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Rangitoto volcano excursion

– Auckland, New Zealand, 2014 –

David J. Lowe, Kate Lewis Kenedi, & Peter J. de Lange

This trip is sponsored by
The Royal Society of New Zealand
University of Waikato
University of Auckland
Department of Conservation

Acknowledgements

These field excursion notes comprise updated and expanded versions of guides written by Lindsay et al. (2010) and Smith et al. (2012). The excursion leaders (p.3) are very grateful to support from Richard Meylan and Debbie Woodhall (RSNZ), Phil Shane, Bridget Lynn, Gary Smith, Rhys Gardner, and other helpers. For a superb book on Auckland and its volcanoes, including Rangitoto, please see Hayward et al. (2011a).

Photo front cover: View southeastward from Rangitoto's summit over scoria cone (foreground) and rocky lavas and pohutukawa forest towards Islington Bay, just beyond which is southern tip of Motutapu Island. In the distance is Waiheke Island and to the right, Moutihe Island.

Photo above: Setting out at start of summit track near the DOC centre at Rangitoto Island wharf, with slopes of volcano rising over lavas and (steeper) scoria cones in far distance (top left) (both photos by D.J. Lowe).

Citation: Lowe, D.J., Kenedi, C.L., de Lange, P.J. 2014. Rangitoto volcano excursion, Auckland. Pre-conference field trip, 30th August, 2014, *31st ICSU General Assembly, International Council for Science, Auckland, New Zealand*. 22pp.

Rangitoto: Auckland’s youngest volcano

Field trip leaders

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Date and time of trip Saturday, 30 August, 2014, 12:30 pm – 5:30 pm
The ferry departs from Pier 2 of the Ferry Terminal building, downtown Auckland, at 12:30 pm. It departs Rangitoto Island wharf at 5:00 pm. ***NB: Times may vary according to weather conditions.***

What to bring, track conditions

Please wear boots or ‘strong’ trainers/shoes, a raincoat/windproof is essential, and carry (or wear) a warm jumper in backpack as needed. The forecast is for some showers and easterlies but, if sunny for long spells, a sun hat and sun block are also needed. The walk is a moderate one on rough tracks and requires a moderate level of fitness. At the coast the tracks are gentle but steepen near the island’s summit. Much of the summit track is sheltered. Do not go off the track because the a’a lava fields comprise very unstable, loose, sharp and glassy angular material which is very dangerous to try to walk over. Please also be especially cautious on the steeper tracks descending from the summit where loose gravels can make for occasionally ‘slippery’ conditions. Lunches and drinks will be provided at the time of departure from the Ferry Terminal. Take plenty to drink.

Overview

Rangitoto is one of Auckland City’s more iconic landscape features. Guarding the entrance to the Waitemata Harbour, Rangitoto is a symmetrical, ~6-km wide, basaltic shield volcano that last erupted ~550 years ago shortly after the arrival and settlement of Polynesians in the Auckland region (c. 1280 AD). Rangitoto is by far the largest, and also the youngest, volcano in the Auckland Volcanic Field (AVF). The AVF is a monogenetic volcanic field consisting of approximately 53 individual eruptive centres, all of which are within the boundaries of the Auckland urban area. Recent research has revealed more about Rangitoto’s eruptive history, which may date back to c. 1500 years ago (Shane et al. 2013). Some of these findings have been noted below and will be discussed further while we ascend its summit and explore its various landscape and vegetational features.

Key facts

Maori name: Rangitoto, Maori for “blood red sky,” is derived from the phrase Nga Rangi-i-totongia-a Tama-te-kapua, meaning “the day the blood of Tamatekapua was shed”, referring to a battle between Tamatekapua and Hoturoa, the commanders of the Arawa and Tainui canoes, respectively, at Islington Bay (e.g. Murdoch 1991; Hayward et al. 2011a).
Height: 260 m above sea level.
Age: Formed mainly during two eruptions c. 600 and 550 cal years ago (c. 1400 AD and 1450 AD). New (controversial) evidence suggests that intermittent activity, spanning ~1000 years, began c. 1500 years ago.
Composition: Basalt lava, scoria, and ash. Broadly bimodal compositionally: ‘high’ and ‘low’ SiO_2 contents.
Volume volcanic material: ~1.8 km^3 (approximately half the volume of magma erupted from the entire AVF).

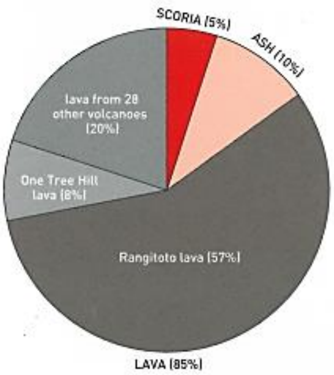
Introduction to the Auckland Volcanic Field (AVF)

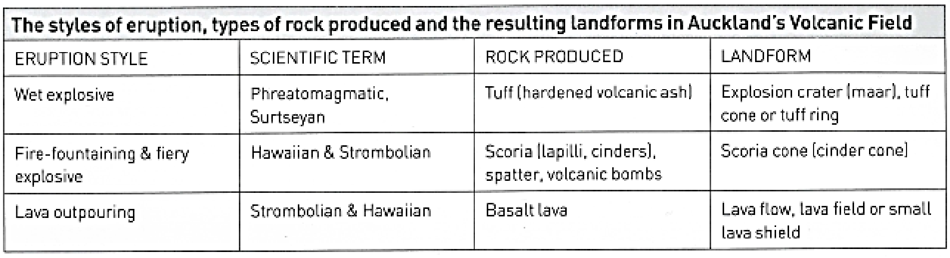
A volcanic field comprises an area where magma production rates are low and numerous eruptions occur at the land surface at widely spaced vents over a period of thousands to hundreds of thousands of years. The AVF is an excellent example of such a field, and consists of around 53 volcanoes within a 20-km radius of central Auckland (Hayward et al. 2011a) (see Fig. 2 below). With the exception of Rangitoto, each volcano erupted only once over a period of possibly weeks to several years in a single eruption episode (possibly with multiple phases), and with each eruption episode in a different place so that a new volcanic crater or cone is produced (hence the term 'monogenetic' is usually applied to such volcanic fields). The AVF has been active since c. 250,000 years ago. Rangitoto's latest activity was only about 600 to 550 years ago (c. 1400 to 1450 AD) and the field is considered to be still active and likely to erupt again (a summary of ages of volcanoes in the AVF is given below).

The basaltic magma generating Auckland volcanoes derives from the mantle 70−90 km beneath the land surface (Hayward et al. 2011a). Magmas contain almost all of Earth's known chemical elements, but typically they consist of just nine: silicon, oxygen, aluminium, magnesium, iron, calcium, sodium, potassium and titanium. Oxygen and silicon together are the most abundant elements, making up 48–76% by weight of most magmas. The chemistry of magma, especially silicon content, is important for influencing the way it erupts. Three main magma types, and resulting volcanic rocks, are identified on the basis of their chemical composition: andesite, basalt, and rhyolite (Smith et al. 2006).

- Andesite magma is intermediate in composition and physical properties. Erupting at around 800–1,000 °C it is more viscous than basalt, but much less viscous than rhyolite. Andesite magma cools to form dark grey lava if gas-poor, or scoria if gas-rich.
- Basalt is rich in iron and magnesium, but has less silicon than other magmas. It erupts at very high temperatures (around 1100–1200 °C) as a very fluid magma. Basalt magma with very little gas cools to form black, dense lava, but where magma erupts with lots of gas it cools to form ragged scoria.
- Rhyolite magma is rich in silicon, potassium and sodium and erupts at temperatures between 700°C and 850°C as an extremely viscous (sticky) magma. Rhyolite magma containing lots of gas bubbles cools to form pumice. Because it is low in iron, rhyolite is normally light-coloured – it may vary from white to pink or brown. Obsidian is a type of rhyolite produced when lava is chilled to form glass (from Smith et al. 2006).

The shape of an Auckland volcano depends on the styles of eruptions that formed it, and its size depends on the volume of magma erupted and the duration of the eruption phases (Hayward et al. 2011a). Three different styles of eruptions in the AVF have resulted in three different types of volcanic rock and three distinct landforms: (*i*) lava flows, (*ii*) scoria cones (sometimes called cinder cones), and (*iii*) explosion craters or tuff cones/rings (Figs. 1 and 2).





The styles of eruption, types of rock produced and the resulting landforms in Auckland's Volcanic Field

ERUPTION STYLE	SCIENTIFIC TERM	ROCK PRODUCED	LANDFORM
Wet explosive	Phreatomagmatic, Surtseyan	Tuff [hardened volcanic ash]	Explosion crater [maar], tuff cone or tuff ring
Fire-fountaining & fiery explosive	Hawaiian & Strombolian	Scoria [lapilli, cinders], spatter, volcanic bombs	Scoria cone [cinder cone]
Lava outpouring	Strombolian & Hawaiian	Basalt lava	Lava flow, lava field or small lava shield

Figure 1. *Left*: Proportions of lava, scoria, and ash erupted from Auckland volcanoes. *Right*: Relationships between eruption style and landforms in AVF (both from Hayward et al. 2011a, p.3 & 5).

Ages

Dating the individual volcanoes (centres) in the AVF has been problematic for various reasons (e.g. Nichol 1992). Lindsay et al. (2011) recently reviewed the topic and assessed 186 age determinations that had been derived using five different dating techniques. They concluded that only three centres are reliably and accurately dated and eight are reasonably reliably dated (Fig. 3). Another 20 centres have been dated using tephrochronology. This method uses layers of tephra (Greek, *tephra*, 'ashes') – explosively erupted, loose fragmental volcanic material including volcanic ash (particles < 2 mm in diameter) (Lowe 2011) – preserved in lake sediments, and of known age, to date interbedded local basaltic ash layers using stratigraphic relationships (order of occurrence in the sedimentary sequences). The tephras also provide isochronous tie points to connect cores from different lakes and to help synchronise their time scales (see also Green et al. 2014). A good example of lake-based research is that of Molloy et al. (2009) (Fig. 4). Bebbington and Cronin (2011) used a different approach to age modelling and concluded that the spatial and temporal components appear independent and hence the location of the last eruption provides no information about the next.

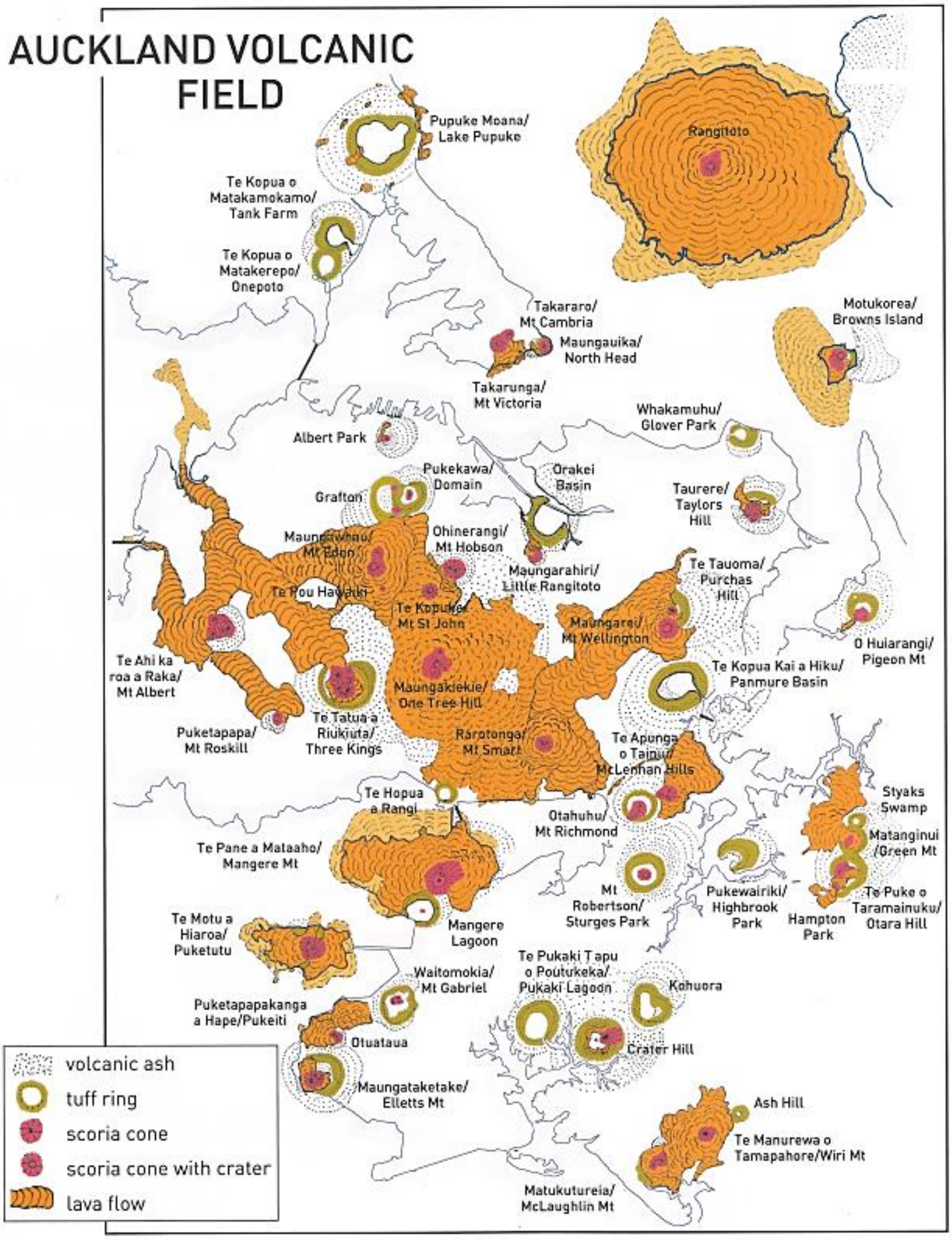


Figure 2. Map of volcanoes making up the AVF (from Hayward et al. 2011a, p.4).

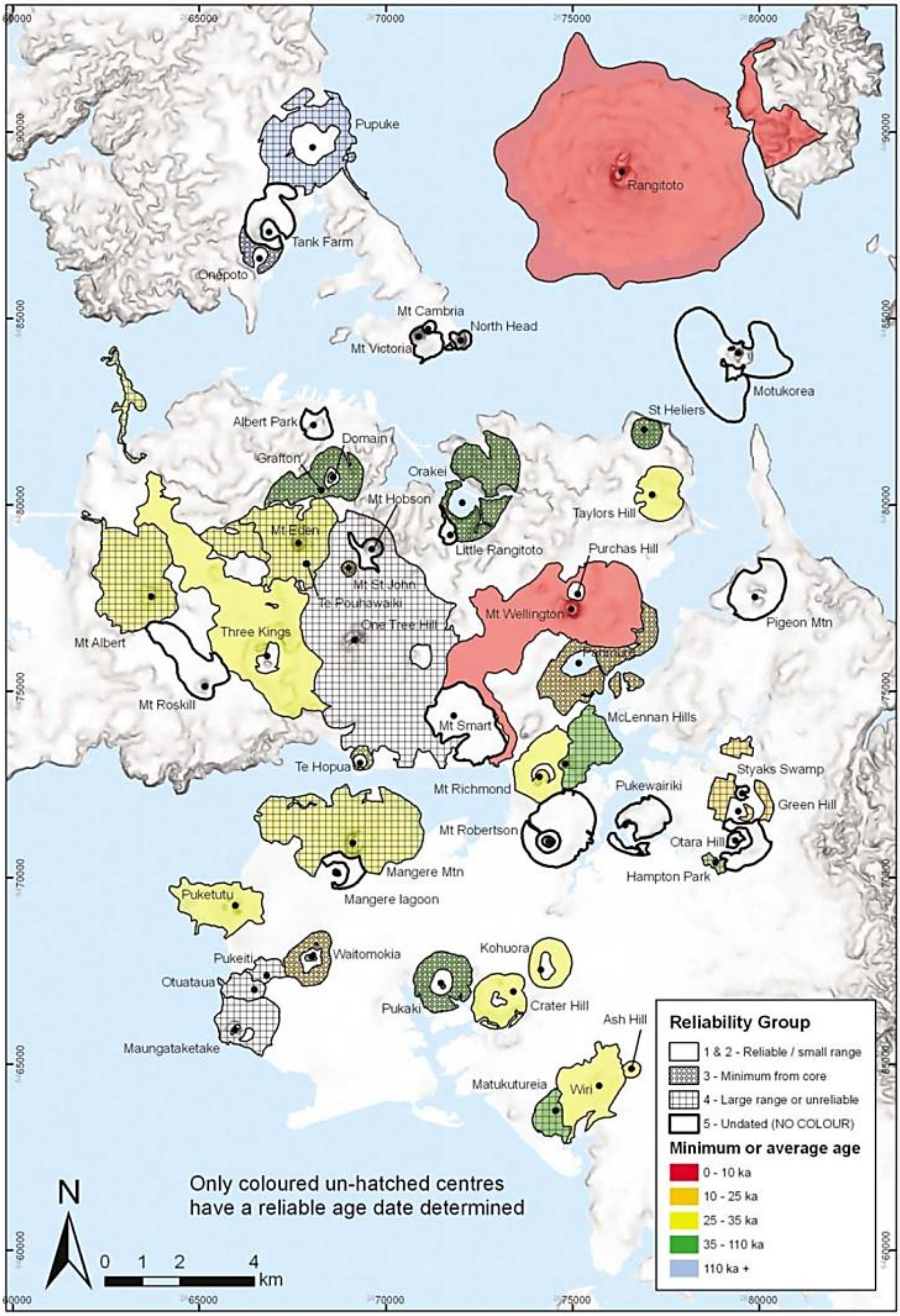


Figure 3. Volcanic deposits in AVF mapped according to their ‘best’ age estimate (from Lindsay et al. 2011, p.389).

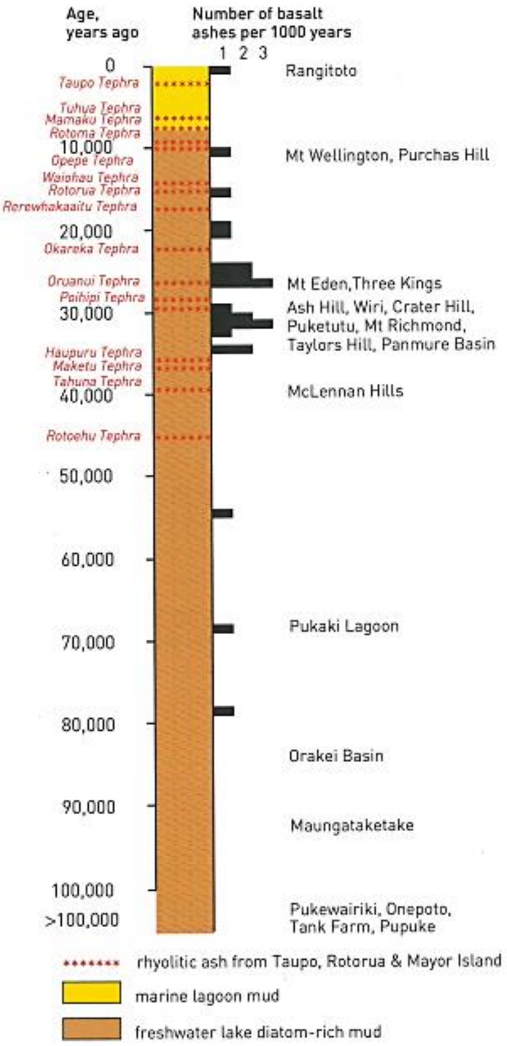


Figure 4. Composite sequence of AVF-derived basaltic ash eruptives intercalated with distal rhyolitc tephra layers (in red font) (derived from volcanoes in central North Island and Mayor Island) preserved within lake sediments in five volcanic craters (from Hayward et al. 2011a, p.28, after Molloy et al. 2009).

Paleoclimate studies

The sediments deposited in crater lakes provide a gold-mine of environmental change as well as a record of volcanic activity, and around ten lakes and lagoons have been drilled or cored in the AVF (Hayward et al. 2011a). In some lakes, the sediments are laminated (possibly on an annual basis). Various components including pollen have been extracted from the sediments and analysed by groups of specialist scientists in multidisciplinary palaeolimnological projects (e.g. Newnham et al. 2007; Augustinus et al. 2008, 2011, 2012; Stephens et al. 2012; Striewski et al. 2013). Studies of the Holocene, and of human impacts, include those of Newnham and Lowe (1991), Horrocks et al. (2002, 2005), Augustinus et al. (2006), and Heyng et al. (2014).

A general review of past climates of New Zealand since 30,000 years ago was developed by Barrell et al. (2013) for the New Zealand INTIMATE project (INTegration of Ice core, MArine, and TErrestrial records). They identified a general sequence of climatic events, spanning the onset of cold conditions marking the final phase of the Last Glaciation, through to the emergence to full interglacial conditions in the early Holocene. To facilitate more detailed assessments of climate variability, a composite stratotype was proposed based on terrestrial stratigraphic records. The type records were selected on the basis of having very good numerical age control and a clear proxy record. In all cases the main proxy of the type record is pollen. The type record for the emergence from glacial conditions following the termination of the Last Glaciation (post-Termination amelioration) is in a core of lake sediments from Pukaki crater (maar) in Auckland (near Auckland International Airport), and spans the period from c. 18,000 to 15,600 cal. years ago (Barrell et al. 2013).

Rangitoto volcano

Rangitoto is a graceful, almost symmetrical, volcanic cone which dominates the skyline to the northeast of Auckland City (Figs. 5, 6). It is the youngest and largest of the ~53 volcanoes in the AVF (Hayward et al. 2011b). The estimated volume of basalt in the volcano (1.8 km^3, dense rock equivalent) is about half the volume of all of the basalt in the field (Fig. 1). The volcano has a complex structure created during two distinct periods of eruption within the last ~600 years (see below for notes about possible earlier activity). The lower lava-covered slopes are relatively gentle (~4° slope angle) although they steepen towards the summit of the island (~12°) where the upper part of the volcano is made up of scoria cones. At the summit there is a central crater 60 m deep and 150 m in diameter. A second smaller crater to the east and a complex series of mounds, ridges and depressions to the north of the main crater show that activity was not confined to a single vent. Some of these features are remnants of older craters which were destroyed as the eruption progressed.

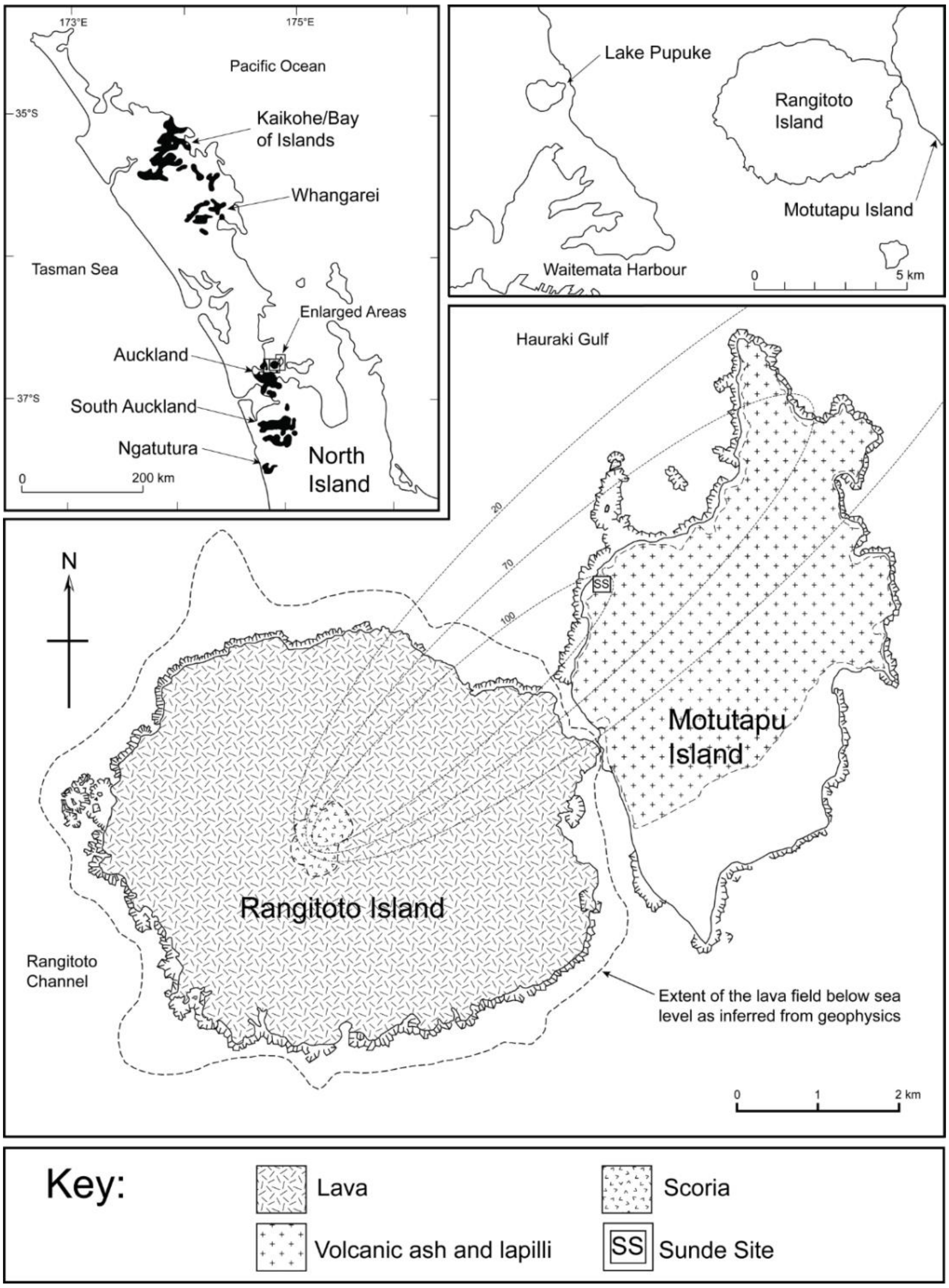


Figure 5. Geological sketch map of Rangitoto volcano and adjacent Motutapu Island, showing the main Rangitoto eruptive products. Ellipses show generalised areas of equal ash thickness (in cm) (termed isopachs) for the Rangitoto eruption of c. 600 years ago. Insets show the location of the Auckland Volcanic Field and other basaltic intraplate volcanic fields in the upper North Island, and the position of Lake Pupuke relative to Rangitoto. Adapted from Needham et al. (2010) (p.128).

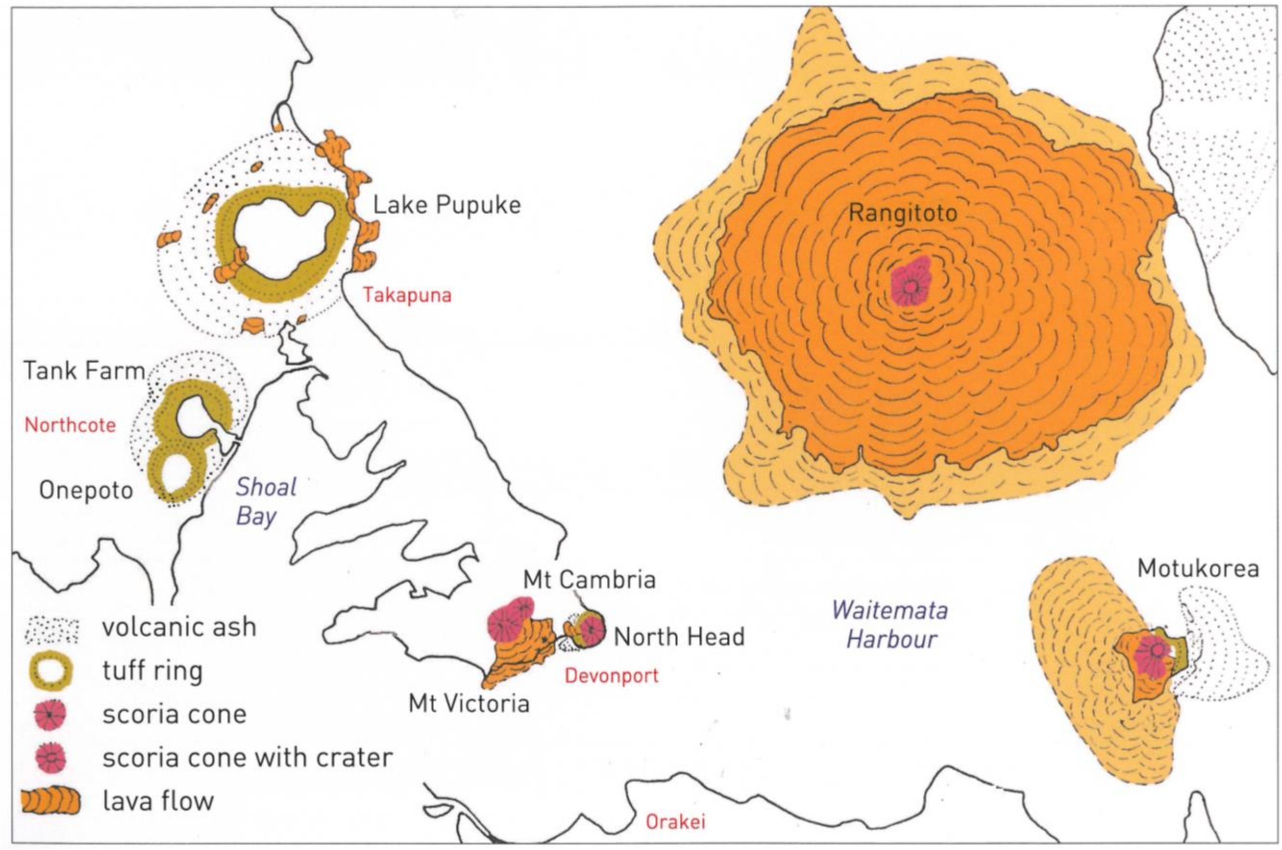


Figure 6. Volcanoes of the Waitemata Harbour and the North Shore (from Hayward et al. 2011a, p.100).

Figure 7. *Left*: Small historic bach (holiday cottage) near Rangitoto Wharf (photo by D.J. Lowe). *Right*: Map of Rangitoto showing the location of the University of Auckland drill site of February, 2014. The following notes are courtesy of Phil Shane, University of Auckland (pers. comm. 10 August 2014). “The ~150 m hole resulted in excellent core recovery (>95%) with core diameters of 10 cm and 7 cm (at greater depth) providing ample sample material. The upper 128 m of core comprises at least 27 lava flows with thicknesses in the range 0.3 m to 15 m, representing the main shield-building phase. The dense and mostly massive flow units are separated by autoclastic lava breccia created during flow emplacement. The lavas overlie marine sediments with intercalated lava and pyroclastics. The initial pyroclastic sequence comprises about 8 m of phreatomagmatic ash and lapilli, representing the subaqueous birth of the volcano. Miocene sediments were encountered at ~150 m”.

Formation of the island

Rangitoto began as a series of explosive phreatomagmatic eruptions caused when magma, originating from the mantle at depths of about 80 km, broke through the sea bottom at the entrance to the Waitemata Harbour (Figs. 8, 10). A series of ash explosions built up a low cone which eventually acted as a rampart and prevented the magma from interacting with sea water. A period of mildly explosive magmatic activity followed, during which lava fountaining and intermittent explosive activity built up an overlapping series of steep sided scoria cones (e.g. North Cone, Fig. 9), and covered much of nearby Motutapu Island in ash (Fig. 10). The alkaline basalt chemistry of these older deposits is similar to other Auckland volcanoes and is probably from an initial smallish eruption perhaps equivalent to Mt Wellington in size.

Following a time break of maybe a few decades, a new fire fountaining eruption occurred, producing the current summit scoria cone (i.e. Central Cone; Fig. 10). Towards the end of this eruption, lava flows broke out from fractures around the flanks of the cone to create a smooth apron of lava. The basaltic rocks produced during this younger (and larger) eruption have a different geochemical composition (sub-alkaline), suggesting the magma was formed from extensive melting of rock at a shallower depth in the mantle (about 60 km). It is possible that the passage of the first batch of magma through the mantle somehow triggered melting in another (higher) zone in the mantle on its way to the surface (Needham et al. 2010; McGee et al. 2011).

Two distinct alkaline and sub-alkaline macroscopic (visible) ash layers present in swamps on the nearby Motutapu Island, and in lake sediments from Lake Pupuke on the mainland, allowed Needham et al. (2011) to date the eruptive phases of Rangitoto (Fig. 11). Twigs, charcoal, and peat associated with the two ash layers selected for radiocarbon dating yielded ages of 553 ±7 calendar (cal) years BP and 504 ± 5 cal years BP (Needham et al., 2011) (BP = before present, ‘present’ being 1950 AD).

More recent research studying ‘non-visible’ ash layers, known as cryptotephras (‘hidden’ tephras), which are glass shard and/or crystal concentrations not visible as layers in the field; Lowe, 2011), also found in lake sediments from Lake Pupuke, suggests that Rangitoto may have been active intermittently since ~1500 cal years BP, a longevity of ~1000 years (Shane et al., 2013; Fig. 11). Based largely on this evidence, in February, 2014, University of Auckland (UoA) researchers drilled a 150-m deep borehole into the western flank of the volcano and obtained (mostly) continuous core through the sequence of volcanic deposits (Fig. 7 and photo above). This core is currently being analysed as a masterate project at the UoA.

In a further effort to understand the origins of the island, including existing faults and possible seismic activity, UoA and the DEVORA (Determining Volcanic Risk in Auckland) project installed a specialized borehole seismometer into the hole left by the coring (photo at left). This sensitive instrument records any seismicity that occurs under Rangitoto as well as the surrounding area. We are most interested in whether small earthquakes occur under Rangitoto that are too small to be seen on seismic recordings from the rest of the Auckland seismic network and whether we can locate faults based on the occurrence of these small events.

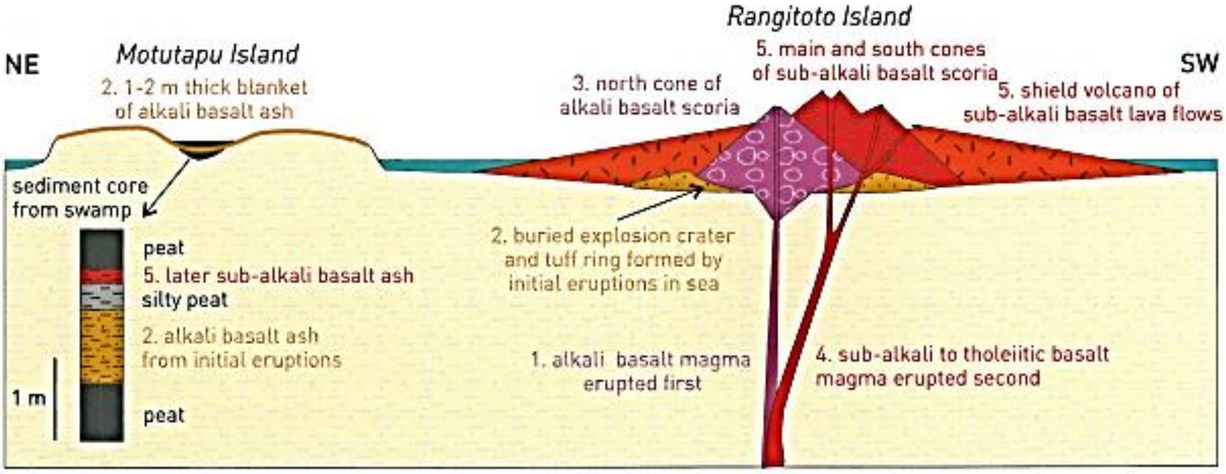


Figure 8. Cross section through Rangitoto volcano showing its latest eruption sequence (1 to 5) and the mantling of nearby Motutapu Island with wind-blown ash (from Hayward et al. 2011a, p. 102). See Fig. 10.

Figure 9. *Top*: Rubbly a'a lava flow surface rucked up into curved ridges as the lava within the flow moved slowly downslope. *Left*: Aerial views of two scoria cones (upper photo) and the summit crater (lower photo) (photos from Hayward et al. 2011a, p.103, 104).
Below: Weathering in a vesicular bomb near summit – the yellowish brown colouration is a hydrous alteration product ("gel-palagonite"), very likely a nanocrystalline variety of smectite(s) (Churchman and Lowe, 2012) Lens cap is 5 cm in diameter (photo by D.J. Lowe).

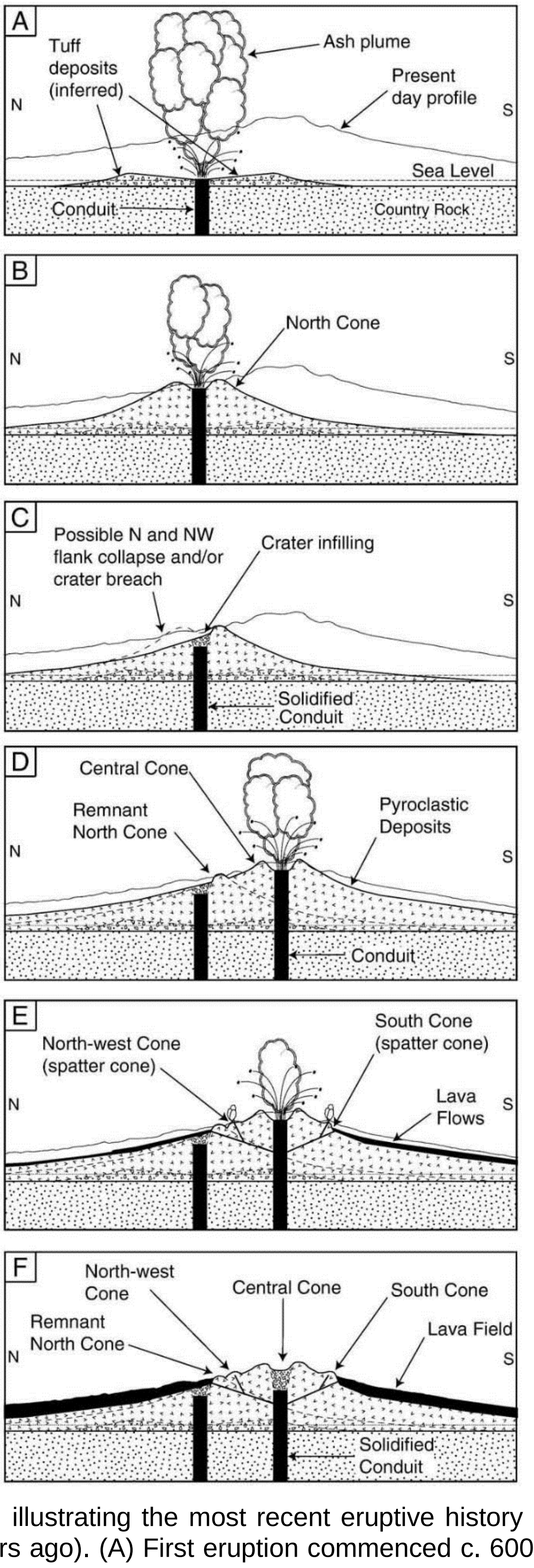


Figure 10. Schematic diagram illustrating the most recent eruptive history of Rangitoto volcano (i.e. the phases from c. 600 to 550 years ago). (A) First eruption commenced c. 600 years ago, probably erupting through shallow seawater and generating a phreatomagmatic tuff ring; (B) strombolian style activity resulted in the formation of a scoria cone ~200m asl, depositing ash on nearby Motutapu Island; (C) a period of quiescence of several decades followed the first eruption, during which the original conduit partially solidified; (D) the early stages of the second eruption, c. 550 years ago, were dominated by Strombolian style activity, which built a steep-sided scoria cone forming the present-day summit and deposited a thin layer of ash on Motutapu; (E) a period of lava effusion lead to the development of the extensive lava field and associated near-vent spatter cones; (F) the main features of Rangitoto volcano today (from Needham et al. 2010, p.131).

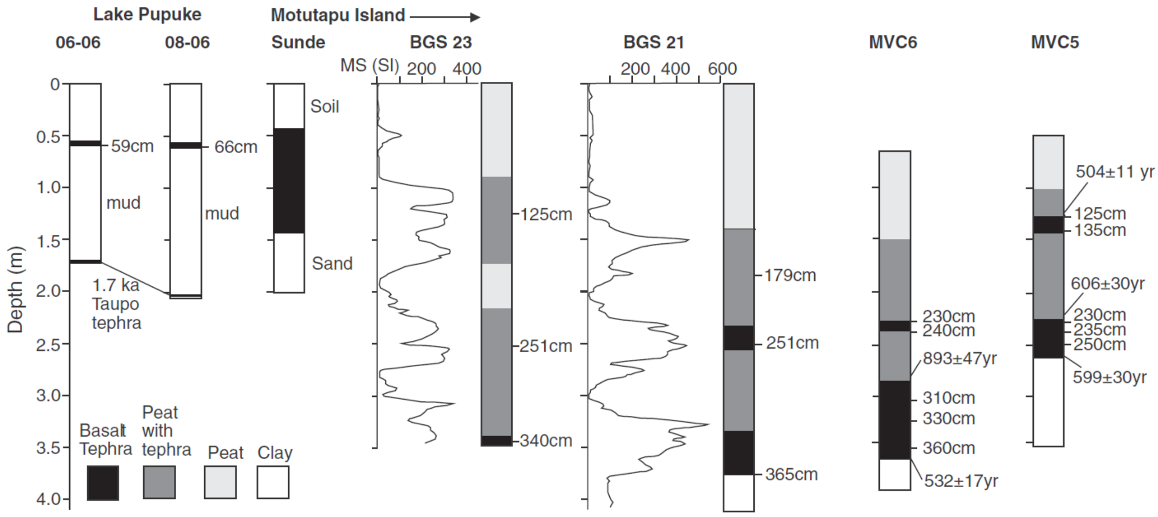


Fig. 2. Summary logs of cores containing Rangitoto tephra examined in this study, with magnetic susceptibility data (MS in dimensionless SI units) for BGS 23 and 21. For site locations see Fig. 1A and Supplementary data. Macroscopic tephra layer samples used in geochemical studies are marked as depths (in cm, right of log). Ages for MVC5 and 6 are calibrated radiocarbon data from Needham et al. (2011). The Sunde site is an outcrop on Motutapu Island.

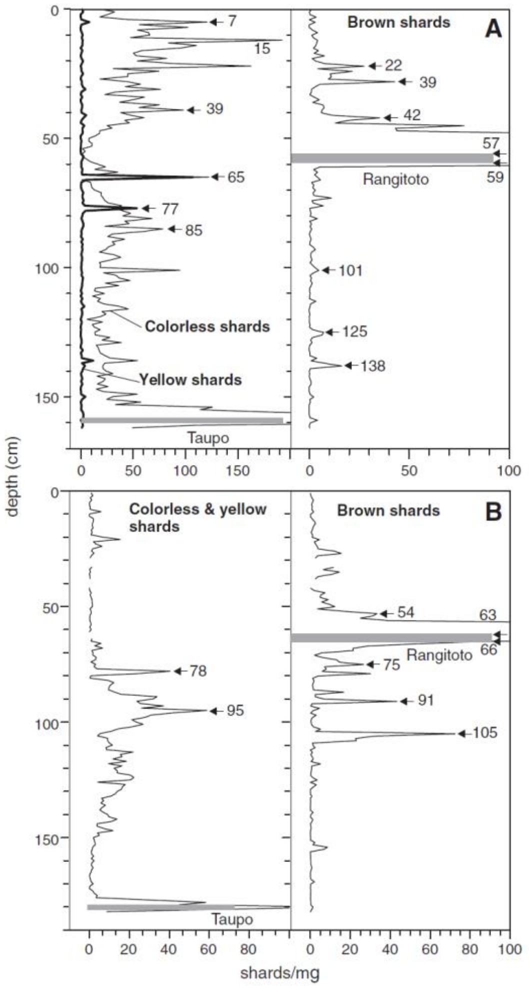
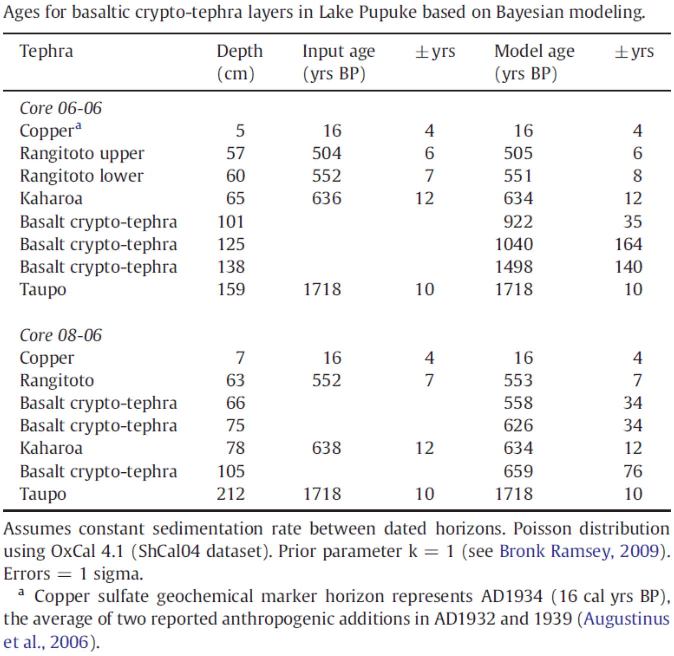


Fig. 4. Concentration of shards in sediment samples from Lake Pupuke cores 06-06 (A) and 08-06 (B). Numbers represent depths (cm) of samples used in geochemical studies. Macroscopic tephra layers of Rangitoto and Taupo tephra are shown as grey bars. Note differences in scaling of shard concentrations (x-axis).



Ages for basaltic crypto-tephra layers in Lake Pupuke based on Bayesian modeling.

Tephra	Depth (cm)	Input age (yrs BP)	±yrs	Model age (yrs BP)	±yrs
Core 06-06					
Copper[a]	5	16	4	16	4
Rangitoto upper	57	504	6	505	6
Rangitoto lower	60	552	7	551	8
Kaharoa	65	636	12	634	12
Basalt crypto-tephra	101			922	35
Basalt crypto-tephra	125			1040	164
Basalt crypto-tephra	138			1498	140
Taupo	159	1718	10	1718	10
Core 08-06					
Copper	7	16	4	16	4
Rangitoto	63	552	7	553	7
Basalt crypto-tephra	66			558	34
Basalt crypto-tephra	75			626	34
Kaharoa	78	638	12	634	12
Basalt crypto-tephra	105			659	76
Taupo	212	1718	10	1718	10

Assumes constant sedimentation rate between dated horizons. Poisson distribution using OxCal 4.1 (ShCal04 dataset). Prior parameter k = 1 (see Bronk Ramsey, 2009). Errors = 1 sigma.

[a] Copper sulfate geochemical marker horizon represents AD1934 (16 cal yrs BP), the average of two reported anthropogenic additions in AD1932 and 1939 (Augustinus et al., 2006).

Figure 11. *Top*: Stratigraphic and chronological evidence of 2 separate phases, c. 600 and 550 years ago, of Rangitoto activity as recorded by ashfalls in Pupuke sediments and on Motutapu Is. *Bottom*: Evidence from the cryptotephra record for prolonged activity at Rangitoto beginning c. 1500 years ago. Taupo (232 ± 10 AD) (base of sequence) and Kaharoa (1314 ± 12 AD) tephras (65 in A, 78 in B), and a 20th Century copper spike, provide independent ages for the sequences (figures from Shane et al. 2013, pp.176-178).

Maori presence and earliest Polynesian settlement

Although no oral tradition has survived that describes the eruption and formation of Rangitoto (see Lowe et al. 2002), it is known that Maori (descendants of the initial Polynesian settlers) were living on the adjacent Motutapu Island at the time. Ash from the latest eruption phases buried wood and shell of a habitation site in Administration Bay, and excavations at the Sunde Site have revealed casts of Maori dog and human footprints in the ash (photo at right is from Nichol 1982), together with evidence for gardening activities (Davidson 1978; Nichol 1981).

The timing of the earliest Polynesian settlement of the New Zealand archipelago, the last substantial land mass in the world (outside polar regions) to be colonized by humans, has been controversial, partly because it has been so recent (Lowe 2011). Radiocarbon age data, potentially open to question because of likely contamination in lake sediments by in-washing of old carbon as a result of Polynesian deforestation activities, inbuilt age, or dietary effects, effectively resulted in two contradictory models of settlement: ‘early’ settlement about 1500–2000 years ago (Sutton 1987) versus ‘late’ settlement about 700 years ago (Anderson 1991). The rhyolitic Kaharoa tephra, erupted 700 years ago (2014 is the septingentenary of the eruption) from Mt Tarawera in winter, 1314 ± 12 AD (Hogg et al. 2003), is distributed widely over much of eastern and northern North Island, and is present in Lake Pupuke as a cryptotephra (Shane et al. 2013; Fig. 11). It provides a ‘settlement datum’ or isochron to help determine which model was more likely to be correct by linking and dating palynological (pollen) evidence of initial human impact (derived from analyses of cores from peat bogs and lakes) with archaeological and artefactual evidence (Newnham et al. 1998).

No cultural remains are known to occur beneath the Kaharoa tephra apart from a rat-nibbled seed on the northeast coast of the Coromandel Peninsula (Wilmshurst and Higham, 2004), and palynological evidence for earliest human-induced impact (a sustained deforestation signal comprising a decline in tall trees and a concomitant rise in bracken spores) occurs stratigraphically just before its deposition in five pollen profiles out of around two dozen documented sites (Lowe 2011). The use of the Kaharoa tephra isochron, together with a wide range of evidence including lake- and bog-derived pollen records, bones of the commensal Pacific rat *Rattus exulans*, rat-nibbled seed cases and snail-shells, fire records, ancient DNA, and archaeological and (reliable) radiocarbon data, all support the ‘late’ settlement model (Lowe et al. 2014). The earliest Polynesian settlement of New Zealand is now dated at c. 1280 AD (Higham et al. 1999; Wilmshurst et al. 2008, 2011, 2014). The presence of the rat-nibbled seed beneath Kaharoa tephra, and the sustained rise in bracken spores starting just below the tephra in pollen profiles, are consistent with earliest settlement occurring a few decades prior to the c. 1314 AD eruption of Kaharoa (Lowe et al. 2000, 2014) (cf. Jacomb et al., 2014).

Soils

The youthfulness of the latest eruptives on Rangitoto Island, and of the ash fallout deposits on adjacent Motutapu and Rakino islands, means that the soils are only weakly developed recent soils at best. Bare lavas are ‘nonsoils’.

Rangitoto Island

The soils may be mapped into two groups (i) on lavas, and (ii) on the scoria cones. The bare-rock lavas are ‘nonsoils’ in *Soil Taxonomy* (Soil Survey Staff 2014), and Rocky Raw Soils in *New Zealand Soil Classification* (Hewitt 2010). Sand-sized fragments of rock and partly-decomposed litter can occur in cracks and crevices in the lava. If these sand and organic materials are ≥ 5 cm in thickness then such small patches of soil are Lithic Udorthents (sandy Entisols) or Lithic Udifolists (shallow organic soil or Histosols) (ST), or Rocky Recent Soils (NZSC). On the scoria, the soils may qualify as Vitrandic Udorthents (ST), or as Typic Tephric Recent Soils (NZSC) provided A horizons (including, if present, partly decomposed litter horizons designated F, H) are ≥ 5 cm in thickness (Fig. 12).

Motutapu Island

The ash mantle on Motutapu Island, generally < 1 m in thickness, provided a new material in which soil could form over the past 500-600 years (Fig. 12). The ash buried a pre-existing soil (Ultisol in ST, Ultic Soil in NZSC, meaning strongly weathered, clayey, slowly permeable, acid soils). The modern soil although fertile is coarse grained (sandy) and has a low water-holding capacity. Where the ash mantle is > 50 cm thick, the soil is either a Typic Udorthent or a Vitrandic Udorthent (both being Entisols) in ST; where the ash is < 50 cm thick, the paleosol is ‘recognised’ and the soil is possibly an Aquandic Palehumult (needs certain properties). In NZSC, the soil is a Tephric Sandy Recent Soil.

Figure 12. *Photos upper left and right* show section of scoria near the summit and associated soil profile of Rangitoto gravelly sand (pocket knife for scale). *Photo lower left* shows weak soil profile developed in red (oxidised) scoria (lens cap 5 cm in diameter) (photos by D.J. Lowe). *Photo lower right* shows soil profile of Rangitoto sandy loam formed on Rangitoto ash over a buried Ultisol/Ultic Soil on Motutapu Island (scale in inches; photo by H.S. Gibbs).

Flora of Rangitoto

The flora on Rangitoto is unique among the islands situated in the Hauraki Gulf because of the island’s young age, and the fact that technically Rangitoto is an ‘oceanic’ island. This means that as Rangitoto emerged from the sea, and was never connected to the mainland of New Zealand, its flora and fauna are derived entirely from long distance dispersal – an oddity indeed for an island which sits on a continental shelf in such shallow water. The island is home to some 582 vascular plant taxa of which 228 (39%) are indigenous (Wilcox 2007). Although there are no endemic vascular plants, the island is a stronghold for a number of plants that are now 'threatened' or 'at risk', or both, on the adjacent mainland, e.g., the white-flowered kohuorangi or Kirk's tree daisy (*Brachyglottis kirkii* var. *kirkii*), wild carrot (*Daucus glochidiatus*), and plumed greenhood (*Pterostylis tasmanica*) (de Lange et al. 2013). Kirk's tree daisy is declining on the mainland because of possum browse, and the same was happening on Rangitoto until possum were eradicated from the island in 1996. Aside from flowering plants, conifers, ferns and clubmosses, Rangitoto is also home to 94 mosses (three naturalised) and 70 hornworts and liverworts (one, *Lunularia cruciata*, is naturalised). While the mycobiota of the island have yet to be properly studied, 194 lichens (lichenized fungi) have been recorded from the island together with c.170 fungi. The island is the type locality for a number of mosses and liverworts, several of which were long believed endemic to the island, e.g., *Lepidozia elobata*, *Plagiochila bazzanioides*, and *Tortella mooreae* (now *T. cirrhata*). The occurrence of endemic mosses and liverworts on an island with a flora believed to be c. 550–600 years or less in age was always considered anomalous, and it is not surprise that all of these 'endemics' have since been discovered elsewhere in New Zealand, although, oddly, not so far from the adjacent mainland.

Ecologically what marks Rangitoto is the dominance of pohutukawa (*Metrosideros excelsa*) – Rangitoto supports the single largest tract of this forest type in New Zealand, and the role that this species has played in the colonisation of bare lava. This is of course a key process repeated by the genus *Metrosideros* throughout the Pacific where they all play a critical role in converting bare lava to forest. On our visit, though, note the dominance of lichens, mosses and at times liverworts, all of which play an important role in converting lava to 'soil' thereby allowing other plants to establish.

Several other botanical features of Rangitoto are worth noting, namely the occurrence of many vascular plant epiphytes in terrestrial settings, the porous lava providing them with the same conditions found in forest canopies. Also there are 'weed' species, many of which derive from the distinctive holiday cottages (or 'baches') on the island (predating c. 1940). Some of these weed species are components of the Macronesian flora of the Canary Islands, brought to New Zealand as ornamentals and, finding Rangitoto offering a range of habitats similar to those of their distant volcanic home, they have flourished. Whilst most are aggressive weeds, some (such as the species of the genus *Aeonium* and *Echium*) are actually threatened plants in their distant home, and so present a 'slight' conservation management dilemma.

Now that Rangitoto and nearby Motutapu Island are 'pest-free', both islands afford innumerable opportunities for the restoration of flora and fauna now extirpated or threatened in the wider Hauraki Gulf region. As such the island has been subjected to a number of indigenous fauna introductions, and a range of plants have also been trialled, including the 'threatened' scurvy grass *Lepidium flexicaule*, last seen on the island in 1906.

Some geological features

A walk on Rangitoto (Fig. 13) reveals many interesting volcanic features. The gentle lower slopes are composed of many overlapping lava flows whose surfaces commonly show good **pahoehoe** textures near to their source, and **a'a** textures at their distal (coastal) ends. Toward their distal ends the margins of many flows are defined by prominent **levees** formed by accumulation of chilled lava at the margins of moving flows. The a'a type of lava is by far the most common on Rangitoto.

A small but well-developed system of **lava tunnels** linked by **lava trenches** occurs on the south-eastern flanks of Rangitoto Island close to the boundary between the summit **scoria cones** and the surrounding **lava field**. The tunnels formed after still-molten lava withdrew from a channel roofed by chilled lava; the trenches formed in places where the roof was too thin and collapsed as the lava withdrew, or where a roof did not form.

The summit **scoria cone** rises from the "**moat**" at the top of the lava slopes. As seen from Auckland the cone consists of multiple structures, with two outer hills flanking the younger summit cone and crater. It is thought that there are remnants of earlier cones destroyed by later eruptions. Good exposures of **scoria** forming the summit area are seen on tracks on the north-eastern side (Fig. 12); these formed by episodic **fire fountaining**. When fresh, the scoria is normally dark grey to black but reaction with water percolating through the hot porous scoria soon after the eruption has caused some of the clasts to turn a deep red because of oxidation of the iron in them.

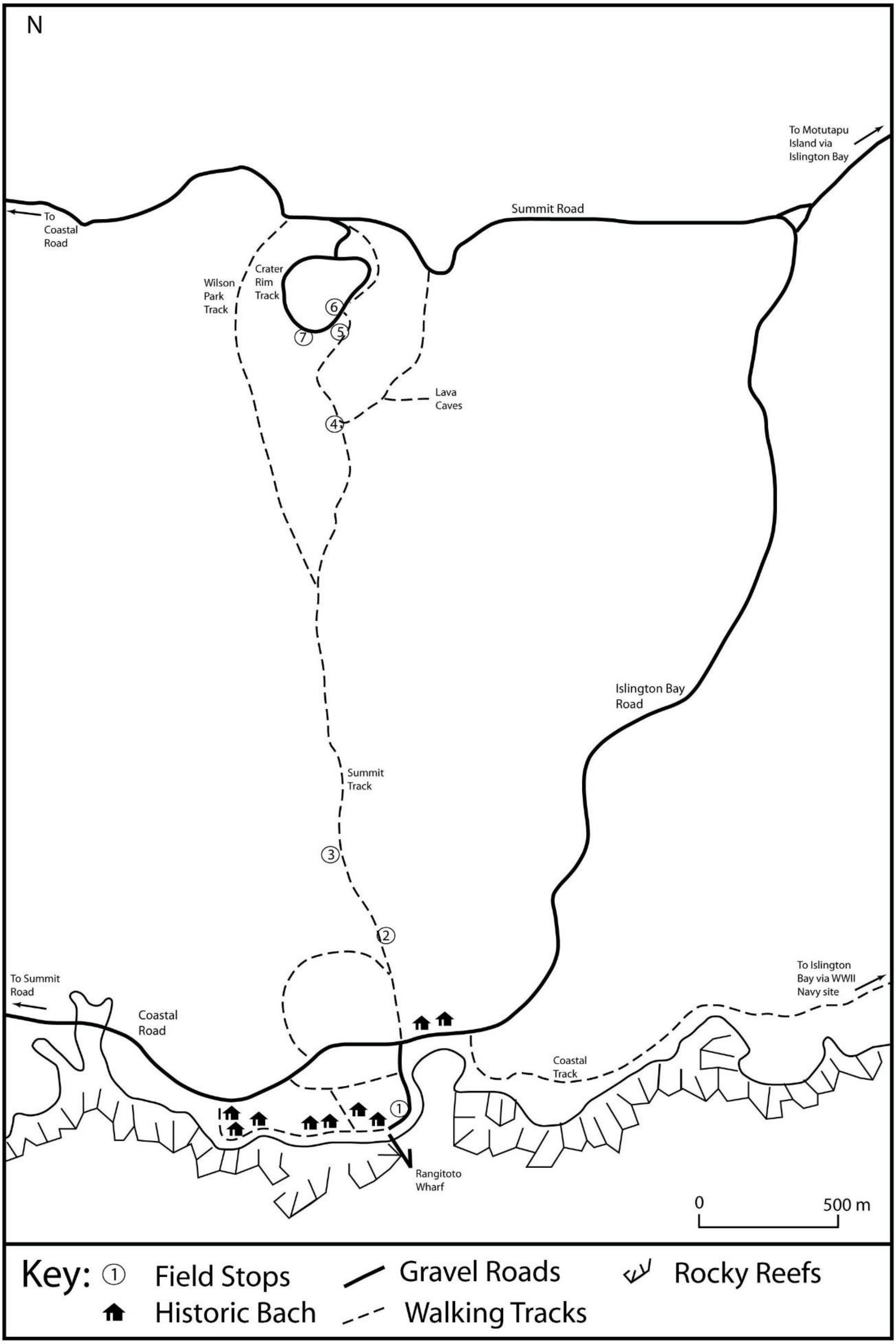


Figure 13. Map showing the localities of the various field stops and general geographical features of the southern part of Rangitoto Island (from Lindsay et al. 2010).

Description of field stops (Fig. 13)

Ferry arrives approximately 1.00 pm

1. **Information shelter at Rangitoto Wharf** *Introduction, lunch, and briefing*. Toilets available.

   After a short ferry ride we will arrive at Rangitoto Wharf, situated on the southern coast of Rangitoto Island and at the periphery of the Rangitoto lava field. Sea level has remained essentially the same since the eruptions of Rangitoto, so the features seen on the coast will shed some light on how the lava interacted with the sea water towards the latter stages of the second eruption. Be sure to look at the smooth, wrinkly, curved lava features that snake their way into the water parallel to the wharf.

   We will stop here to listen to brief presentations:
   Dan Hikuroa (Maori perspective)
   Kate Lewis Kenedi (volcanic perspective)
   Peter de Lange (vegetation perspective)

2. **Raised margin of lava flow** *Brief discussion of the Rangitoto lava field and of lava flow textures*.

   As we make our way towards the summit we will see the features and textures of the Rangitoto lava field. *Please stay on the track at all times*. Near the source of lava effusion (at the base of the scoria cone) the lava field is quite thick, up to 50 m, whilst at the coast it is considerably thinner, less than 20 m in thickness (although individual flows themselves are no more than 5 m thick). The majority of the lava field is comprised of blocky, clinker a'a lava flows, with rarer occurrences of smooth, ropey pahoehoe lava flows along the main track to the summit and along coastal areas, e.g. near Islington Bay and the Rangitoto Wharf.

   During eruption, the a'a flow tops transported brecciated, broken lava blocks downslope, which sit atop a more massive flow core (see photos below). The blocks form at the leading edge of a flow due to instantaneous cooling with the air or water. Blocks generally tumble down the steep flow fronts and are either 'bulldozed' or buried by the advancing flow. Rocks on the outside of the flow tend to be highly vesicular and glassy, whilst those from the flow interior tend to be more massive and crystalline.

Figure 14. Blocky lavas on lower summit track (photos by D.J. Lowe).

3. **DOC information point** *This is on the boardwalk, on the left side of the main track, as we ascend. It provides a good opportunity to discuss the structure of the lava field and view to summit. Also a viewpoint southwest towards Auckland City.*

4. **Moat between lava field and summit cone** *Pause to regroup and discuss the two eruptive styles of Rangitoto.*

   At an elevation of 150 m the southern and eastern flanks of the volcano are dominated by an unusual moat-like structure, which defines the boundary between the lower lava-covered slopes and the scoria crown. It likely formed as a result of a subsidence event following the release of significant volumes of lava from fissures on the upper flanks.

5. **On track immediately before summit crater** *Deposits of lapilli from the scoria cone*.

   Exposed in cuttings next to the summit track not far from the main crater are layers of the pyroclastic material (pyroclastic literally means ‘fiery fragmental’) comprising scoria of lapilli (clasts 2-64 mm in diameter) and bombs (rounded clasts >64 mm) that make up the central scoria cone of Rangitoto. These glassy, highly vesicular rock fragments originate from gas-rich molten or semi-molten lava that has been ejected into the air, quickly cooled and deposited close to the vent, frequently still partially molten. The clasts are typically cylindrical, spherical, teardrop, dumbbell or button-like in shape, and generally take their shape when they are airborne. Also common in the pyroclastic deposits of Rangitoto is ‘welded’ scoria, which forms when semi-molten scoria fragments ‘stick’ to other fragments when they land. The accumulation of the pyroclastic fragments described above formed the Rangitoto scoria cone. Much of the scoria is dark or black; red scoria indicates Fe-bearing minerals have been oxidised during eruption. Weak soils have developed on the scoria (Fig. 12).

6. **Summit crater** *Not far from Stop 5 is the observation deck located on the rim of the main crater of Rangitoto.*

   The near circular bowl-shaped crater of Rangitoto is approximately 150 m in diameter and 60 m in depth, and reaches a height of ~260 m above sea level (Fig. 9). This is the position of the vent for the second Rangitoto eruption c. 550 years ago (of the latest eruption sequence), which started off as a moderately explosive (Strombolian style) eruption, forming the scoria cone, and then becoming more effusive (Hawaiian style) towards the latter stages of the eruption.

7. **Summit** *Discussion of the Auckland Volcanic Field and of the two most recent eruptive phases of Rangitoto. Leave this stop by 3:30 pm.*

   At the summit we are presented with a 360° view of Rangitoto volcano and the surrounding natural and human-made features. To the southwest we can see the Auckland CBD, situated next to the Waitemata Harbour, and some of the other larger volcanic cones (Mt Wellington, Mt Eden, One Tree Hill, The Domain, Mt Mangere) in the AVF. To the west we see the residential suburbs of North Shore City and smaller volcanic cones (North Head, Mt Victoria) and slightly larger explosion craters (Lake Pupuke, Tank Farm, Onepoto Basin). To the north-east we see Motutapu Island, which was covered in significant volumes of volcanic ash from the Rangitoto eruptions. Ash from both Rangitoto eruptions has also been found in drill core from Lake Pupuke (Figs. 5, 6, 11). To the south and southeast we see the other islands of the Hauraki Gulf, the islands of Waiheke and Motuihe, and volcanic cone(s) of Motukorea (Brown’s Island), notable not only for its beautiful cones but also for its own special mineral, motukoreaite (Rodgers et al. 1977).

8. **Descent** *Please take care on the descent as the scoria gravel can be unstable under the feet.*

9. **Baches adjacent to the wharf**

Time permitting, we can look at some of the baches – small holiday cottages – that form a still-active community on Rangitoto (Fig. 7). The baches were built in the 1920s and 30s and consist of private holiday dwellings and boatsheds as well as communal facilities such as a swimming pool and a community hall. Built by families during the depression era, they demonstrate a do-it-yourself attitude. Since 1937 it has been prohibited to construct new buildings on the island, and in the 1970s and 80s baches were pulled down, as the original leases expired, in an effort to diminish human influence on Rangitoto. However efforts prevailed to preserve the last remaining baches (34, from a maximum number of 140) as artefacts of New Zealand’s architectural and social history.

Ferry departs 5:00 pm

Times subject to change according to weather – talk to the trip leaders!

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