows from Lake Pupuke volcano about 140 000 years ago forms the reef at the north end of Takapuna Beach on Auckland's North Shore. Several thin lava flows passed through the forest, and left hardened crusts around the boles of many trees. The tree trunks were incinerated to leave hollow moulds that now stand on the shore. Takapuna fossil forest is the best example in New Zealand of a forest engulfed and preserved by lava flows. Yet part of it was destroyed by the construction of a launching ramp and car park in the 1970s. The remainder still has no protection.

Ihumatao PHOTO: BRUCE W HAYWARD

How Lava Caves Are Formed

Lava caves are quite common overseas but in New Zealand they are present only in the Auckland volcanic field, where over 30 substantial caves are known. Wiri Lava Cave is New Zealand's longest



Wiri Lava Cave PHOTO: P CROSSLEY

(290m) and best preserved lava cave. It once carried lava from a small scoria cone called Wiri Mountain or Matukutureia. It has a classic “gothic arch” roof, where the pressure of the surrounding solidified lava has caused the ceiling to sag and a distinct apex to form. The ropey floor is the surface of the last lava flow that moved through the cave.

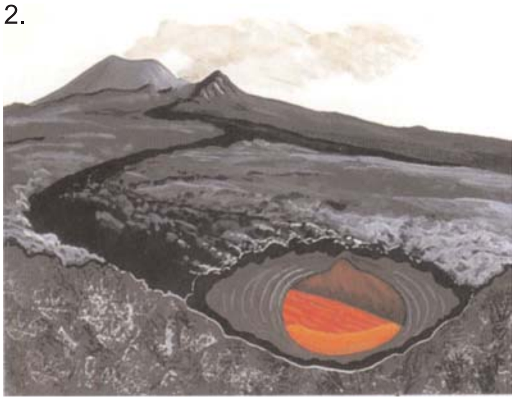
Hot gases usually fill the air gap between the top of the flowing lava and the cave roof. These extremely hot gases remelt the cooled basalt lining of the cave giving it a glazed appearance. Remelted lava dribbles down the walls and drips from the roof before cooling again to form small lava stalactites.

1. A river of basalt lava flows down a valley from the volcanic vent. It quickly develops a crust or envelope of cooled solid lava, with hot fluid lava still flowing along inside.
2. The crust thickens from the inside as cooling lava adheres to it. As the lava supply ebbs, the molten material continues to flow and drains out, leaving empty tubes, or *lava caves*.
3. Often the lava is supplied in pulses and refills part of an existing tube. The upper surfaces of these pulses within the tube may begin to crust over the leave surge benches of cooled lava to mark their maximum height on the cave wall.
4. When the supply of lava ceases, most drains out of the tube, though some is likely to congeal to form a flat floor to the lava cave.

Lava stalactites PHOTO: BRUCE W HAYWARD

1.

2.



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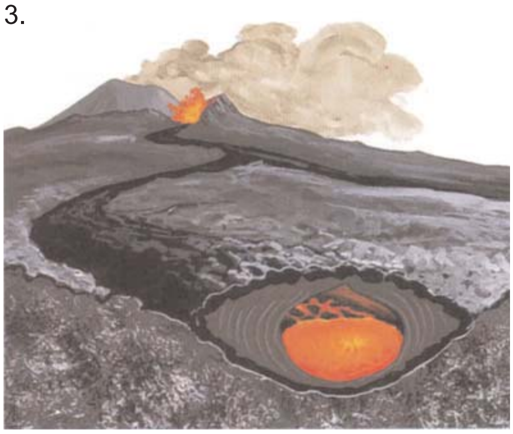

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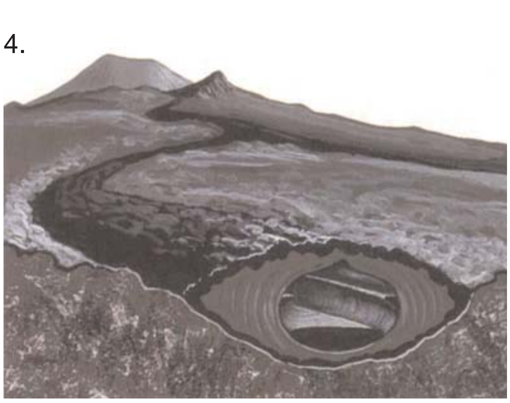


DIAGRAMS BY G COX

TYPES OF VOLCANOES

The size and style of volcanic eruptions vary tremendously, with a wide range of landforms and deposits produced.

What is a volcano?

A volcano is an opening (or vent) in the surface of the earth or sea floor from which very hot melted rock (called magma) emerges. This material is ejected in explosive bursts of gas and debris, as flowing fountains of lava spray and froth, and as rivers of molten rock. This volcanic debris piles up or spreads out to produce many different kinds of volcanic rocks and landforms, as illustrated throughout this exhibition.

Volcanoes Erupt in Three Plate Tectonics Settings

Plate Subduction Zones — Where the overlying lithosphere is melted to form new magma by the heat of water driven out of the subducting slab and by friction along the boundary.

Plate Spreading Zones — Where the crust is slowly pulling apart and magma from the underlying asthenosphere oozes to the surface and is erupted mostly as undersea pillow lavas.

Hot Spots — Where thermal "plumes" of extra hot mantle rise carrying low density magma up through the overlying crust to erupt at the surface anywhere within a tectonic plate. As the plate moves over this hotspot, a chain of volcanoes is produced eg Hawaii, Auckland.

Tuff PHOTO: BRUCE W HAYWARD

These hot spots in the mantle may exist for millions of years while the overlying lithospheric plate moves along above it. This may produce a line of extinct volcanoes that are progressively older as you move away from the presently active centre.

Explosive Eruptions and Tuff Rings

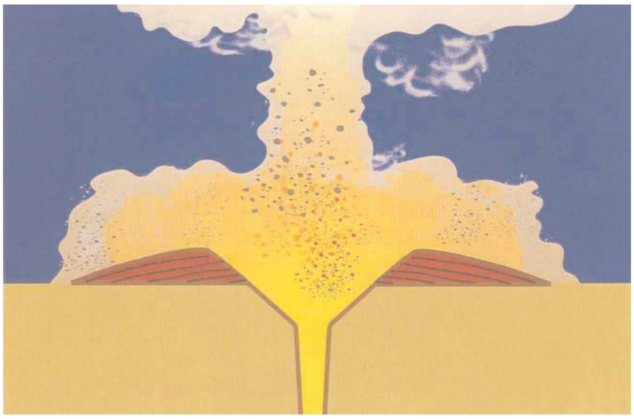


DIAGRAM BY N GUY

Explosive eruptions occur when rising magma encounters ground-water or sea water, which produce superheated steam. Gases dissolved in the magma are released explosively with the steam, and a mushroom-shaped cloud of shattered rock and ash (tuff) is thrown hundreds of metres into the air.

Ash and lapilli are volcanic particles ejected from the vent during an explosive eruption. Ash is fine-grained volcanic material whereas lapilli are pebble-sized lava particles (up to 6cm across). When ash and lapilli accumulate in layers on the ground they form a soft, compacted rock called *tuff*. Lithic tuff consists of broken-up fragments of the underlying sandstones and mudstones that were blasted out to clear the throat of the volcano during early explosive eruptions. These fragments are usually mixed with basaltic ash or lapilli and accumulate in layers to form the tuff rings around the explosive craters. Fine ash may persist as a thin mantle for several kilometres downwind from the vent.

Auckland's Volcanoes

Three styles of eruption were involved in the building of Auckland's volcanic field. Each has produced its own type of rock and landform. While some of

Auckland's volcanoes were created by only one style of eruption, many were created by a combination. The style of eruption at any particular time depends on how much gas is dissolved in the magma, the rate of magma upwelling, and whether it comes in contact with water.

Most of Auckland's volcanoes start life with a series of explosive eruptions that clear the throat and create a wide, shallow explosion crater, up to 1km across and 100m deep. The debris from the collapsing ash eruption column, along with material blasted out horizontally, builds up as a low circular rim (called a *tuff ring*) around the crater. Pukaki Lagoon, near Auckland Airport, is one of Auckland's best preserved explosion craters with surrounding tuff ring.

Pukaki Lagoon PHOTO: BRUCE W HAYWARD

Each volcano is formed during one eruption of just a few days duration, or a short sequence of eruptions, lasting no longer than a few years. Once eruption has ceased, the magma in the subsurface plumbing solidifies so the volcano never erupts again.

The magma that feeds Auckland's volcanoes originates from a very hot upwelling portion of the asthenosphere some 100km beneath Auckland. Periodically a large "batch" of molten magma develops, becomes buoyant and rises up through the denser overlying lithosphere and erupts at the earth's surface to form a volcano. This type of magma is very hot (1100°C) and very fluid, so it rises quite quickly, reaching the earth's surface within several days to a week.

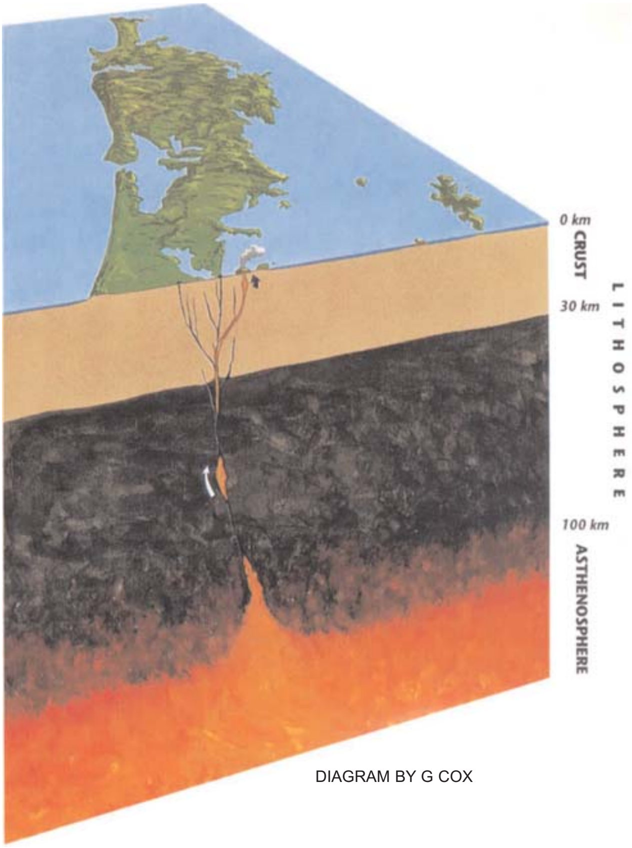


DIAGRAM BY G COX

Shapes of Volcanoes in New Zealand

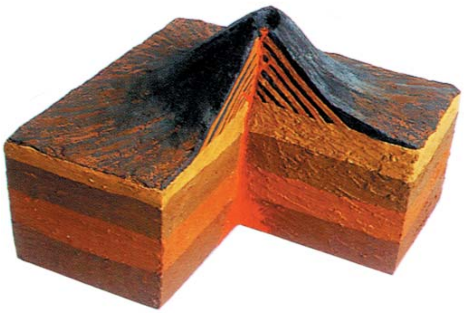
Hot liquid material deep beneath the earth's surface is called MAGMA. It is a mixture of liquid rock, solid rock crystals and dissolved gases. When magma is erupted from a volcano it is called LAVA.

The composition of the magma controls the type of volcano that forms.

MODELS MADE BY M K EAGLE, PHOTOGRAPHED BY K PFEIFFER

Scoria Cones — Scoria cones are small, steep-sided cones, usually with a deep central crater. They are formed by fire-fountaining eruptions of gas-rich basalt or andesite magma, which reaches the surface without coming into contact with water. Frothy lava thrown high into the air cools to form scoria which piles up in steep slopes. New Zealand examples are Ngaruahoe and in the Auckland (eg Maungakiekie and Maungawhau), Whangarei or Kaikohe lava fields.

Tuff Rings — A tuff ring is a shallow crater surrounded by a low rim of debris. Tuff rings are formed during explosive eruptions when gas-rich basalt magma comes in contact with groundwater as it rises to the surface. The water is heated to produce superheated steam. The resulting explosion sends a cloud of pulverised rock and ash into the air, settling in a ring hundreds of metres from the explosion. Tuff rings are a mixture of ash and lapilli (pebble sized lava particles). The Auckland Domain and Lake Pupuke are examples of Tuff rings.



Stratovolcano — Stratovolcanoes have the typical cone-shape usually associated with volcanoes and are often surrounded by a wide, gently sloping ring plain composed of volcanic mudflow (lahar) deposits. They are large cones built up of andesite lava flows interlayered with more explosively erupted ash and coarse debris blown out of the crater. Because andesitic and dacitic lava is more viscous, the stratovolcano has steeper sides than a shield volcano.

New Zealand examples are Mt Taranaki and Mt Ruapehu.

Caldera Volcano — A caldera volcano is a huge basin-like depression formed by the collapse of the roof of a gas-rich rhyolite magma chamber that has been emptied by huge explosive ignimbrite or ash eruptions. New Zealand examples include Lake Taupo and Lake Rotorua.

Lava Dome — A lava dome is a steep-sided rounded hill or mountain formed when thick, gas-poor rhyolite or dacite lava is squeezed upward and outward around the vent, like toothpaste or firm toffee. New Zealand examples include Mt Ngongataha and Mt Maunganui.

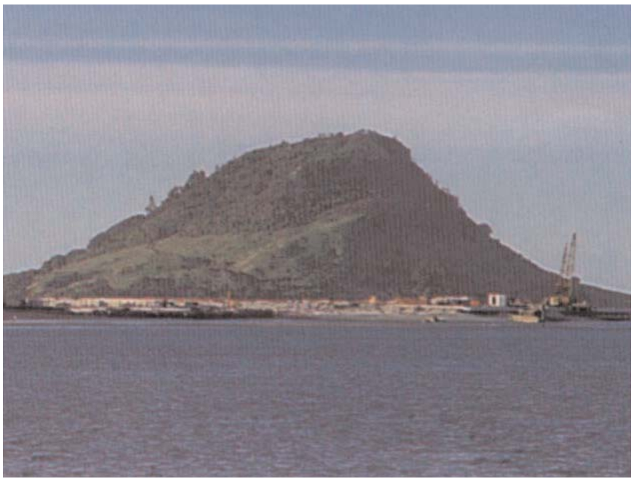
Shield Volcano — A shield volcano is a broad, gently sloping volcano build up from numerous very fluid basaltic lava flows producing very gentle flanks. They are made up almost entirely of lava flows. The flows are extruded in relatively quiet eruptions from fissures or craters near the summit. Rangitoto is an Auckland example. Other examples in New Zealand are the extinct Lyttelton and Akaroa volcanoes, near Christchurch. Shield volcanoes are some of the largest volcanoes on Earth.

Mauna Kea in Hawaii being the largest, rises nearly 9km from the floor of the Pacific Ocean, making it the tallest mountain on Earth. It is a huge basalt shield volcano that erupted over a hot spot in the underlying mantle.

Lake Rotorua caldera volcano PHOTO: L D HOMER, GNS SCIENCE

Mt Ruapehu stratovolcano PHOTO: BRUCE W HAYWARD

Mt Pinatubo PHOTO: IAN SMITH



Mt Maunganui dome PHOTO: L D HOMER, GNS SCIENCE

Mauna Kea, Hawaii PHOTO: BRUCE W HAYWARD

Mt Pinatubo, Philippines, is a stratovolcano on the Pacific Ring of Fire. Its huge eruptions of ash high into the atmosphere in 1992 have been blamed for recent changes in the world's climate.

Other famous examples include Mt Fuji in Japan, Mt Etna in Sicily and Mt Vesuvius in Italy.

The great San Francisco earthquake of 1906 was just one of the larger earthquakes that occur every year on the Pacific Ring of Fire. These quakes are caused by the enormous collision forces between the crustal plates on this zone.

Fire Fountains and Scoria Cones

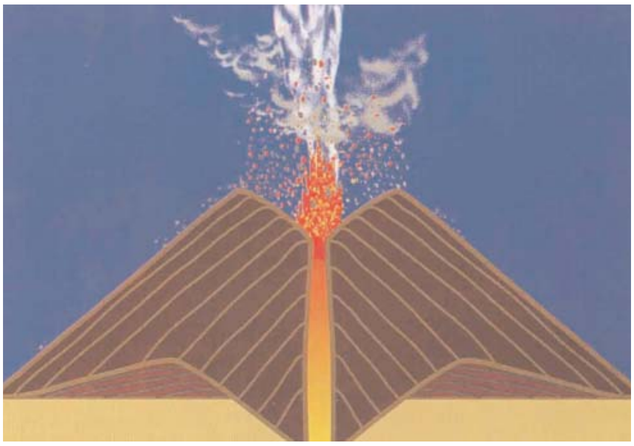


DIAGRAM BY N GUY

Fire fountaining occurs when gas-rich magma reaches the surface with out coming into contact with water. The gas is released quickly, creating frothy lava that is periodically thrown from the vent as brightly glowing fragments.

The frothy fragments accumulate around the vent to form a steep-sided cone of lava spatter called *scoria*. The scoria cones are typically steep-sided, with slopes close to 33° being determined by the angle of rest of loose scoria. They rise to heights of up to 100m and generally have a deep central crater, as seen at Mt Eden. Scoria cones are the features most commonly recognised as volcanoes in the Auckland area.

Scoria is the solidified, irregularly-shaped, red-brown to black basaltic lava froth, produced by fire fountaining. It is full of holes called vesicles, which were formed when gas bubbles in the liquid lava were trapped as the lava solidified.

Scoria PHOTO: BRUCE W HAYWARD

Volcanic bombs are blobs of hot lava which are thrown from a vent during a volcanic eruption. Spindle bombs like this one from Mt Mangere, spin and solidify during flight to attain their aerodynamic shape.

PHOTO: K PFEIFFER

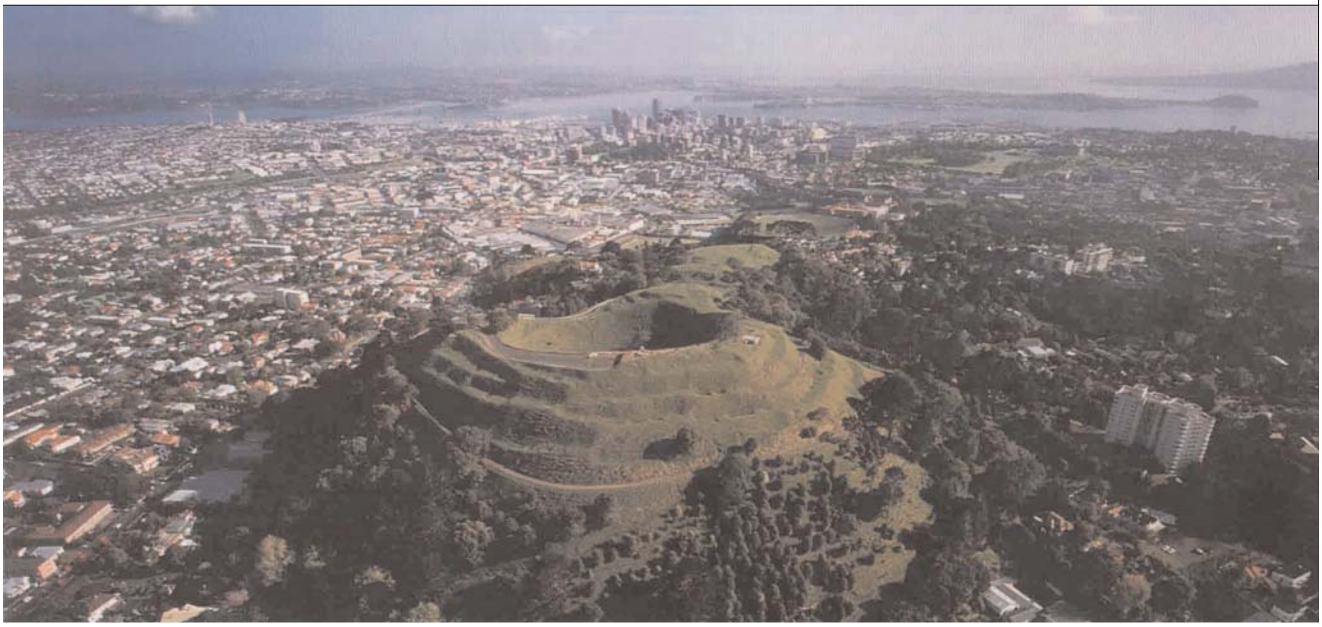
TYPES OF LAVA AND MINERALS

Ignimbrite Eruptions in New Zealand

In the last one million years there have been 20 to 30 huge ignimbrite eruptions from at least seven caldera volcanoes in the Rotorua-Taupo region in the centre of the North Island. These eruptions have spread ignimbrite, pumice and ash over vast areas of northern New Zealand and the Pacific Ocean. For several million years before this the Coromandel Range and Great Barrier Island region was similarly overwhelmed by ignimbrite eruptions.

Hinuera Stone

PHOTO:
BRUCE W HAYWARD



Maungawhau (Mt Eden) PHOTO: L D HOMER, GNS SCIENCE)

Hinuera Stone is an unwelded ignimbrite with large pumice fragments in a matrix of glassy ash and small scattered crystals of quartz. This ignimbrite is widely used in New Zealand for stone walls and cladding. It has been quarried since the 1950s from an ignimbrite that erupted 750 000 years ago from the Mangakino area, central North Island.

The old Dominion Museum building, Wellington

PHOTO: BRUCE W HAYWARD

A welded ignimbrite near Putaruru was quarried commercially as a building stone from the 1930s to 1950s. The old Dominion Museum building, in Wellington, is the most substantial building made of Putaruru Stone.

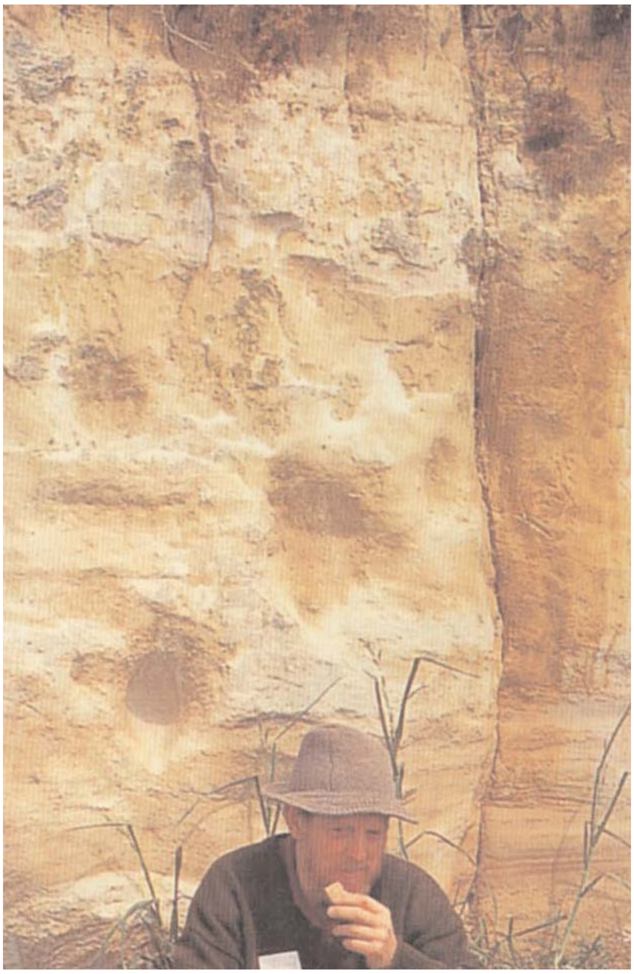
Ignimbrite Deposits

Hot ignimbrite flows sweep outwards and deposit thick sheets of pumice and ash over large areas near the vent (up to 30km away), and thinner veneers further away (50–200km distant). These flows cool rapidly around their outer margins to form unwelded ignimbrite rocks. The inner parts of thicker flows retain sufficient heat to soften the pumice and ash, which fuse together to form a hard, welded ignimbrite when the flow stops.

Ignimbrite sheets deeply bury much of the central North Island. Younger, less eroded sheets form enormous plateaus, such as the Mamaku Plateau, erupted from Lake Rotorua caldera 140 000 years ago, and the Kaingaroa Plateau, erupted from the Okataina caldera 150 000 years ago.

Kaingaroa Plateau PHOTO: L D HOMER, GNS SCIENCE

The three meter thick deposits of rhyolitic ash on the banks of the Tamaki Estuary, near the heart of Auckland, was erupted more than a hundred thousand



Rhyolite ash, Tamaki Estuary PHOTO: BRUCE W HAYWARD

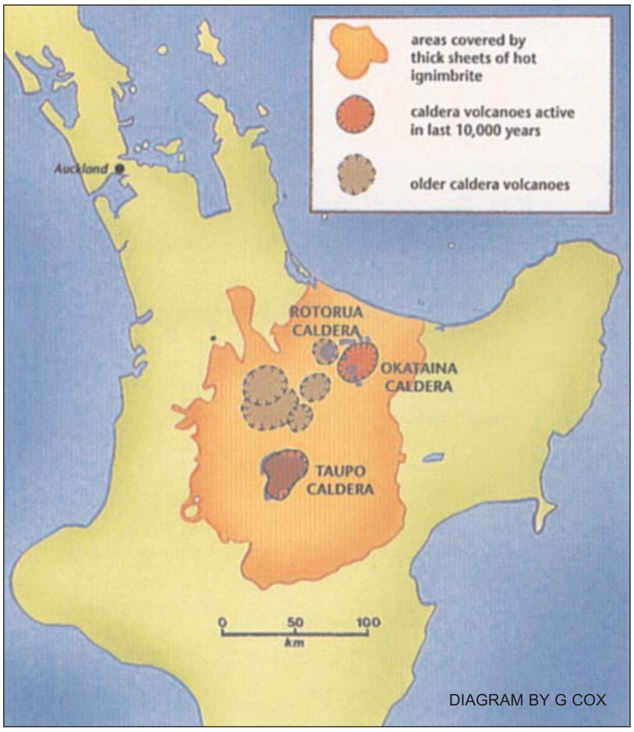


DIAGRAM BY G COX

years ago, from a caldera volcano in the Taupo-Rotorua area. Baked vegetation beneath the ash layer indicates that it was still hot when it arrived. It is the distant portion of an ignimbrite flow that was so large that it blanketed the Auckland area within an hour of being erupted.

Lava Flows and Fields

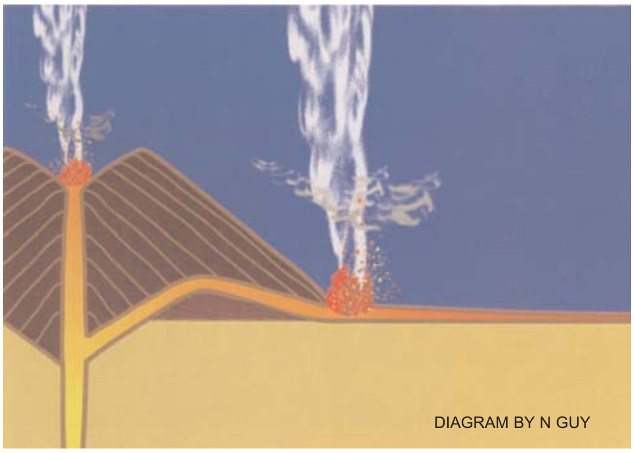


DIAGRAM BY N GUY

Lava flows develop when degassed magma rises in the vent and bursts out from the side of the cone or breaches the crater rim. Only about half of Auckland's volcanoes produced lava flows. Most of these flowed like rivers down existing valleys, but where the outpouring of lava was considerable, the valleys filled and the lava spread out as extensive sheets around the cone (eg One Tree Hill, Mangere Mountain). There are two types of flow in the Auckland field — pahoehoe and a'a.

Pahoehoe lava flow, Mangere Mountain PHOTO: BRUCE W HAYWARD

Pahoehoe lava is very fluid and can flow rapidly (up to 10km/hour). These flows have smooth, ropy surfaces wrinkled into low curved ridges, like this flow from Mangere Mountain. As pahoehoe lava cools it may change into a flow with a'a characteristics.

A'a lava, Rangitoto PHOTO: L O KERMODE

Meola Reef PHOTO: L D HOMER, GNS SCIENCE

A'a lava is quite thick and viscous, because it is extruded at a cooler temperature than pahoehoe. It oozes out quietly and sluggishly within a carapace of broken chilled lava blocks, to form thick flows near the vent, with very rough, rubbly surfaces, like this Rangitoto flow.

Meola or Te Tokaroa Reef is the end of the *longest lava flow* (10km) in the Auckland field. It was extruded from Three Kings volcano and flowed down an existing valley and out into the Waitemata Valley, almost reaching Birkenhead.

Basalt columns, old Mt Eden Prison Quarry PHOTO: L O KERMODE

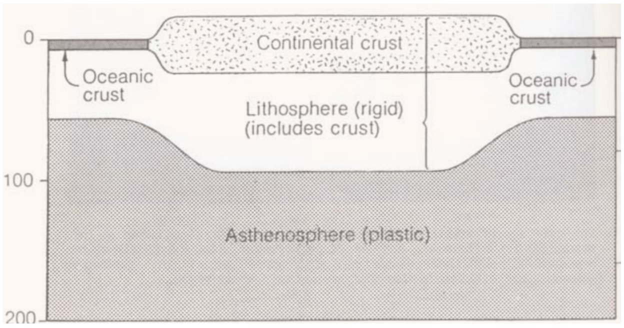
When Auckland's lava flows cooled they solidified to form a hard, dark grey, fine-grained rock called *basalt*. As lava solidifies it contracts and a regular pattern of fractures develops producing prominent basalt columns.

What is Magma and Lava?

Hot liquid material deep beneath the earth's surface is called *magma*. It is a mixture of liquid rock, crystals and dissolved gases. When magma is erupted from a volcano it is called *lava*. Magma that is full of dissolved gases usually explodes when it reaches the surface, blowing the lava into frothy fragments that are ejected into the air as *ash*, *pumice*, or *scoria*. Magma, that contains less dissolved gas is usually erupted as fluid lava flows.

A single eruption may expel only a dribble of lava or an enormous volume. Eruptions may last a few seconds to many years. The style of eruption depends on variations in the viscosity, gas content, and chemical composition of the lava and whether it comes in contact with water.

The inside of the earth is divided into a number of layers. The outer layer of solid rock is called the lithosphere, and is approximately 100km thick. Under this is the 250km thick asthenosphere which consists of extremely hot, partially melted material that flows like warm tar, in huge circular convective cells and drives the movement of the overlying plates around the earth's surface.



Cross-section of the earth showing Lithosphere and Asthenosphere — The lithosphere is topped by a thin oceanic crust and a thicker continental crust

Land under Stress

New Zealand's geological conditions are complex. The country lies astride the boundary between the Australian and Pacific Plates. In some places one plate is sliding beneath the other, while elsewhere the two are pushing past each other. Most of the geographic features we recognise as characteristic of New Zealand — its elongate shape, the Southern Alps and the Volcanic Plateau — are direct results of this setting.

BASALT V GRANITE

The two most common rocks at the Earth's surface are basalt and granite. Both were originally liquids. If basalt were milk, granite would be cream — always floating to the top.

At subduction zones where two plates collide, the lighter granite will almost always ride up over the heavier basalt, which is forced back down into the fiery earth where it came from.

Granite is magma that never made it far enough through the volcanic process to be erupted. Instead, it cooled and slowly solidified — allowing time for its big crystals to form.

Granite lies underneath every continent in the world. Its very high silica levels make it tough, lighter than basalt, and durable.

Because it does not get recycled, some granite is very old. The granites around Karamea formed approximately 380 million years ago, making them some of New Zealand's oldest rocks.

Basalt is a dense rock, rich in iron and magnesium. It's a kind of rock version of Selley's "no More Gaps". When two tectonic plates are forced away from one another by convection currents beneath, basalt fills the gaps and cools to make a new solid piece of tectonic plate.

UNDERWATER VOLCANOES

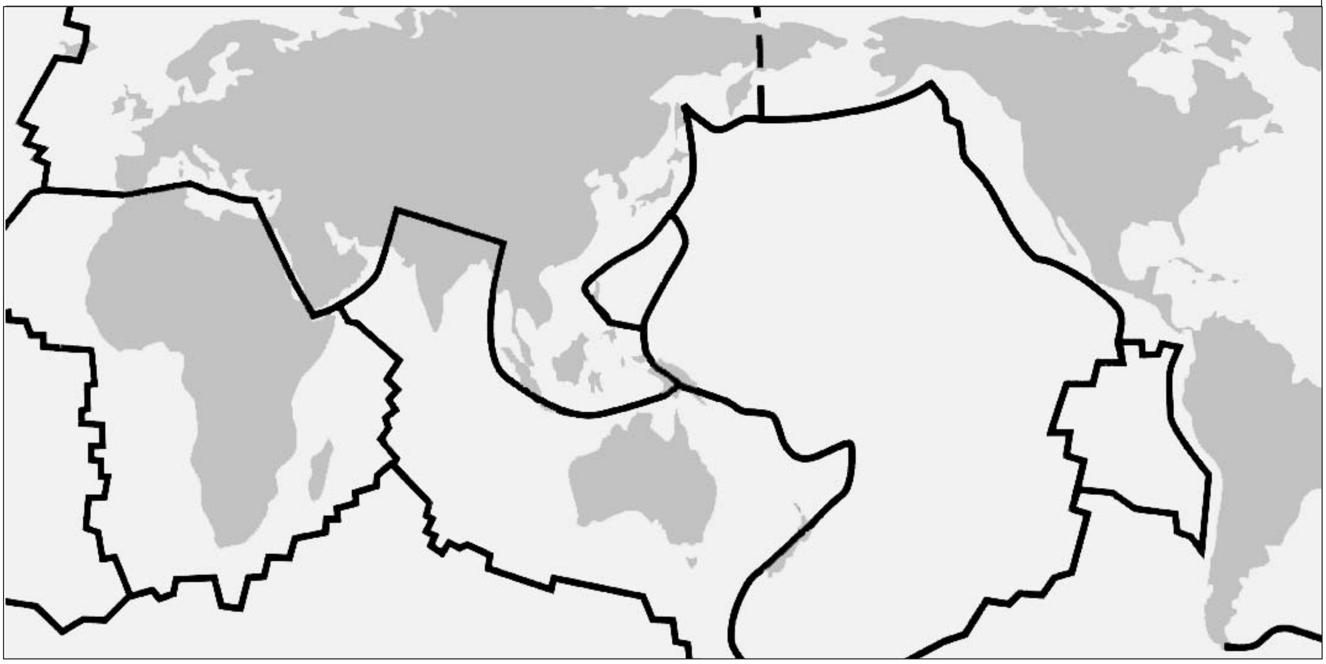
Seventy percent of Earth's volcanoes are not "on earth" at all — they're underwater.

There are three types of underwater volcanoes: hot spot volcanoes like the Hawaiian volcanoes before they rose above sea level; subduction volcanoes where tectonic plates are colliding; and volcanoes at "mid-ocean ridges", where new ocean floor is being continually created.

In Maori myth the great navigator Ngatoroirangi summoned fire from Hawaiki when he was freezing to death on the slopes of the mountains of the central North Island. His sisters sent him a taniwha of fire from Hawaiki, which travelled under the water and the earth, coming up to breathe at White Island and Rotorua before ending up at Taupo and Tongariro. Perhaps the straight line of underwater volcanoes to the northeast of New Zealand is also a marker of that epic underwater journey.

PLATE TECTONICS / CONTINENTAL DRIFT

The Earth's crust is broken into many fragments called tectonic plates. Plates are like plates of armour and are made up of a proportion of oceanic crust and a proportion of continental crust. These move at different rates. They spread apart, push past, override



World map showing the boundaries of tectonic plates. The arrows show the directions they move in. As the plates move, they pull apart, collide, grind past or dive beneath one another, the way luggage does on an airport conveyer belt.

and dive under each other, constantly moving the continents around the globe.

There are three main types of plate boundaries: divergent/spreading centres, convergent/ subduction zones and transform margins.

Upwelling in the mantle forms new oceanic crust, which then spreads apart. The crust ultimately gets recycled as it becomes subducted under more buoyant crust, like continental or younger, oceanic crust.

Sea Floor Spreading Zones

The magma reaches the Earth's surface through an opening between two tectonic plates, up to 5km under the sea surface in the middle of some ocean basins. It solidifies to produce new crust and pushes out the older crust symmetrically away from this "spreading centre". This produces a long chain of undersea volcanoes, also called a mid-oceanic ridge.

Subduction Zones

Old oceanic crust is heavy and dense. Over time, parts of it sink back into the mantle, creating a tectonic plate boundary as it slips under another piece of crust. Subduction of old oceanic crust can happen under continents, such as the South American west coast or under younger oceanic crust, such as in the Tonga-Kermadec area, just north of New Zealand.

As the crust is drawn back into the mantle, a deep trench develops at the point of subduction, where the sea can be up to 10km deep. A New Zealand example is the Hikurangi Trough, which is off the east coast of the North Island.

During subduction, sediment that has settled on the ocean floor is scraped off the subducting plate and gets plastered onto the edge of the upper plate. The compression causes friction between the two plates, which in turn causes earthquakes and pushes up mountains.

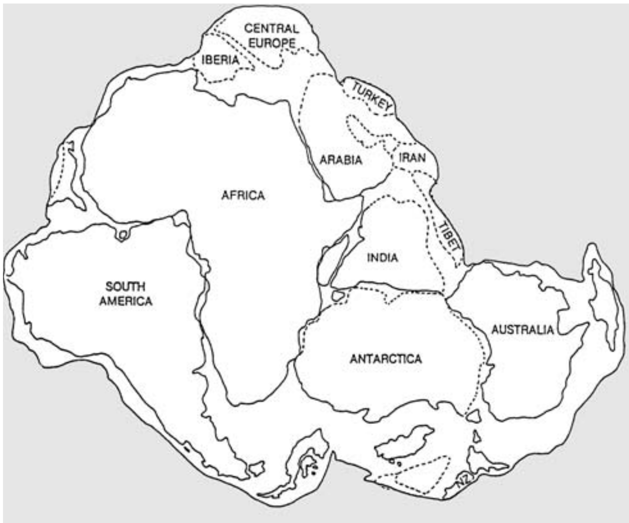
New Crust forming and spreading out from an upwelling in the mantle.

Once this oceanic crust sinks well down into the mantle, it starts to soften and become plastic again. But because there are traces of water in this crust, partial melting occurs and this extra hot material rises up as magma through the mantle and the over-riding crust. Once it reaches Earth's surface, it is erupted as lava to form volcanoes.

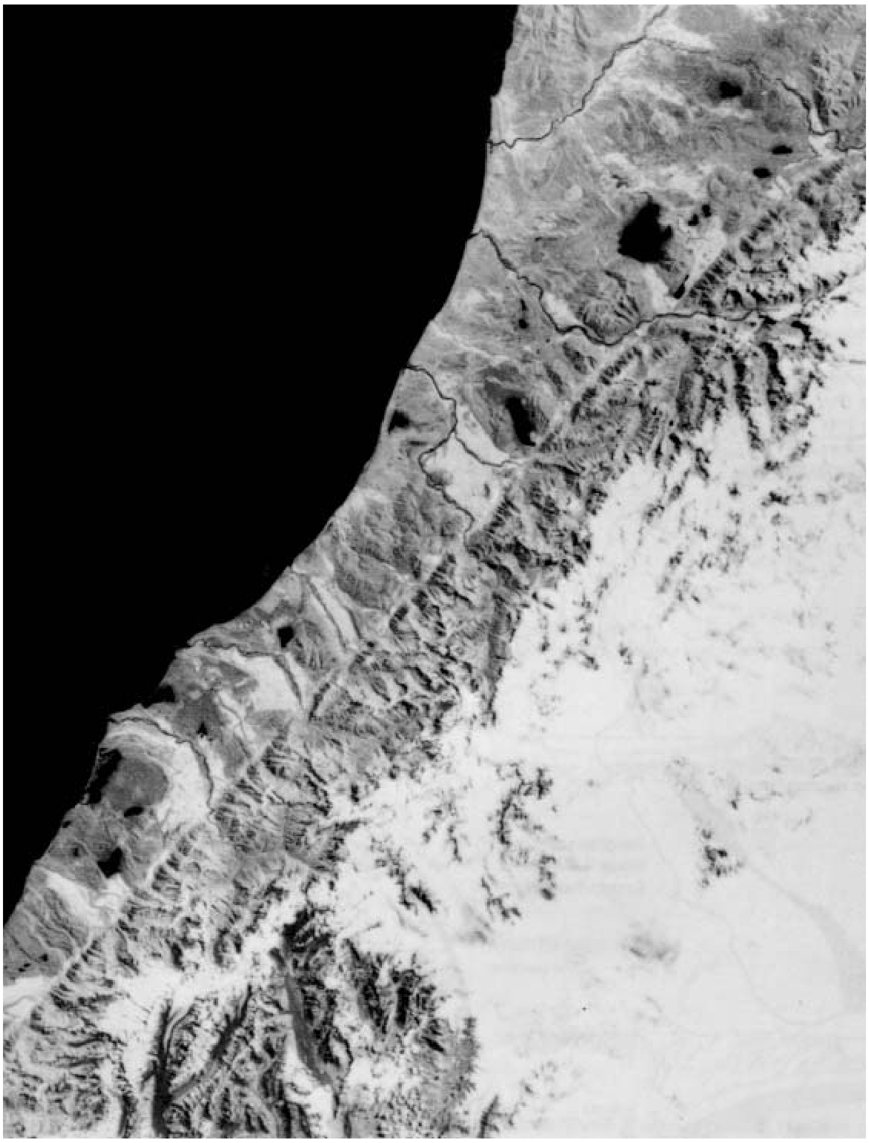
Transform Margins

Transform margins occur where 2 plates slide past each other, neither creating nor destroying oceanic crust.

An excellent example of a transform boundary is the Alpine Fault in the South Island, one of the longest natural straight lines on Earth.



Gondwana



Alpine fault from space

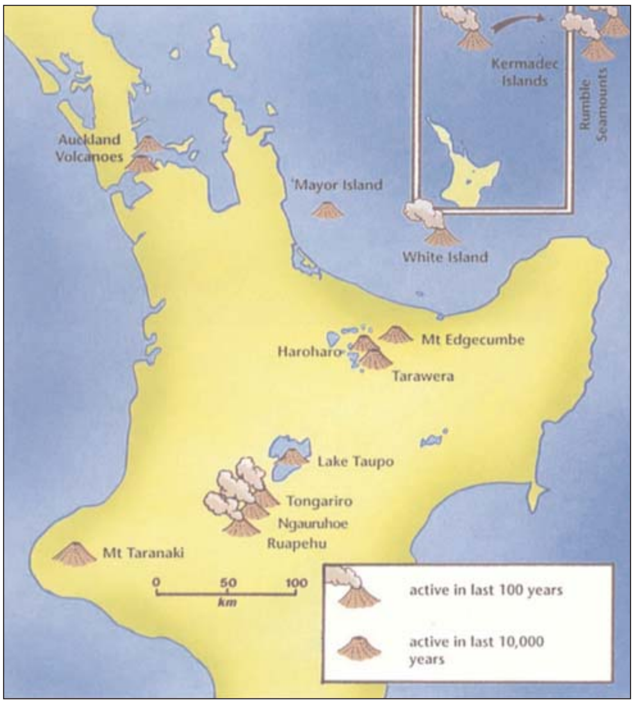
Plate Tectonics and Continental Drift

The land areas of the world have changed dramatically in the past due to the movement of the plates that make up the earth's surface.

The theories of continental drift and plate tectonics have revolutionised our understanding of the world in the last forty years. Detailed studies of the world's rocks and their magnetic history and age can now tell us the past movements of the world's continents over the last 600 million years.

Continental Jigsaw Puzzles

The remarkable close fit between the coastlines of Africa and South America was recognised in the 1850s, but it was not until 1912, that a German scien-



Active volcanoes in New Zealand DIAGRAM BY G COX

tist, Alfred Wegener, proposed the theory of "Continental Drift".

The continents fit together like a jig-saw puzzle or pieces of torn paper. Not only do the outlines of the torn pieces fit together but the printing on them (equivalent to rock types) also matches across the edges of the separate pieces.

Fossil Evidence for Continental Drift

The presence of fossils of a 250-million-year-old (Permian) seed fern, *Glossopteris*, in New Zealand, Australia, Antarctica, South America, Africa and India, provides evidence that these areas were once linked together as the ancient supercontinent, Gondwanaland.

The similarity of animals and plants in widely separated lands, both now and in the past, provided the first clues that continents may have drifted apart.

Active Volcanoes in New Zealand

Like other countries on the Pacific Ring of Fire, New Zealand is periodically rocked by earthquakes and pierced by volcanic eruptions.

All active volcanoes in New Zealand are in the northern half of the North Island and in our territorial waters offshore to the north. Five volcanoes have been active during the past 100 years — Kermadec Islands, White Island, Tongariro, Ngauruhoe and Ruapehu. Several underwater volcanoes off the Bay of Plenty (Rumble Seamounts) have also erupted in the last 100 years. Other volcanoes or volcanic fields that have erupted in the last 10 000 years and are still considered likely to erupt again are the Auckland field, Mayor Island, Mt Edgecumbe, Haroharo (near Rotorua), Tarawera, Lake Taupo and Mt Taranaki.

New Zealand Astride a Plate Boundary

Today the collision boundary between two of the world's plates runs along the length of New Zealand. In the north, the Pacific plate is being subducted beneath the Australian plate, producing magma that rises to the surface and erupts in a zone stretching northwards from Ruapehu. South of the South Island, the Australian plate is being subducted beneath the Pacific. This produces magma that has erupted to form Solander Island and a zone stretching to the south. Between the two volcano-producing subduction regions, is a region with no active volcanoes. Here the plates are largely moving sideways past each other along the Alpine Fault.

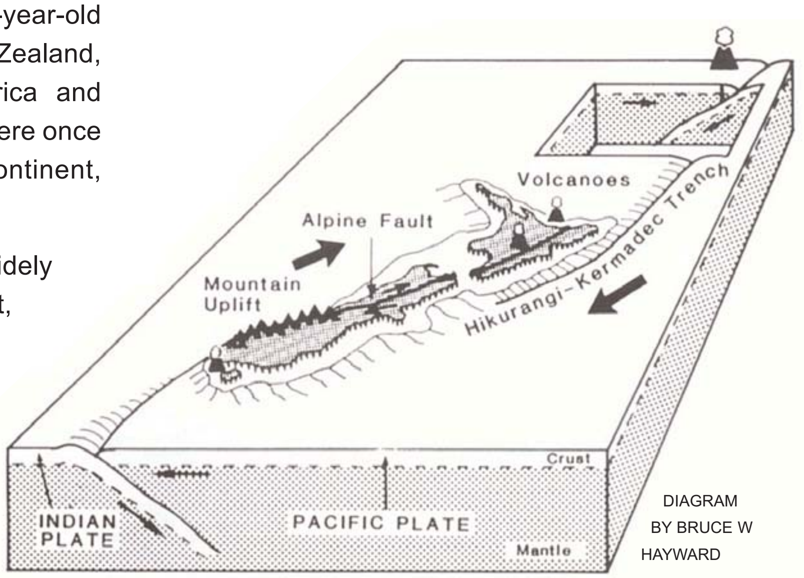
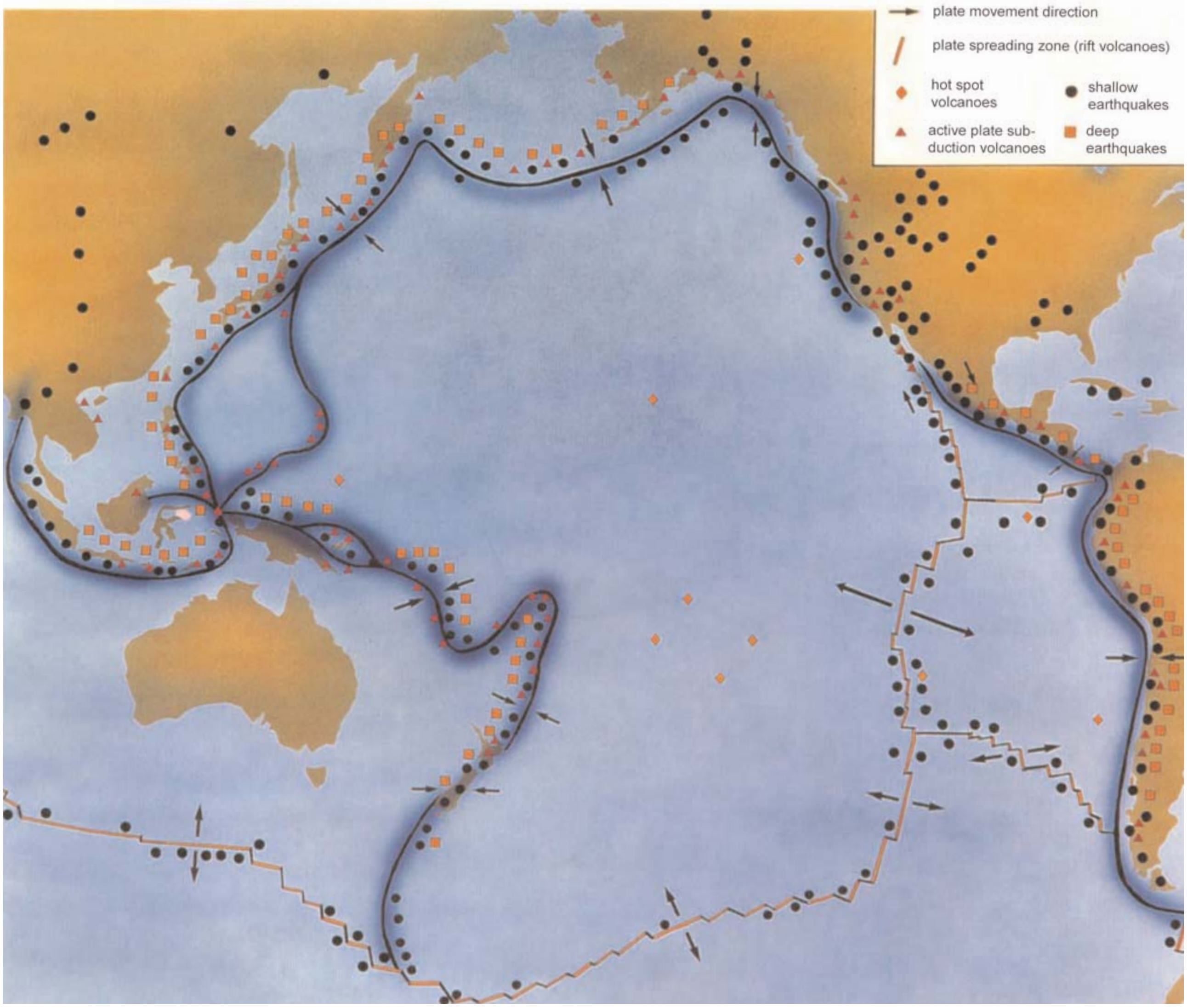
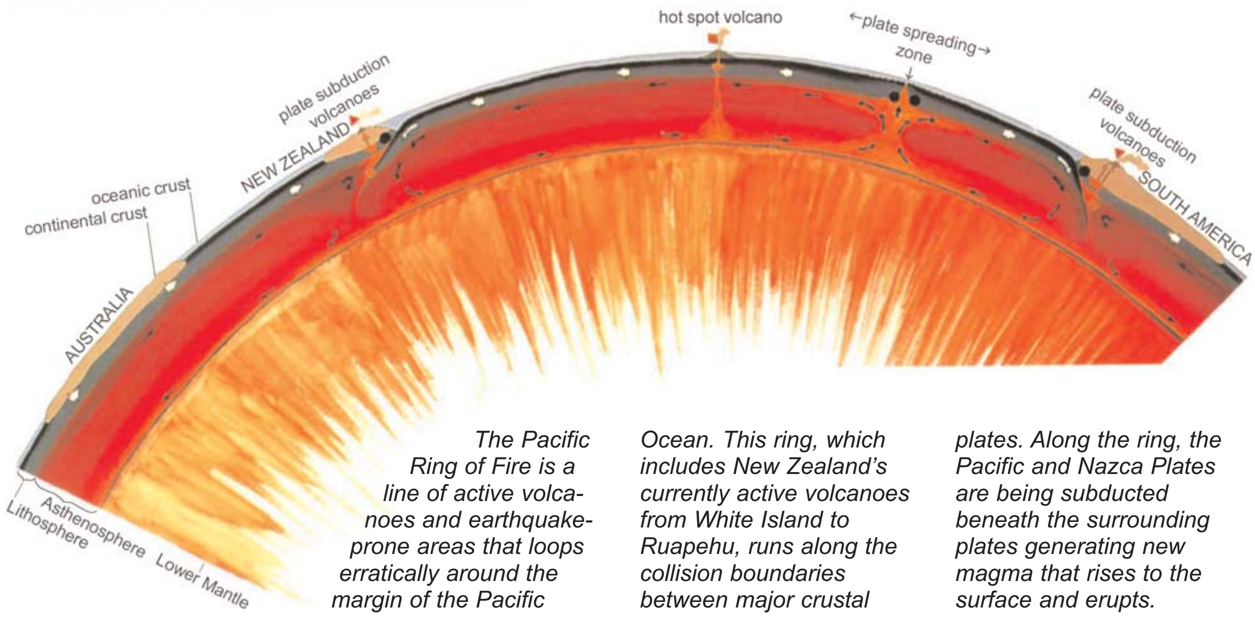


DIAGRAM BY BRUCE W HAYWARD

EARTH'S FIERY FURNACES — The Pacific Ring of Fire





The Pacific Ring of Fire is a line of active volcanoes and earthquake-prone areas that loops erratically around the margin of the Pacific Ocean. This ring, which includes New Zealand's currently active volcanoes from White Island to Ruapehu, runs along the collision boundaries between major crustal plates. Along the ring, the Pacific and Nazca Plates are being subducted beneath the surrounding plates generating new magma that rises to the surface and erupts.

The World's Largest Volcanic Eruptions

The eruptions of Mt Pinatubo in the Phillippines and Mt St Helens in the western United States have been the largest recent eruptions on earth. The eruption of Krakatoa in Indonesia has been the largest eruption in the last 200 years. But these have been small compared with the Taupo ignimbrite eruption in the centre of New Zealand's North Island 1800 years ago. This was the largest eruption on earth in the last 5000 years.

The Taupo-Rotorua region has been devastated many times in the last million years by large ignimbrite eruptions. Some such as the world's largest known eruption, from Lake Taupo 26 500 years ago, were up to ten times larger than that of 1800 years ago. The lake that formed was 141 metres above the present lake level.

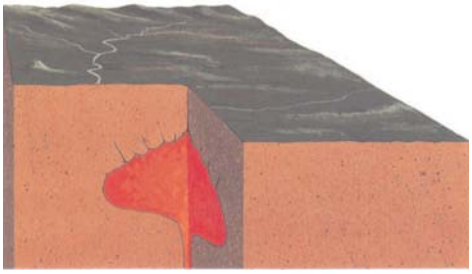
Bubbles and Bangs — Ignimbrite Eruption Mechanism

1. A large body of rhyolite magma forms a reservoir or magma chamber a few kilometres below the earth's surface.

2. Huge volumes of gas-rich pumice and ash are ejected into the air, powered by the release and expansion of volcanic gas. Light volcanic ash rises 50km into the atmosphere. The plume is blown sideways by the wind and ash falls to the ground over a wide area, downwind from the vent.

3. Lower, denser parts of the eruption column collapse, forming superheated clouds of gas, ash and pumice. These flow across the ground away from the vent at speeds of up to 1000km an hour, like horizontal snow avalanches. These are ignimbrite flows.

4. Ignimbrite eruptions are extremely large and rapid. The shallow magma reservoir empties in a matter of hours to days. The ground above collapses into the empty reservoir forming a giant crater, called a *caldera*. This may fill with water to become a lake.



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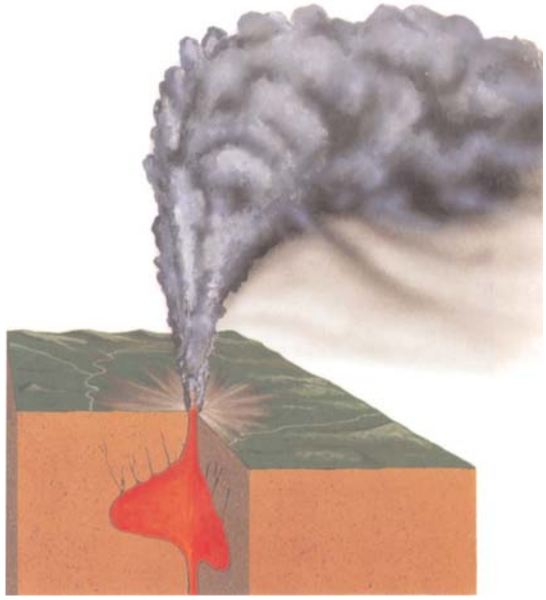

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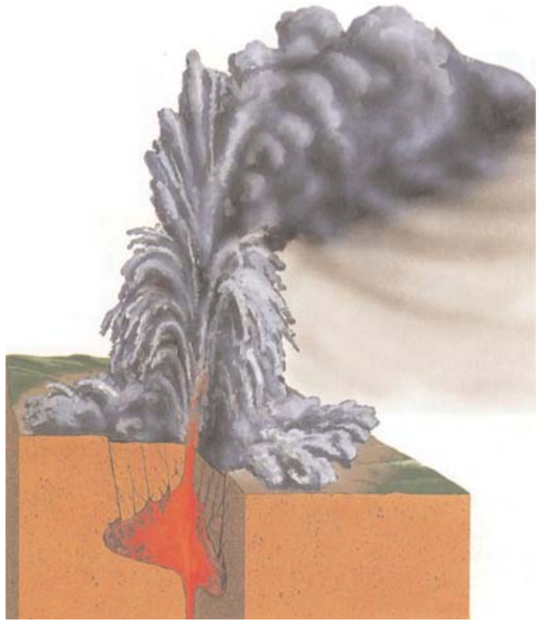

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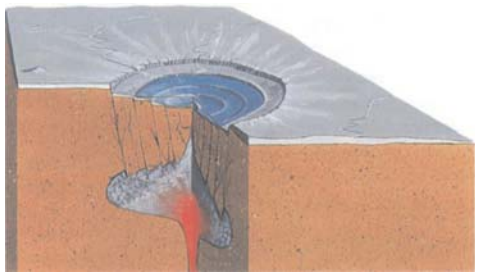

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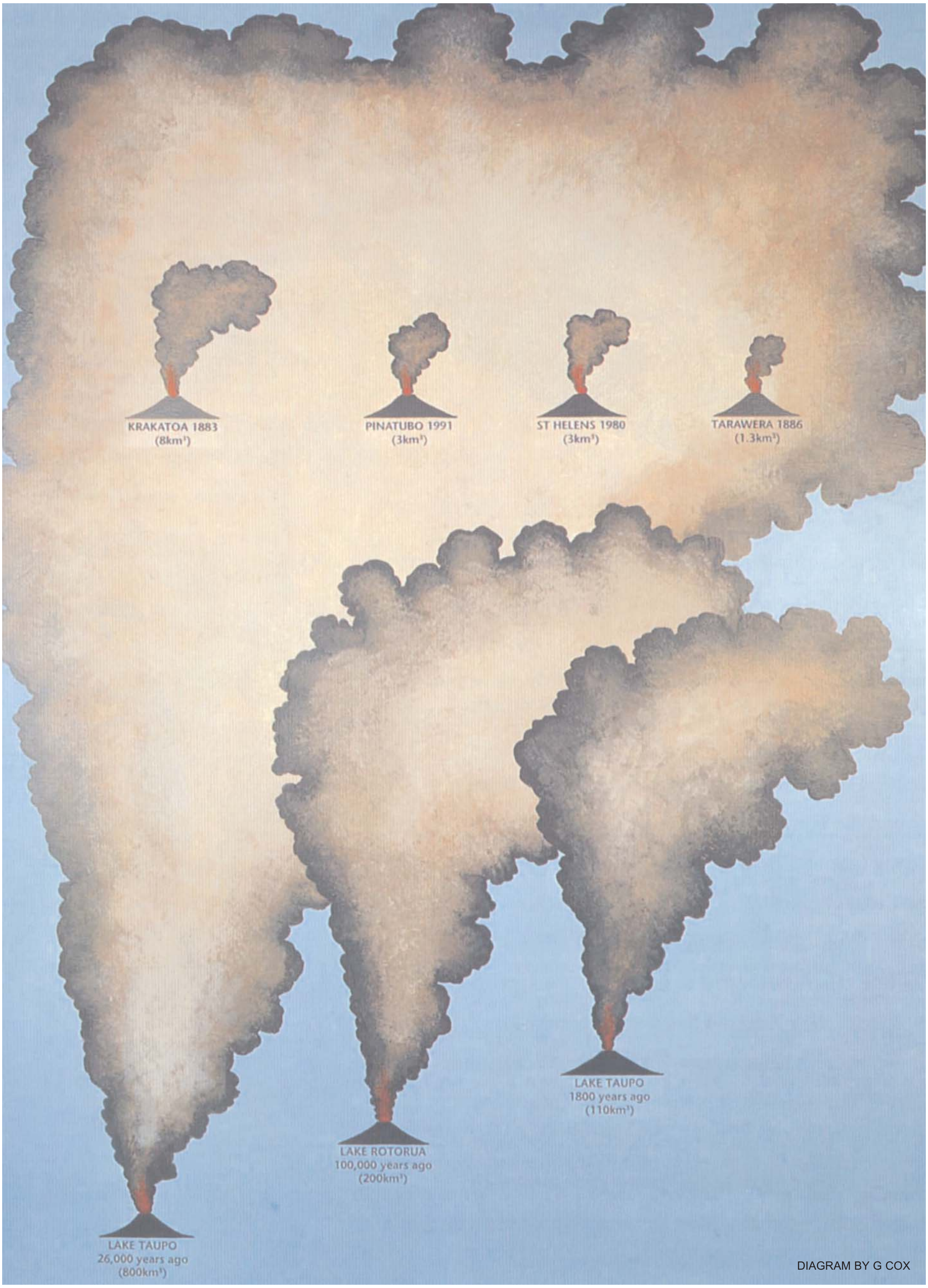

KRAKATOA 1883
(8km³)
PINATUBO 1991
(3km³)
ST HELENS 1980
(3km³)
TARAWERA 1886
(1.3km³)
LAKE TAUPO
1800 years ago
(110km³)
LAKE ROTORUA
100,000 years ago
(200km³)
LAKE TAUPO
26,000 years ago
(800km³)
DIAGRAM BY G COX

Lake Taupo PHOTO: L D HOMER, GNS SCIENCE

TAUPO: The World's Largest Historic Eruption

The largest and most violent volcanic eruption on earth in the last 5000 years was the ignimbrite eruption from Lake Taupo, in the centre of New Zealand's North Island, 1800 years ago. Ignimbrite is a term for rock produced from a pyroclastic gravity fall deposit.

This region has been devastated many times in the last 1 million years by large ignimbrite eruptions, some even larger than 1800 years ago.

The Taupo Volcanic Zone

The Taupo Volcanic Zone is the most active rhyolitic region on Earth, regularly producing many large scale eruptions. This vast area of volcanoes has resulted from the stretching and twisting of the North Island as the positions of the Australian Plate and the Pacific Plate change. In the north, the Pacific Plate is being subducted below the Australian Plate, while in the south this situation is reversed.

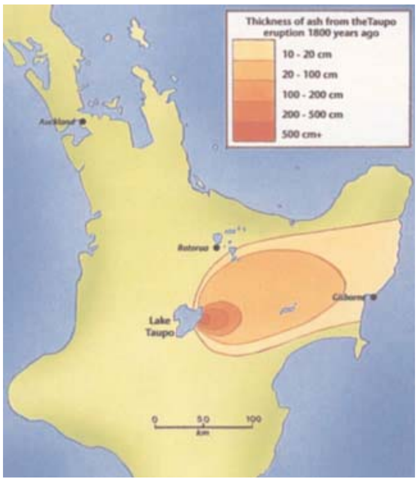
The Lake Taupo caldera volcano began erupting 300 000 years ago. The modern caldera or collapse crater, in which Lake Taupo sits, was largely formed by its largest eruption, 26 500 years ago.

Its second largest eruption, 1800 years ago, produced an enormous quantity of ash and hot ignimbrite flows that devastated an area of the North Island, now populated by over 200 000 people.

The 1800 year old Taupo eruption took place from vents along the eastern side of Lake Taupo in the vicinity of present day Horomatangi Reefs. The eruption deposits blocked the outlet from Lake Taupo and raised the lake level by 33m above its present level for some time.

The early stages of the 1800-year-old Taupo eruption ejected pumice and ash 50km into the air. Westerly winds blew the eruption plume eastwards. The fragments rained to the ground and accumulated in a layer 5 m thick just to the east of Lake Taupo thinning to 15cm thick by the time it reached Gisborne 180km away on the east coast.

The final stage of the brief 1800-year-old Taupo eruption was a catastrophic ignimbrite flow of hot ash and pumice that devastated 20 000km^2 of the central



Distribution and Depth of 1800-year-old Taupo Ash

DIAGRAM BY G COX

Distribution of 1800-year-old Taupo Ignimbrite Sheet

DIAGRAM BY G COX

North Island. The flow moved outwards across the ground at speeds of 600–900km/hour and travelled 70–90km from the vent. Areas over-run by the flow were buried under hot pumice and ash which destroyed all vegetation.

Will Lake Taupo erupt again?

YES — Lake Taupo is still an active volcano and is expected to erupt again, but we have no idea when. There have been 28 eruptions of various sizes in the last 27 000 years. The last eruption was the large Taupo eruption 1800 years ago. On average every 900 years.

TYPES OF VOLCANIC ROCK

What is a rock?

It is a naturally-occurring aggregate of minerals. A piece of concrete is made up of minerals, but since it is artificial, it is not a rock. Rocks can be classified in three broad categories: Igneous, Sedimentary and Metamorphic.

Type 1: Igneous Rocks

Are formed when magma (molten rock) cools and solidifies. There are two types of igneous rocks — plutonic and volcanic.

Igneous Plutonic

Plutonic rocks form from magma trapped below the Earth's surface. This magma cools slowly, and large crystals of minerals form in the rock. The slower the rocks have cooled, the larger the crystals.

Examples:

Granite — Granites crystallise from magmas with a composition characteristic of continental crust. They are high in silica, and rich in elements such as potassium and sodium. Granite polishes well and is prized for its colourful appearance which is due to the crystals of quartz (whitish) feldspar (often pinkish) and brown biotite. It is often used in construction of buildings and as flooring or benchtops.

Igneous Volcanic

Volcanoes erupt different types of magma that are classified mainly by silica content (SiO_2). They range from a silica content of about 50% in basalt to greater than 70% in rhyolite. The higher the silica content the more viscous and sticky the magma is, and that controls how explosive the eruption will be. Once magma reaches earth's surface and flows along the ground, it becomes known as lava.

Magma cools quickly when it reaches the Earth's surface in a volcanic eruption. Small crystals already form underneath the ground, but when the eruption happens the rest of the magma chills almost instantly to form tiny crystals and glass. Gas is often trapped during the formation of these rocks, resulting in many holes in the rock surface.

Examples:

Rhyolite — Rhyolite is a low density high silica rock, most commonly erupted through continental crust. It is the volcanic equivalent of granite. Pumice and obsidian have an identical rhyolitic chemical composition, so what makes them look so different? The Pumice is full of holes and represents the froth on top of the magma, resulting from the rapid release of gases in the initial stages of an eruption. The Obsidian is a volcano's dying gasps. Although the quietly erupted magma cools quickly to form glass, it is usually devoid of gas bubbles (vesicles) and the microstructure is such that light is absorbed by its surface, making Obsidian appear dark. Rhyolitic rocks can be found around Lake Taupo. Obsidian can also be found on Mayor Island and near Kaeo in Northland.

This is very sticky, viscous magma which erupts at the lowest temperature of around 850–800 °C. It can produce the most violent types of eruptions and leaves deposits called ignimbrite. Taupo is a rhyolitic volcano. Pumice and obsidian are rhyolitic rocks. Associated volcanic shapes include: calderas and lava domes. More than 65% silica.

Basalt — Basalt is a dark, dense volcanic rock low in silica. It is erupted in vast quantities from mid-oceanic ridges, forming the sea floor. The Auckland volcanoes (not Waitakeres) are basaltic volcanoes. Scoria is a form of basalt produced by fire fountaining. The rock has many holes due to being produced in a frothy, gas-filled manner.

Basaltic magma has the hottest temperature, around 1200–1150 °C. It is very fluid and produces the least violent eruptions. Scoria is a type of basalt formed during gaseous fire-fountaining. Associated volcano shapes include: scoria cones, shield volcanoes and tuff rings. Less than 52% silica.

Andesite — Andesite has an intermediate composition between basalt and rhyolite, and is erupted from volcanoes usually at convergent plate boundaries, such as the Waitakeres and Ruapehu in New Zealand, or the Andes mountains of South America, from which andesite gets its name.

Intermediate in composition between basalt and rhyolite, andesite magma erupts at temperatures around 1100°C. Mt Ruapehu is an andesitic volcano. Associated volcanic shapes include stratovolcanoes and scoria cones. 52-65% silica.

TYPE 2: Sedimentary Rocks

Sedimentary rocks are rocks that form from the accumulation of sediment. Sediments form from the erosion of older rocks exposed on land and carried into lakes or seas by rivers, deposited, and then compacted into a solid mass. Sedimentary rocks include plant and animal matter which can accumulate in such great abundance that the biogenic sedements form rocks such as coal and limestone. Still others are precipitated from mineral-rich solutions, such as halite from brine.

As more sediment is deposited on top, it squeezes water from the underlying sediments and packs the particles closer together. Sometimes the particles are cemented together with calcite or silica, deposited from fluids percolating through the sediment. Other times the cement is clay, formed from some of the particles breaking down.

Examples:

Limestone — When shelled organisms die, their shells fall to the sea floor and become cemented together, forming limestone. Limestone is usually a chalky white colour. Limestone fizzes with acid. One example is the Portland stone used in the construction of Auckland Museum.

Sandstone — Sand deposited by rivers and on beaches, when compressed and cemented, becomes sandstone. Because of all the vigorous washing, the particles are all a similar size and can be seen with the naked eye. Sandstone varies in colour according to its composition.

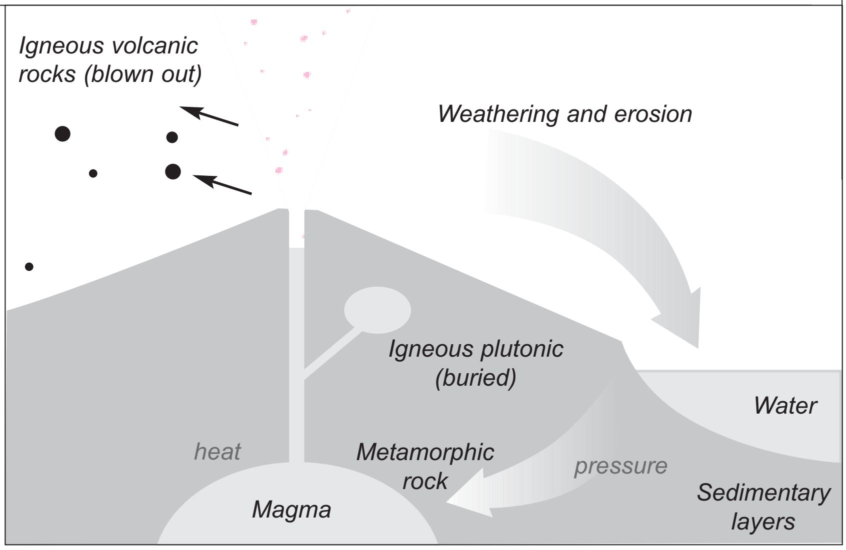
Mudstone — Mudstone is made up of particles too fine to be seen by the naked eye. Mud usually settles in quiet environments such as lakes and the deep ocean where the water currents are weak. Mudstone varies in colour from dark grey to pale yellow.

Shale — Shale is mudstone which flakes in fine layers.

Siltstone — Finer than sandstone, coarser than mudstone; particles are still visible.

Conglomerate — In high energy environments like river channels and steep slopes, pebbles and boulders are deposited along with finer sediments, which then consolidates into conglomerate. Conglomerate particle sizes vary greatly. A rock containing particles all the same size is well sorted, a conglomerate is usually poorly sorted. Colour varies according to the rocks composition.

Breccia — Breccia is similar to conglomerate rock, although its particles are angular. This means the particles have not been in water long. Breccia also can be made of angular volcanic particles.



The Rock Cycle

TYPE 3: Metamorphic Rocks

Rocks can get deeply buried in the crust, experiencing high pressure and temperature. They deform, change (morph) and recrystallise in a process called metamorphism. It is possible to see layers in many metamorphic rocks. Any pre-existing rock (igneous, sedimentary or metamorphic) can be metamorphosed.

Examples:

Slate — In the first stage of metamorphism, a rock becomes flattened like book pages. Slate is a fine-grained rock which was originally a mudstone. Slate varies in colour although is often black with greenish tints. It cleaves (splits) into thin layers and is often used for footpaths and roof tiles because of this.

Schist — Schist is a metamorphic rock with promounced platy fabric. Under higher pressure and temperature, new crystals start to grow and form bands of different mineral composition. Schist contains mica and can have garnets and quartz veins are often conspicuous.

Gneiss — With further metamorphism, the crystals grow larger and the bands become thicker. The schist turns into a gneiss (pronounced “nice”). Gneiss exhibits mixes of pale and dark layers, with frequent bands of quartz and feldspar throughout.

Marble — High temperature and pressure changes limestone into marble. Marble is made of calcite and will fizz with acid. Colours of marble vary. In New Zealand, marble can be found in only a few areas most notably around Takaka (Nelson). Marble is often used in construction, flooring or statues.

Greenstone (Pounamu) — New Zealand’s most famous metamorphic rock is Greenstone — composed mostly of the mineral nephrite. Pounamu is tough as steel, hence its use in early Maori tools. Pounamu can be found only in a few West Coast rivers of the South Island.

THE ROCK CYCLE

The continents are continuously recycling themselves. This Rock Cycle involves processes such as volcanism, erosion, deep burial and remelting.

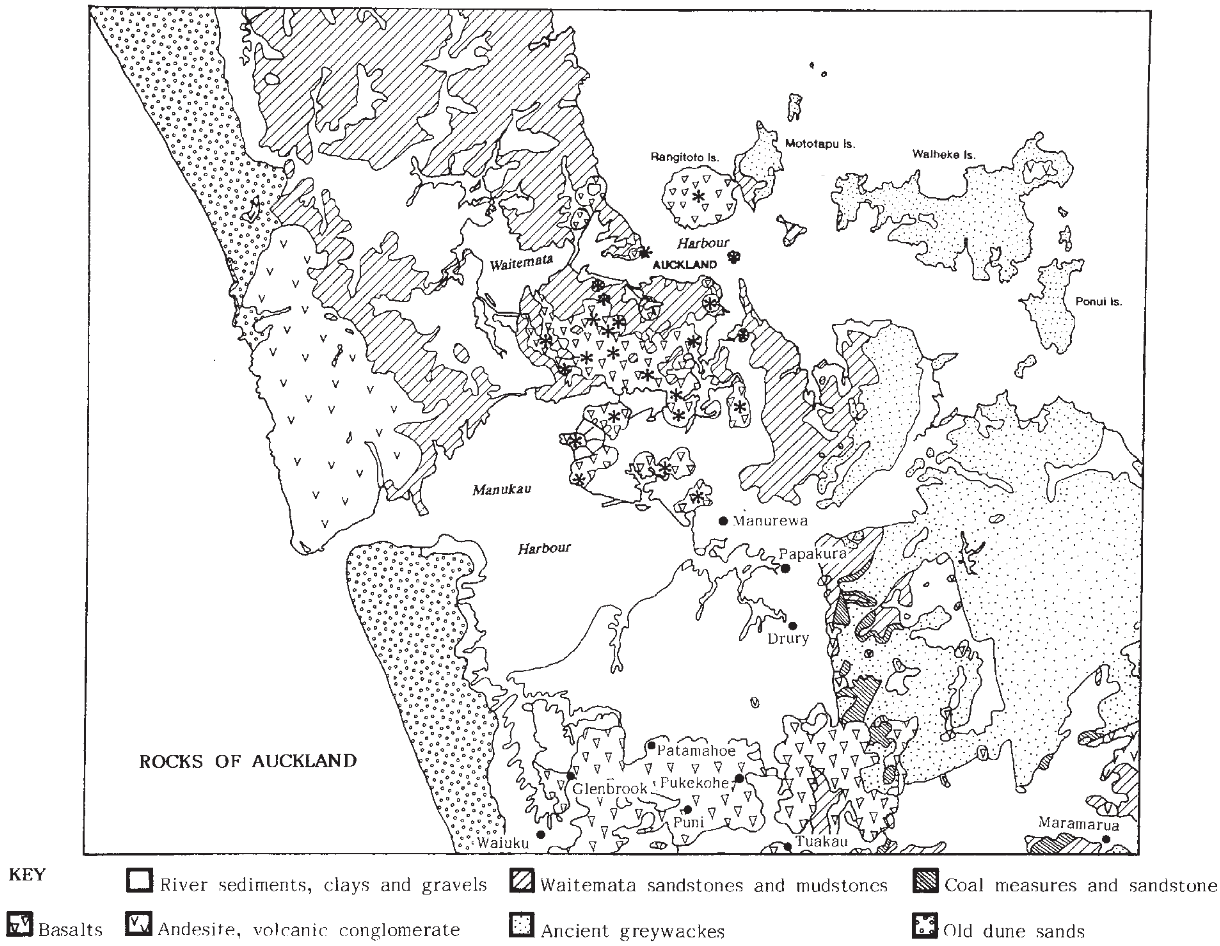
MINERALS

What is a mineral?

It is a natural inorganic solid with a specific internal structure and chemical composition.

There are many different types of minerals. They are vary on the basis of chemical composition. e.g. Silicates, Oxides, Sulphides, Halides, Carbonates, Hydroxides, Phosphates, Nitrates amongst others. However, there are only a few common rock-forming minerals.

The silicates are the main rock-forming minerals that make up most of the crust and mantle. Quartz and fledspar are the most common minerals within the Earth’s crust.



Silica and oxygen combine with metallic ions to form the building blocks of our planet.

Examples:

Quartz — Quartz is made of silica. The colour ranges enormously according to impurities and can be almost any colour — clear, opaque, white or purple (amethyst). Quartz crystals are six-sided. They are hard and cannot be easily scratched. Quartz is common in many rocks.

Feldspar — Feldspars contain silica, aluminium and a number of other elements. Colour ranges from white to pink, the pink being common in granite. Feldspar crystals are four or six-sided. They are used to make porcelain and also are used in some kitchen abrasive cleaners. They break down chemically to form clay minerals.

Mica — Mica forms as large flat crystals and flakes into thin sheets. One form is brown or blackish and shiny and is called biotite, a mix of iron and magnesium. Flakes are sometimes called "fools gold" as they resembles flakes of gold. Another form is white and silvery and is called muscovite. Muscovite was used in windows in Moscow, hence the name. Mica is found in granite and schist.

Calcite — Calcite is calcium carbonate and does not contain silica. Calcite crystals are soft and are easily scratched.

Identifying Minerals

When identifying minerals, we can use their physical properties as an aid.

Crystal form: the way the crystal faces are arranged.

Cleavage: the tendency for a mineral to break along certain weak planes in their crystal structure.

Hardness: a measure of a mineral's resistance to abrasion.

Specific gravity: the density of a mineral.

Colour: there can be many colours for each mineral, not very diagnostic.

Streak: each mineral leaves a distinctive streak when rubbed against unglazed porcelain.

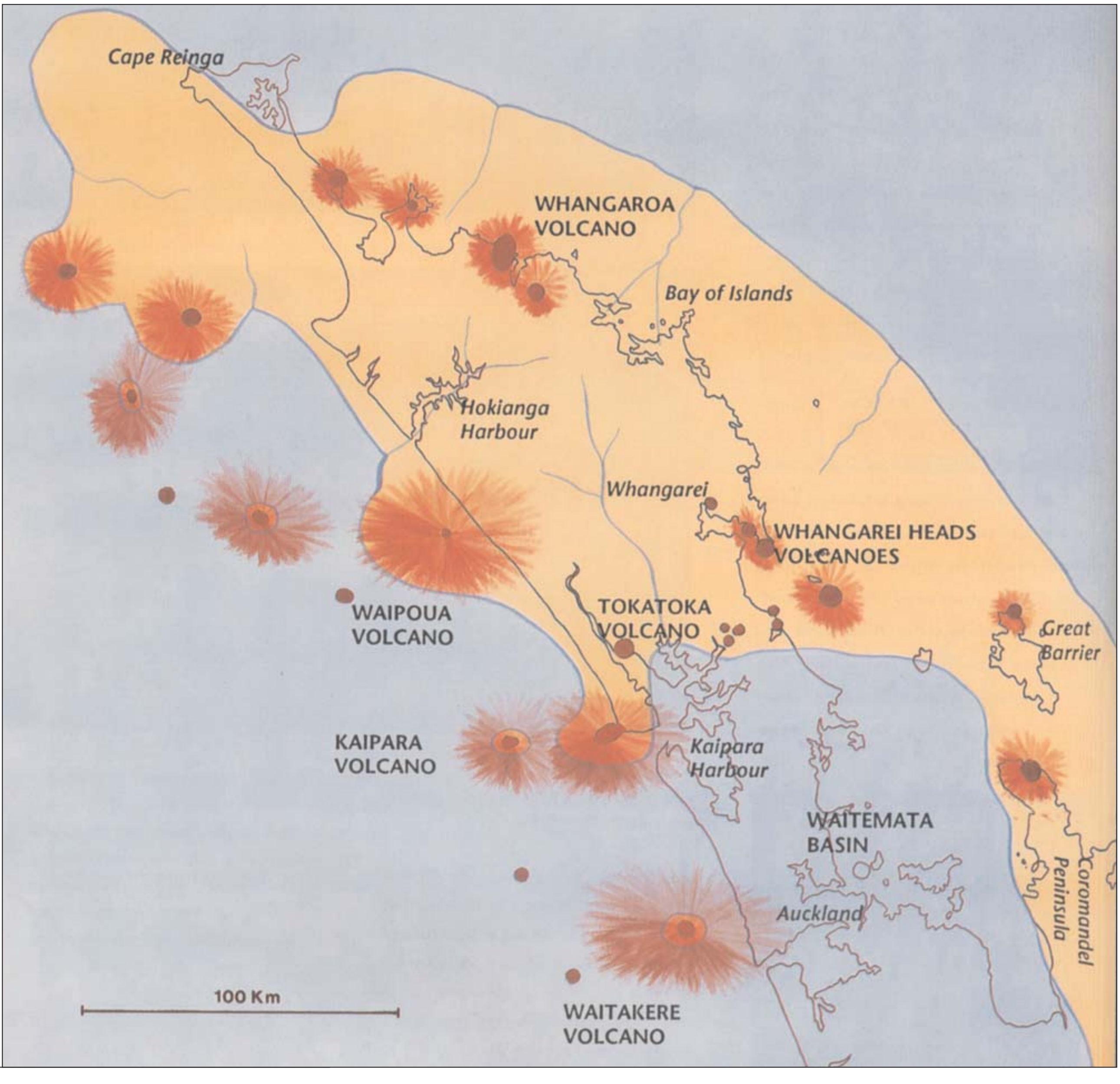
Dating Rocks and Rock Layers

Geologists often work out the age of rocks by the fossils that occur in them. Many organisms that were alive in the past have since become extinct. So even if the actual age of the rock is not known in years, it can still be assigned to a Geological Era or Period eg Devonian, because of the unique fossils it contains.

When igneous rocks are found in a record such as this they can be radiometrically dated ie an age in years can be worked out by measuring the decay of radioactive elements in the rock.

After rocks are deposited they become buried and can be buckled or folded by tectonic processes associated with plate collision such as mountain building. Earthquakes fracture rock, causing displacement of blocks along fault lines.

Lower rock layers are generally older than upper rock layers. Sometimes the rocks may get pushed up and eroded and a soil may develop on this new surface. When younger rocks are deposited over the surface, it produces what geologists call an unconformity denoting change in the environment and commonly an interval of geologic time missing from the rock record.



GIANT VOLCANOES OF NORTHLAND'S PAST

Northern New Zealand 20 million years ago. Two belts of large volcanoes erupted along either side of the ancient Northland Peninsula between 22 and 16 million years ago. The eastern belt produced eight stratovolcanoes, each the size of modern Mt Taranaki or Ruapehu. The western belt produced seven giant volcanoes (six stratovolcanoes and one shield volcano), with numerous smaller volcanoes between.

Twenty million years ago all of Northland was submarine and a 3000m deep marine embayment (the Waitemata Basin) extended over the Auckland area. Sand and mud washed into the Waitemata Basin from eroding volcanoes, which filled the basin with layers of sandstone and mudstone, which have since been uplifted and eroded to form most of the coastal cliffs around Auckland. The erupted lava was mostly andesite, generated by subduction under Northland at the edge of the Pacific plate beneath the Australian plate. The Waitakere and Waipoua volcanoes are the largest stratovolcano and largest shield volcano (respectively) ever to have erupted in New Zealand.

Volcanic Conglomerate, Waitakere Ranges

PHOTO:
BRUCE W HAYWARD

The Waitakere Ranges are mostly composed of erosion resistant volcanic conglomerate that accumulated on the eastern submarine slopes of the growing Waitakere Volcano. The volcano grew to a height of about 3000–4000m above the sea floor and at times was capped by one or more active volcanic islands. All but the Waitakere Ranges on the eastern margin of this ancient giant volcano has been eroded away.

Whangaroa Volcano Ring Plain

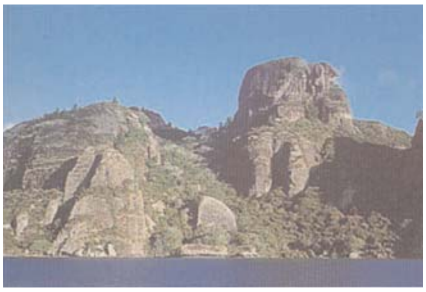


PHOTO:
BRUCE W HAYWARD

The spectacular bluffs and coastal cliffs around Whangaroa on Northland's east coast are the eroded remains of the laharic ring plain that 20 million years ago surrounded several stratovolcano cones that were erupting in the Whangaroa to Doubtless Bay area.

Whangarei Heads Stratovolcano

PHOTO:
BRUCE W HAYWARD

The eye-catching pinnacles of Mt Manaia, Whangarei Heads and Hen Island on the east coast of Northland, are remnants of several steep volcanic cones that 20–16 millions years ago formed the Whangarei Heads stratovolcano. Today, erosion is controlled by prominent sets of vertical joints that periodically spall off large blocks creating the steep bluffs and pinnacles.

Volcanic Skeleton

PHOTO:
B N THOMPSON

South of Dargaville, in the north Kaipara area, a small (5 to 10km diameter) stratovolcano has been completely eroded away except for the remains of over

70 volcanic pipes, plugs and irregular bodies of lava that had cooled in the plumbing beneath the volcano. They are composed of erosion resistant andesite and basalt and today form numerous small hills and occasionally spectacular rock pillars, as seen here at Tokatoka.

Waipoua Shield Volcano

PHOTO:
BRUCE W HAYWARD

The Waipoua forest area on the west coast of Northland, is the greatly eroded remains of a huge shield volcano. It is composed of extensive sheets of basalt flows interspersed with volcanic ash that has sometimes been baked red by the heat of the overlying flow. The Waipoua shield volcano grew to 50km across and sloped gently up to the highest point (about 2500m) located some 10km offshore of Maunganui Bluff.

Waitemata Sandstones and Undersea Volcanic Debris Flows

PHOTO:
BRUCE W HAYWARD

Alternating layers of sandstone and mudstone form many of the coastal cliffs around Auckland. These rocks accumulated as sand and mud on the floor of the Waitemata Basin, 22 to 19 million years ago. The sand was eroded from the Northland volcanoes and flushed as turbulent slurries (turbidity currents) down into the deep marine basin via submarine canyons from the Kaipara shelf in the northwest. Within the sequence, there are occasional thick beds composed of dark grey and red volcanic pebbles, grit and coarse sand (called Parnell Grit). This material originated high on the slopes of the Kaipara and Waitakere Volcanoes and was transported into the Basin as turbulent flows of sediment.

VOLCANIC HEROES

A lot of our modern knowledge about volcanoes comes from individuals who risked their lives to study some of the world's most dangerous environments.

In New Zealand volcanologists regularly visit active volcanoes such as White Island to take gas samples and monitor changes in the volcano. Volcanologists in Hawaii don flame-resistant suits to gather lava samples. It's all for a good cause: the more accurate information they have, the better they can understand volcanoes' patterns and behaviour.

The calculated risks do not always work out. Maurice and Katia Krafft were a husband and wife volcanology team. They witnessed and documented erupting volcanoes all over the world, producing a famous film called *Understanding Volcanic Hazards* that was translated into many different languages.

In 1991 the Kraffts were studying the erupting Mt Unzen in Japan when a sudden pyroclastic flow swept over them and a party of journalists and drivers. Everyone in the group died instantly.

GOOD THINGS ABOUT VOLCANOES

Some scientists believe that, without volcanoes, life as we know it would not exist on our planet.

Here's why: almost all life on Earth ultimately depends on photosynthesis — the process by which plants use light energy to convert carbon dioxide (CO_2) and water into sugars.

As rocks "weather" on the surface of the earth they use up CO_2 from the atmosphere, turning it into carbonates ($HC0_3$), which are washed into the sea, taken up by plankton, and eventually become limestone ($CaC0_3$) at the bottom of the ocean. If that was the end of the story, the world would run out of CO_2 and life as we know it would splutter to a halt. Fortunately, in the long term, much of the CO_2 is returned to the atmosphere by volcanoes — the limestone is subducted into the mantle, only to erupt again as a component of magma.

"The garden — the garden — shower it
Shower it o'er with dust
Shower it o'er with ashes
Then will the food flourish
And then all the fruits be saved"

— traditional Maori song from Motuihe Island

BAD THINGS ABOUT VOLCANOES

New Zealand's Volcanic Disasters

Tarawera Eruption, 1886

In the early hours of 10 June 1886, Mt Tarawera and adjacent Lake Rotomahana were ripped apart by violent eruptions along an 8km long rift. These showered the surrounding countryside with thick mud and ash, killing more than 100 people living in Maori villages near the mountain.

PHOTO: J KINDER, AUCKLAND MUSEUM LIBRARY

White Island Volcanic Disaster, 1914

In September 1914, part of White Island's crater wall collapsed into the crater during an eruption. This produced a disastrous volcanic mudflow (lahar), that swept across the crater floor, destroying the sulphur processing plant and overwhelming all ten workmen. Their bodies have never been found.

PHOTO: BRUCE W HAYWARD

Tangiwai Bridge Rail Disaster, 1953

On Christmas Eve 1953, the ice wall of Mt Ruapehu's crater lake gave way. The water poured out and quickly generated a lahar that raced down the Whangaehu River and swept away the main trunk rail bridge at Tangiwai. Soon afterwards the Wellington to Auckland Express plunged into the flooded river with the loss of 151 lives, the worst volcano-related disaster in New Zealand's history.

PHOTO: V C BROWNE & SON

NOT IF BUT WHEN

First, the good news: the odds are that a volcanic eruption won't occur in Auckland during your lifetime. Look at the maths: there have been 48 eruptions over 150,000 years — one every 3,000 years on average.

She'll be right!

Next, the bad news:

a. An eruption may or may not happen soon, but it will almost certainly happen. It's not if, but when.

b. There is no way of knowing when it will happen.

c. The last eruption, of Rangitoto, was by far the biggest.

d. If all that is not scary enough, consider this: Auckland's volcanoes are powered by runny basaltic magma, which rises through the crust quickly — at around five kilometres per hour. So when it happens — whether it's tomorrow or in 3,000 years time — we won't get much warning.

e. It's not just our local volcanic field we have to worry about. Auckland could be affected by a volcano erupting outside the city, such as Taranaki or Ruapehu, just as easily as a local eruption. The chance of ash from one of these volcanoes coating Auckland in the next fifty years is between 15 and 60 percent.

Just in case you're panicking, let's end with some more good news: scientists carefully monitor all of New Zealand's volcanic activity, and the Auckland Regional Council has detailed plans to execute in the event of a volcanic disaster.

IN CASE OF EMERGENCY...

The Auckland Regional Council has a co-ordinated civil defence and emergency management framework that will swing into action if a new Auckland volcano erupts. If your home has been destroyed but you haven't been, the plan covers who will feed you and where you will sleep.

The plans are pretty comprehensive: an Emergency Operations Centre will be set up to co-ordinate and manage the responses to the eruption. St Johns Ambulance will evacuate people to medical facilities; the Red Cross will provide clothing; the Salvation Army will feed evacuees, who will be treated for injuries in first-aid stations set up in buildings belonging to the Church of Jesus Christ of the Latter-Day Saints. Staff at the Shell Wynyard Wharf Terminal will secure bulk fuel tanks, and the Meteorological Service will be responsible for advising aircraft of volcanic ash hazards.

The planning is not for a short term event. Unlike many other natural hazards, a volcanic eruption can occur over months, perhaps even more than a year.

Recorded information: (09) 306 7067
Administration: (09) 309 0443 Fax (09) 379 9956
School Bookings: (09) 306 7040 Fax (09) 306 7075
Email: schools@aucklandmuseum.com

www.aucklandmuseum.com

AUCKLAND MUSEUM
The Domain Auckland
Private Bag 92018 Auckland New Zealand

TAMAKI PAENGA HIRA
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