

U3A

Volcanoes and geothermal areas
in the Taupo Volcanic Zone, NZ



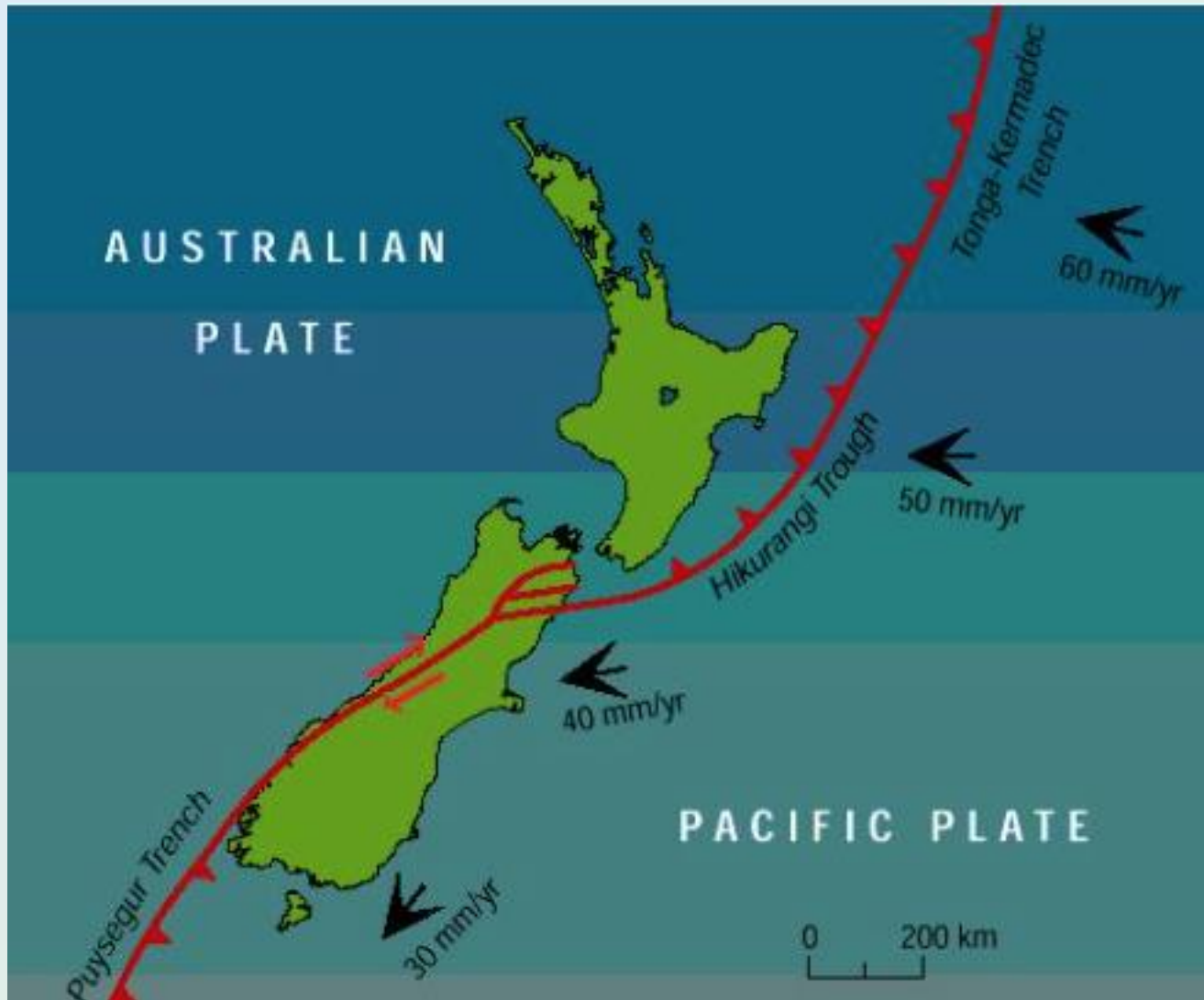
Introduction

- Most of New Zealand's volcanoes and geothermal features are located in the Taupo Volcanic Zone in the central North Island
- the volcanic activity results from subduction of the Pacific tectonic plate beneath the North Island
- volcanic and geothermal activity are due to magma generated on the subducted plate and rising up into the crust

Tectonic setting

- Present geology of NZ → largely determined by its position on edge of two tectonic plates
- boundary between Australian and Pacific plates bisects the country
- in the north of NZ, the Pacific Plate is subducting beneath the Australian Plate along the Tonga-Kermadec Trench
- south of NZ the Australian Plate is subducting beneath the Pacific Plate along the Puysegur Trench
- the Alpine Fault (prominent transform fault through South Island) connects the reversed subduction systems

Tectonic setting



TAUPŌ VOLCANIC ZONE

Taranaki
(West Coast)

Hawke's Bay
(East Coast)



CONTINENTAL CRUST

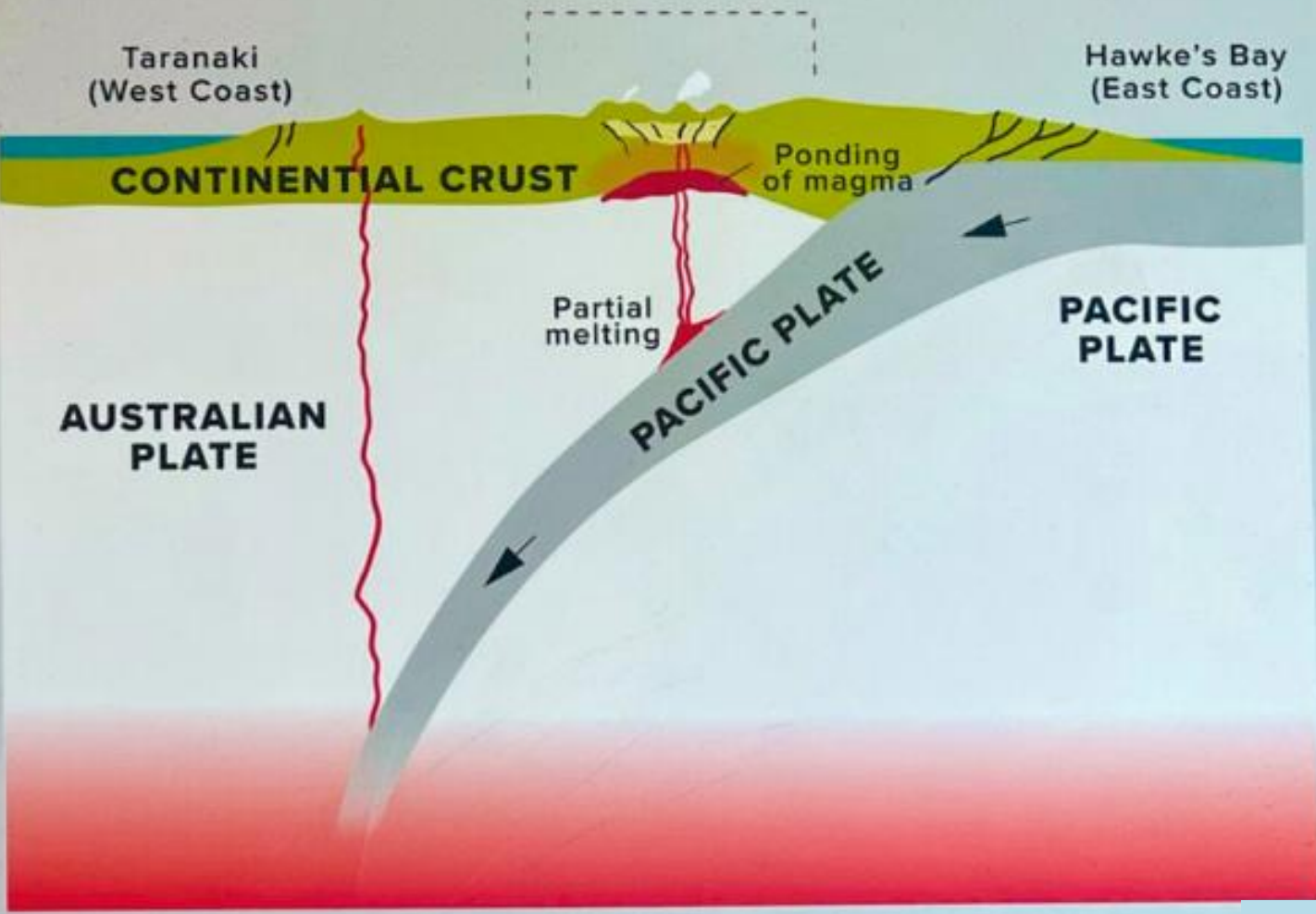
Ponding of magma

Partial melting

AUSTRALIAN PLATE

PACIFIC PLATE

PACIFIC PLATE

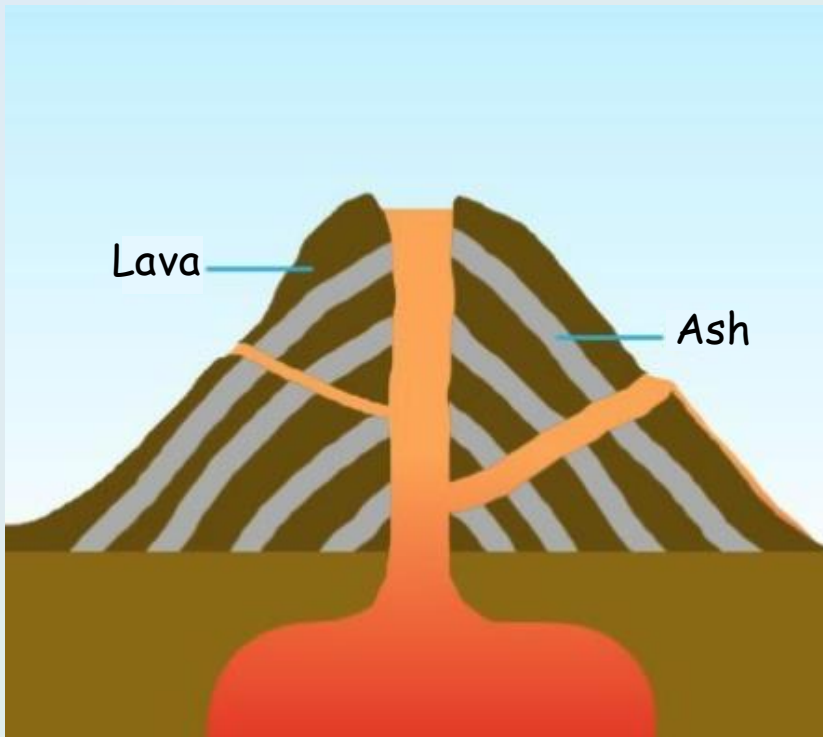


Shape of volcanoes

- The shape of a volcano is determined primarily by the composition of the magma feeding it, style of eruption and material ejected
- andesitic magma may be erupted quietly or explosively, sometimes erupting lava, sometimes pyroclastics
- andesite eruptions may occur intermittently over a long period of time, slowly constructing a steep-sided composite cone
- viscous silica-rich magma, rising slowly in the vent may cause the ground surface to bulge upwards to form a volcanic dome
- more than 150 lava domes are found in the Taupo Volcanic Zone, in addition to andesite, dacite and rhyolite domes are also common

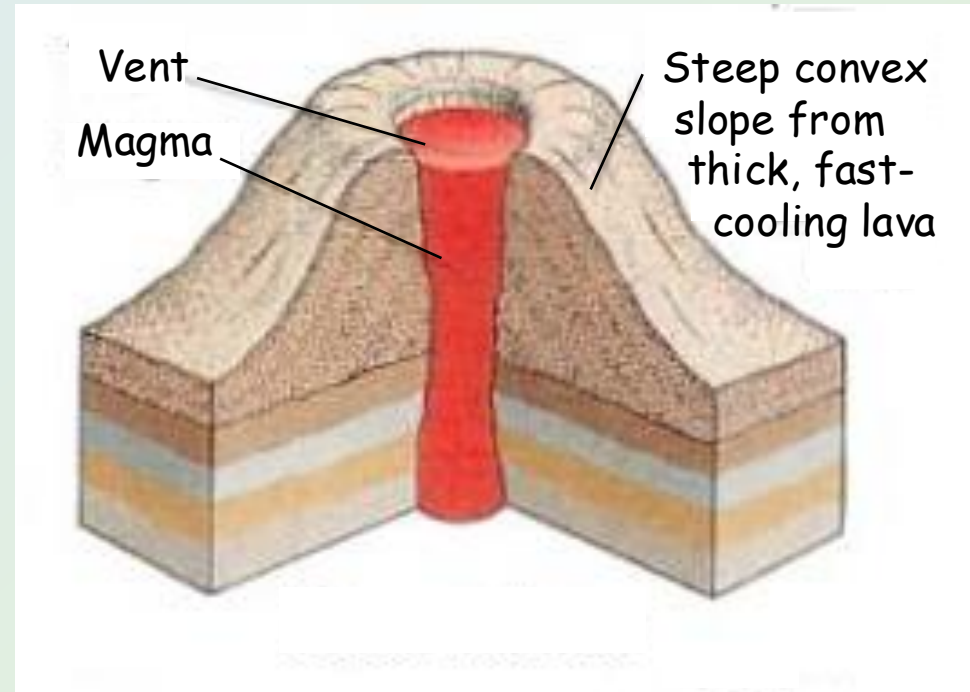
Shapes of volcanoes

Stratovolcanoes are formed by alternating layers of lava, ash and pyroclastic material



Stratovolcano

Lava domes are volcanic formations created by viscous lava that accumulates around a vent or causes ground to bulge upwards

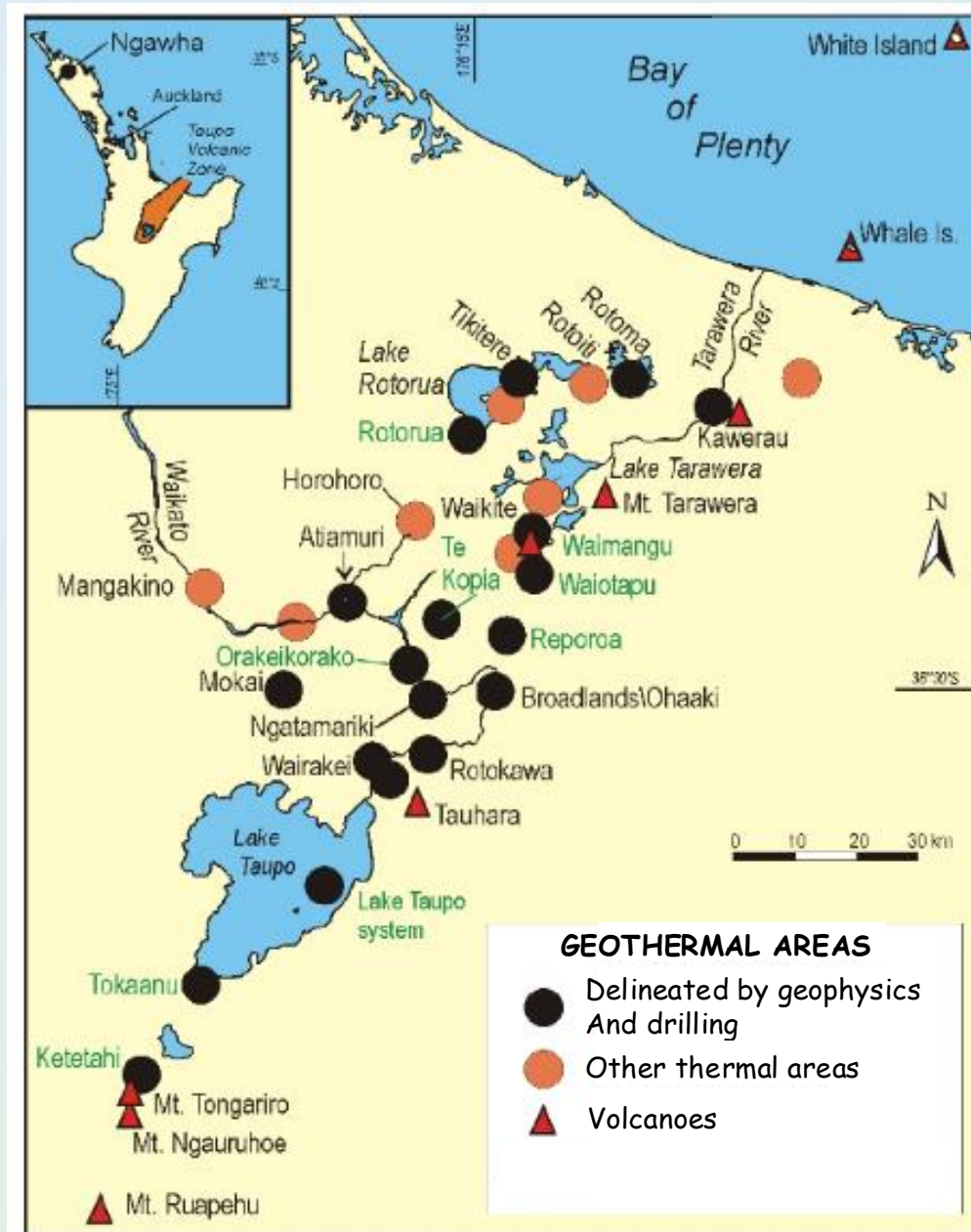


Lava dome

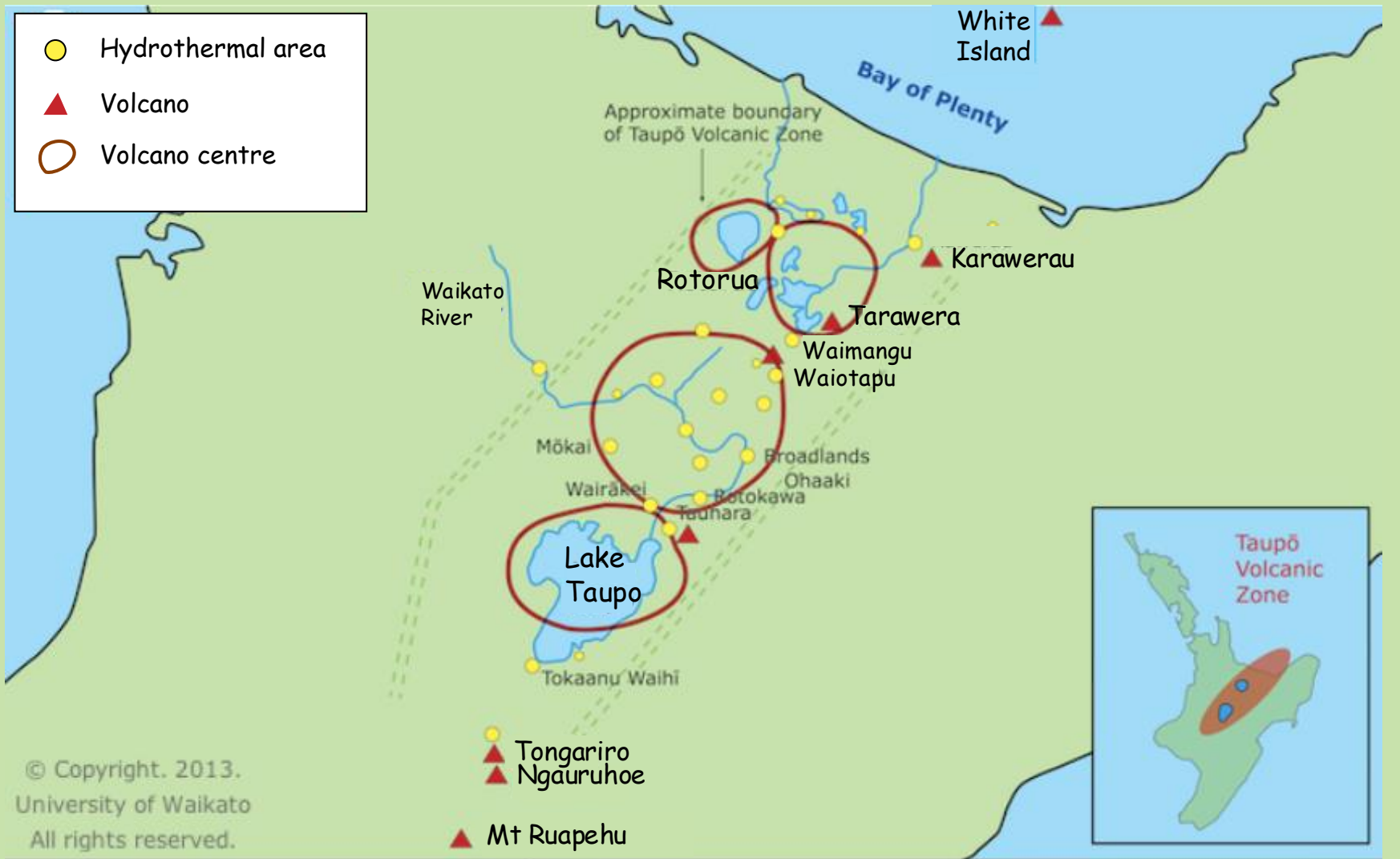
Taupo Volcanic Zone, NZ

- Most of NZ volcanoes and geothermal features are located in the Taupo Volcanic Zone in the central North Island
- Taupo Volcanic Zone → narrow belt of activity only 20-40km wide, spans a distance of 240km from Tongariro National Park to White Island
- this NE trend is characterised by earthquakes and active faults
- volcanoes have been active in the zone for ~1million years
- the volcanoes are a surface manifestation of subduction processes below the North Island

Taupo Volcanic Zone



Taupo volcanic zone



Taupo caldera

- The caldera volcano of Lake Taupo has a complex history going back ~300,000 years
- the Oranui eruption ~26,000 years ago the largest eruption in the known history of the volcano, probably responsible for present shape
- since Oranui eruption → 28 eruptions over 21,000 years
- most recent eruption ~1,800 years ago → most powerful in world in past 5,000 years
- central North island was showered with rhyolite airfall deposits of white and yellow tephra up to 5m deep
- pumice, ash and other volcanic debris filled valleys and depressions forming a layer 30m thick

Lake Taupo



Layers of history - Taupo Volcanic Zone

- Age of the tephra layers can be determined if peat, charcoal or wood are associated with the deposit
- two rhyolitic tephtras have been dated using radiocarbon isotopes
- 1,800 year old Taupo pumice and the ~26,000yr Oranui tephra
→ very useful marker beds for dating landforms in the zone



Charred logs in Taupo ignimbrite from 232CE Taupo eruption

Layers of volcanic history Taupo volcanic zone (Williams 2001)

Formations	Thickness	Description	source
Ngauruhoe	0.22m	Very dark brown fine ash	Ruapehu
Taupo pumice (AD 186)	0.6m	White pumice lapilli and ash	Taupo
Mangatawai Tephra	0.21m	Dark brown and dark grey ash	Ngauruhoe
Rotoaira Lapilli	2m	Yellow & yellow brown ash & lapilli units. Basal sands with olivine andesite cobbles	Te Maari craters
Oruanui or Wairakei	3.6m	Grey brown ash with accretionary lapilli	Taupo

Tongariro volcanic centre

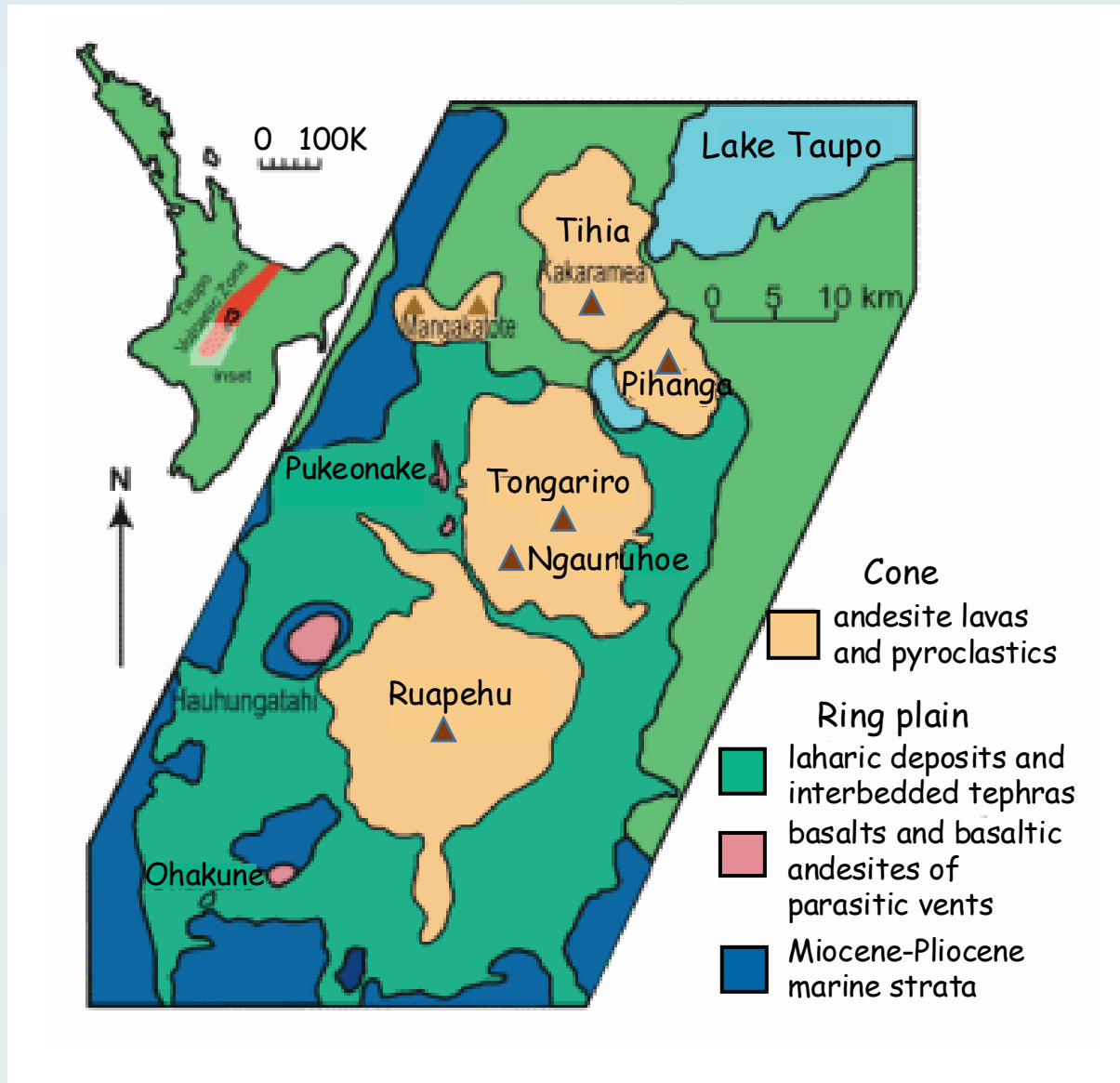
- Volcanoes of Tongariro volcanic centre lie at southern end of Taupo Volcanic Zone are predominantly andesite in composition*
- oldest lava flows are ~260,000years, first eruptions ~ 1Ma
- ~515Ma the area formed part of the sedimentary basin
- volcanic rocks and landforms are not all of the same ages → span ~300,000years



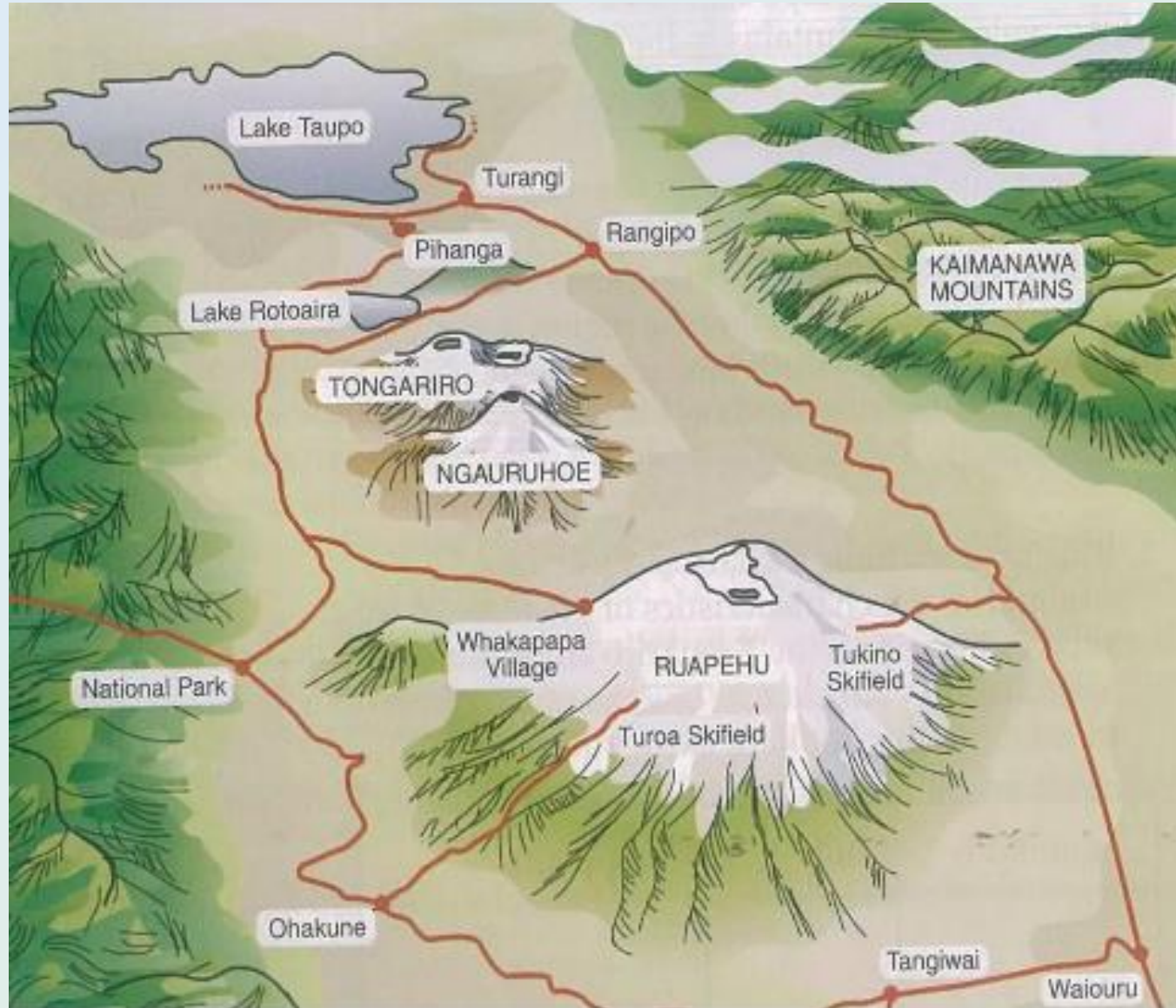
Volcanoes of Tongariro National Park

- The park encompasses a landscape that has been the scene of intense volcanic activity
- volcanoes of the Tongariro centre can be separated into two groups based on size and activity
- northern group comprises two andesitic volcanoes, Tihia and Pahanga; younger vents Tongariro, Ruapehu and Ngauruhoe form southern group
- vents of the southern chain area aligned NE-SW corresponding to Taupo fault belt and active trend of Taupo Volcanic Zone

Tongariro volcanic centre



Volcanoes of Tongariro Park - younger group



Kakaramea-Tihia Massif

- Lower ridge south of Lake Taupo → composed of number of merged volcanic vents → Kakaramea-Tihia Massif
- a 1300m andesite cone of Mt Kakaramea forms the summit of this old volcano
- the lava dome of Mt Tihia lies 3.5km to SE of Kakaramea
- volcanic activity occurred between 100,000 and 230,000 years ago
- tephra near E end of massif has radiocarbon date of 43,000 years
- active groundwater heating on northern slopes of complex

Kakaramea



Mt Pihanga

- Mt Pihanga is a 1326m high volcano located to N of Mt Tongariro
- the cone-shaped andesitic volcano is younger than neighbouring Kakaramea-Tihia complex
- it was active for longer and is less dissected by erosion
- eruptions from Pihanga last occurred more than 20,000 years ago

Mt Pihanga



Tongariro Volcanic Complex

- The Tongariro National Park extends from the shores of Lake Rotoaira to Tama Saddle beyond Mt Ngauruhoe
- the National Park is centred around three active volcanoes, Tongariro 1957m, Ngauruhoe 2287m and Ruapehu 2797m
- K-Ar dating has shown that the massif has grown almost continuously during 275,000 years
- vents of all ages share the same alignment, a NE-SW aligned corridor 5km wide and 13km long

Mt Tongariro

- Early Mt Tongariro was built from overlapping of 6 cones between 275,000 and 65,000 years ago
- an intense period of volcanic activity occurred ~10,000 years ago along a 10km line between the Te Maari crater and Ruapehu*



Mt Ngauruhoe

- About 2,500 years ago, a new vent, the youngest in the Tongariro Volcanic complex began to form (Mt Ngauruhoe)
- frequent eruptions of pyroclastic material and molten lava added height, weight and bulk to the Ngauruhoe cone
- the volcano is composed of intercalated layers of ash and lava ranging in composition from andesite to basaltic andesite
- eruptions from a central crater have constructed steep 30° outer slopes
- Ngauruhoe was mildly active after eruptions in 1950s with eruptions in 1970s

Mt Ngauruhoe



Ruapehu massif

- The andesite-dacite stratovolcano lies near S end of the Taupo Volcanic Zone, 2797m summit highest point in the North Island
- at least 4 distinct cone-building episodes identified during past 250,000 years
- tephra studies indicate that presently active vent has been focus of activity for past 2,500 years
- in past 120 years, dozens of steam explosions have been reported from the active crater

Ruapehu massif



Crater Lake on Ruapehu

- A crater lake with a diameter ~500m normally fills active crater of Ruapehu at elevation of 2530m
- lake is warm, sometimes reaching 60°C +, lake water is highly acidic (pH 0.8-1.5)
- lake is rich in dissolved solids (sulphate, chloride and lesser amounts of Mg, Ca, Na, Fe, Si and other elements)
- chemical constituents of water are derived from volcanic material*
- water heated by volcanic gases, higher temperatures associated with increased volcanic activity and volcanic gases from lake floor fumaroles

Crater Lake Ruapehu



Eruptions from Ruapehu

- Minor phreatic eruptions occur from time to time in Crater Lake, phreatomagmatic occur when rising magma encounters wet sediments on lake bottom
- a chain of violent eruptions follows as water and magma interact and magma chills and shatters
- a steam-rich eruption cloud may rise vertically to hundreds of metres above water surface
- water and lake sediments may surge outwards from base of eruption onto the icefield surrounding the lake
- hot ejecta can cause rapid melting of ice and snow and is often remobilised as mudflows (lahars)

White Island

- White Island is an active volcano situated in the Bay of Plenty 50km north of Whakatane
- two overlapping stratovolcanoes, covers an area 16 x 18km
- central floor of White Island crater is just below sea level
- 3 active hydrothermal sites known as calypso vents identified 15km SW of White Island
- they lie on seafloor at depths >170m and vent high temperature (200°C) gas-rich fluids from deep within the Earth

White Island



Mt Tarawera

- Tarawera is a complex of rhyolite domes and lava formed during several major eruptions in past 20,000 years
- Tarawera contains at least 9 well-exposed lava domes and numerous lava flows
- present summit area of mountain contains several coalesced domes built during eruptions 600-700 years ago
- domes are typical for viscous rhyolite lava having flat summits and steep sides
- domes form by passive extrusion of degassed magma often preceded and sometime followed by explosive eruption

Tarawera eruption

- Mt Tarawera erupted on June 10th 1886
- in just 6 hours, the volcanic domes were destroyed, creating a line of craters along a 14km long rift
- ashes buried the surrounding countryside up to 45m deep affecting an area of some 15,000km²
- the eruption destroyed the Pink and White sinter terraces, the largest silica sinter deposits on Earth
- the eruption killed 120 people, the largest and deadliest volcanic disaster in NZ during past 500 years

Mt Tarawera



NZ Geothermal systems

- Most of NZ thermal activity is located in the centre of the North Island
- hydrothermal features (hot springs, geysers, mud pools and fumaroles) have a natural magma source close to surface in volcanic zones*
- rising hot gases from slow cooling magma, heat up surrounding rocks
- groundwater percolating downwards towards magma is heated through contact with these rocks
- in a geothermal system, heat is transferred partly through the rock (conduction) and partly by movement of water (convection)

Geothermal systems

- Most of the water in geothermal systems is atmospheric, seeping downwards through cracks and cavities in surface rocks
- water descends towards a deep buried heat source and becomes progressively hotter
- hot water is less dense than cold water and rises to the surface and discharges as geysers, hot springs and fumaroles (gas vents)
- 3 requirements for geothermal activity are water, heat and rapid passage to surface
- hot springs generally occur along faults or in topographic low points where water levels are near surface

Hot springs

- Hot springs occur where geothermal water has rapid access to surface
- geothermal water rises along zones of weakness e.g. faults
- geothermal water varies in composition mainly due to interaction with rocks on way to the surface → weakly alkaline, NaCl enriched
- most hot springs lose heat to atmosphere and surrounding rocks at same rate at which heated below → discharge hot, not boiling water

Hot springs, Rotorua



Geysers

- Most geysers have a narrow vent opening to a substantially larger reservoir below surface
- narrow neck of geysers reduces heat loss from the surface
- water in the reservoir increases steadily in temperature until it begins to boil
- mixture of steam and water violently ejected → supply exhausted
→ discharge ceases → reservoir begins to recharge

Whakarewarewa geyser



Fumaroles

- In some areas, hot water reaches close to the surface but is then trapped at shallow levels by a non-porous layer
- the trapped water may boil at depth with steam and gas escaping to the surface through a gas vent (fumarole)
- gases such as CO_2 and H_2S are also held in solution and released when waters near surface
- gases escaping from fumaroles rich in H_2S precipitate yellow sulphur crystals around vent as gases cool
- because the mixture of water and gas may be trapped at depth for some time it may chemically react with soil altering its composition

Fumaroles - White Island



Mud pools

- Mud pools form if steam and gas are released beneath a pond or any other accumulation of water
- the mud pool consists of a mixture of rain water and mud produced by the reaction of parent rock with acid fumes
- steam and gas escaping from boiling water below, produce turbulence in the pool and small eruptions of mud

Boiling mud pool



Boiling mud pool (Frog Pond), Whakarewarewa valley, Rotorua

Geothermal deposits - Sinter

- Sinter is a usually silica deposit precipitated from geothermal water from mineral springs
- solubility of silica increases with increase in water temperature, if the water cools, silica precipitates
- small amounts of other compounds or elements can be incorporated into sinter tinting normally white sinter
- pyrite (FeS_2) gives a dark grey colour, while ferric iron (Fe_2O_3) produces a pink colour
- algal growth on silica surface can produce a range of colours e.g. green, brown, orange

White sinter terraces



White sinter terraces, Waiotapu

Alteration of rock

- Soils in many geothermal areas show a display of colours produced by interaction of heat and geothermal gases and fluids
- altered soils contain the minerals kaolinite, alunite [$KAl_3(SO_4)_2(OH)_6$], silica, gypsum and sulphur
- range of colours is due to varying amounts of other minor components e.g. Fe-oxides and hydroxides (yellow, brown, red), orpiment (As_2S_3) and sulphur (yellow), realgar (AsS orange), cinnabar (HgS purple) and pyrite (FeS_2 grey)
- pools may contain high concentrations of various compounds to produce bright colours

Sulphur deposits - White Island



Waiotapu

- Waiotapu geothermal field occupies an area of 18km² extending SE from Rainbow Mountain, a dacite volcanic dome
- the field occupies the northern end of the Repora caldera
- Waiotapu is famous for the large alkaline spring Champagne Pool
- Champagne Pool has associated sinter deposits of the Primrose terraces*
- the Waiotapu field was formerly more active, numerous collapse craters represent part of a major complex once active geysers and hot springs

Waiotapu geothermal pools



Champagne Pool



Devil's Bath

Whakarewarewa

- Whakarewarewa is the only geyser field remaining in NZ
- its 500-odd hot springs include most forms of geothermal activity with the major feature the alignment of 7 geysers at Geyser Flat
- alignment of 7 geysers → one of the highest concentrations of geysers in the world
- other wonders of Whakarewarewa include an extensive field of steaming hot pools, blue chloride and mud pools

Pohutu geyser Whakarewarewa valley, Rotorua

