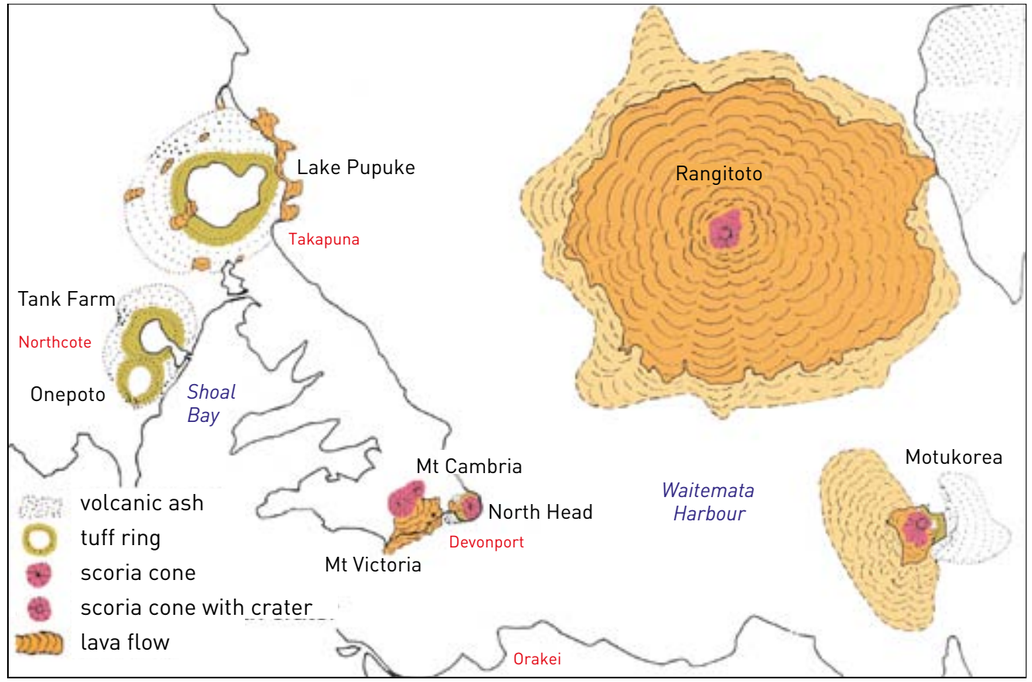
Volcanoes of the Waitemata Harbour and North Shore

Eight volcanoes have erupted in the northern part of the Auckland Volcanic Field. Two are located in the Waitemata Harbour and six on the North Shore. Rangitoto is the only one of Auckland's volcanoes known to have erupted in the sea; Motukorea, also located in the harbour, appears to have erupted on land, when the sea level was lower. On the North Shore there are three volcanoes at Devonport and three in the Takapuna–Northcote area. All three Devonport volcanoes (North Head, Mt Victoria, Mt Cambria) produced scoria cones and erupted lava flows, whereas the three near Takapuna (Pupuke, Tank Farm, Onepoto) erupted explosively, forming large craters surrounded by tuff rings. In the north we have both the youngest (Rangitoto) and oldest (Pupuke, Onepoto) volcanoes in the Auckland field.

One of North Shore's volcanoes has been quarried away (Mt Cambria) and one of the intertidal craters has been reclaimed (Onepoto), but the rest are in good shape. All the scoria cones were modified by pre-European earthworks and used as defended pa. The two most prominent cones at the entrance to the inner Waitemata Harbour (North Head, Mt Victoria) were further excavated by Europeans for naval forts. Parts of Rangitoto were also extensively modified by defence forces during World War II. Today the cones or explosion craters of all remaining volcanoes, as well as the stump of Mt Cambria, are reserves.



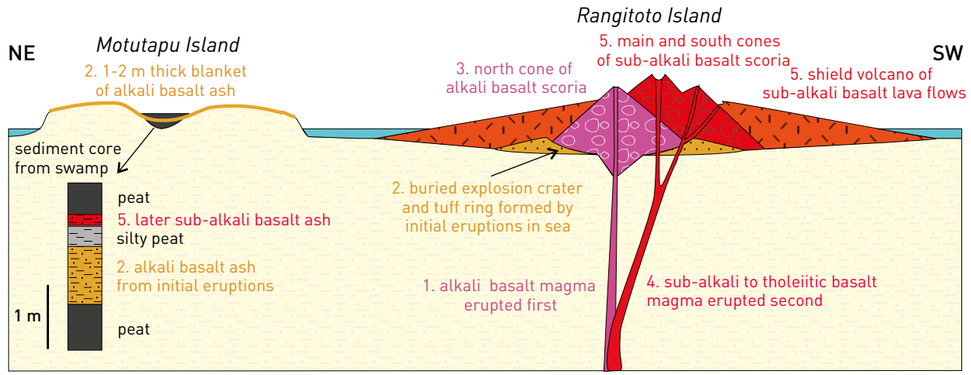
Rangitoto

Rangitoto – which erupted more lava than all the other volcanoes in the field combined – is the youngest and by far the largest of Auckland's volcanoes. Moreover, its fiery display about 600 years ago was the only eruption of an Auckland volcano to be witnessed by humans. We know this because archaeologists have found the remains of a small Maori fishing village buried by around 1 metre of Rangitoto ash on the shore of neighbouring Motutapu Island. There is no evidence that anyone in the settlement was killed by the eruption, but human and dog tracks in the soft wet ash show that the local people were still present during or between some of the eruptions.

The only one of Auckland's volcanoes known to have erupted in the sea, Rangitoto came up in the entrance to the Waitemata Harbour, in the very middle of the main channel (the drowned course of the Waitemata River). Before it erupted, there was a deep-water channel all the way in to where downtown Auckland is now located. Because the eruption blocked the main channel, the harbour authorities had to dig and deepen the present-day Rangitoto Channel through what is the drowned crest of a low ridge of Waitemata Sandstone.

Rangitoto began life with a major phase of wet explosive eruptions that sent large quantities of volcanic ash into the air. Much of it was blown northeast to mantle Motutapu Island with a metre or more of ash. It is inferred that coarser debris and ash built a tuff cone island in the centre of the harbour entrance, any trace of which is now buried beneath later lava flows and scoria deposits. Once the volcano's vent was above water level and the sea was excluded from interacting with the rising molten magma, the eruptions switched to dry-style fire-fountaining and the voluminous outwelling of lava flows which built up the circular shield volcano of Rangitoto that we see today.

Profile of Rangitoto from the south showing the gentle lower slopes of the lava flow shield surmounted by the steeper main scoria cones. The two secondary scoria cones on either side of the main one are not visible from this angle as they are in line with the main cone.



Northeast–southwest cross-section through Rangitoto Volcano, summarising its sequence of eruption (1 to 5)and the mantling of neighbouring Motutapu Island with wind-blown ash.

Geochemical studies by Auckland University MSc graduate student Andrew Needham in 2008 have shown that two different batches of magma sourced from different depths within the mantle erupted to form Rangitoto. The first batch is said to have an alkali basalt composition and came from about 80–90 kilometres down. All the initial thick ash deposits on adjacent Motutapu Island are of this composition, as is the scoria forming the northern cone near the summit of Rangitoto. If any lava flows were erupted during this first phase of eruption they are now buried beneath the voluminous later flows.

Sediment cores taken by Needham in small swamps on Motutapu show 10–100-centimetre-thick alkali basalt ash deposits separated by 30–50 centimetres of swamp silt from much thinner (less than 10 cm) volcanic ash with a tholeiitic basalt composition, erupted from a second batch of magma. All of Rangitoto's lava flows and the main and southern scoria cones were erupted during this second phase. The chemistry of these rocks indicates that it was sourced from 70–80 kilometres depth. It clearly came up the same conduit as the earlier batch and not too long after, as the route had not been blocked by magma cooling and solidifying in it. Solidified basalt had only blocked the plumbing just beneath the northern cone and thus this second batch of magma was re-routed a few hundred metres to the south to erupt at the surface.

It is hard to estimate the amount of time it would have taken for 30–50 centimetres of silt to accumulate in the Motutapu swamps between the two phases of eruption, as much material would have washed off the deforested hills in the first big rainstorms. Similarly, it is difficult to find plant material that may have colonised the new ash and was growing on the site when the second eruptions began and hence would have provided a reliable radiocarbon date of the time between eruptions. Further away, however, there are two thin Rangitoto ash layers (each less than 1 cm thick) in a core from the floor of Lake Pupuke. They too have the two different compositions that Needham has recognised on Rangitoto and are separated by only 1 centimetre thickness of lake sediment. Calculating the background rate of lake sediment accumulation indicates that there was a maximum of 7–20 years between the two phases of eruption of Rangitoto. Archaeologist Reg Nicol, who excavated the buried Maori village site on Motutapu Island, found evidence of gardening activity in the volcanic ash of the first eruptions prior to burial by ash from the second phase.

The second batch of magma may have erupted for several years, building several scoria cones above the vent and extruding massive quantities of lava from all around the base of the growing cones. The youngest scoria cone forms the summit peak and has a substantial, 60-metre-deep crater. The remnants of an earlier cone are partly buried on its south side. Numerous overlapping lava flows gradually built up a gently sloping (about 10°) circular shield volcano that surrounds the central scoria cones. Thus the

TOP A'a lava flows of Rangitoto in the 1860s. PHOTO: JOHN KINDER, 1868, AUCKLAND MUSEUM, JAMES RICHARDSON ALBUM V.5.
ABOVE Painting of the summit of Rangitoto from the east by Charles Heaphy, 1850s. The slightly lower north and south cones are depicted. Note the lack of vegetation at this time. PHOTO: ALEXANDER TURNBULL LIBRARY, WELLINGTON, C-025-001.

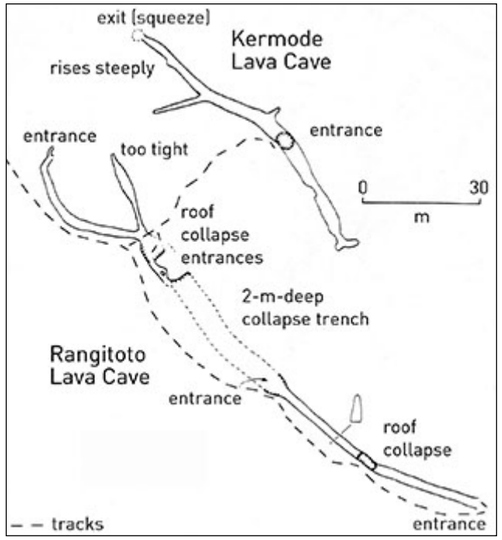
characteristic profile of Rangitoto when viewed from Auckland City comprises the gently sloping shield on either side with three steeper bumps on the crest. The highest central bump is the youngest scoria cone and the lower two are partly buried earlier scoria cones, the northern produced during the first phase of eruption and the southern during the second phase.

Most of the lava flows were of the a'a variety, in which their molten lava slowly moved along inside a thick carapace of broken-up chilled crust. Some lobes with ropey pahoehoe surfaces can be seen near the coast. There is a depressed moat between the top of the lava flows and the scoria cones around their southeast side. The track to the lava caves runs through this moat for some distance. The moat was probably formed by the slight subsidence of the scoria cones into the vent as lava withdrew back down the volcano's throat at the end of Rangitoto's eruptions.

A number of lava caves near the centre of the island are worth a visit, especially if you have a torch. These formed when hot lava drained out from inside the solidified outer crust of the flows leaving hollow tubes. The main 100-metre-long cave is the most publicly visited cave in Auckland and has an unusual trench-like shape with near-vertical walls. Entry and exit points are where the roof has collapsed and there are several other sections of collapsed roof that let in the daylight along its course.

Botanically, Rangitoto is unique in New Zealand, with trees growing directly out of basaltic lava

BELOW Rangitoto's highest scoria cone erupted a few years after the slightly lower northern scoria cone (foreground). The two cones have different chemical compositions and are believed to have erupted from two separate batches of magma.
BOTTOM The steep-sided summit crater and viewing platform on the crest of Rangitoto's highest scoria cone. PHOTOS: ALASTAIR JAMIESON, 2009.



flows. The inhospitable basalt provides the substrate for the largest pohutukawa forest in the world. The amount of vegetation cover is related to substrate. The crumbly scoria cones have already developed a near-continuous forest cover and in places a thin soil layer. In contrast, parts of the lava flows are still bare, supporting only hardy lichens, while other parts are well forested by pohutukawa, creating a mosaic of forest and open areas over the island.

Rangitoto can mean 'blood red sky', but there is no confirming tradition for this translation and while it is attractive to think it refers to the eruption, there is an alternative. The name is traditionally linked with a fight between Tamatekapua and Hoturoa, the commanders of the Arawa and Tainui canoes respectively. Tamatekapua was injured, hence the name Te Rangi i totongia a Tamatekapua – 'the day the blood of Tamatekapua was shed'. The island's creation was associated in tradition with the genesis of the North

ABOVE Map of publicly accessible Rangitoto lava caves reached via a short side track off the main summit track.
BELOW On the north side of Rangitoto some of the rubbly a'a lava flow surface has been rucked up into curved ridges as the lava within the flow moved slowly downslope. PHOTO: ALASTAIR JAMIESON, 2009.

ABOVE LEFT The lower part of the track to Rangitoto's summit from the wharf passes through rubbly a'a lava flows. Next to the track there is a wide, 2–3-metre-deep trench running downslope with ridges of heaped-up angular lava blocks on either side. These are levees formed by the accumulation of chilled lava at the margins of the moving lava flow. The trench is where the molten lava inside the flow drained out leaving the collapsed rubbly roof behind.
ABOVE RIGHT This small conical tower of basalt spatter near the track to the lava caves is called a hornito. These are small mounds of welded lava spatter built by the accumulation of incandescent lava ejected through holes in the roof of a lava tube within a lava flow. Rangitoto is the only place in New Zealand where hornitos are preserved. PHOTO: JESSICA HAYWARD.

Shore volcanoes (see pages 43–44). Its distinctive peaks were known variously as the Nga Pona toru a Peretu ('the three knuckles of Peretu'), and as Nga Tuaitara a Taikehu ('the dorsal fins of Taikehu'). Rangitoto's link with these illustrious ancestors and its long use as a burial place confirm its great spiritual and symbolic importance to local iwi.

The island provided an early source of basalt for use in building construction. It was designated a public domain in 1890 under the control of the Devonport Borough Council. Its management over the next fifty years had an impact on the island's naturalness, yet created a remarkable assemblage of historic cottages or 'baches'. By 1937, when the last leases were granted, there were 140 such buildings on the island, mostly around Rangitoto Wharf and Islington Bay. On the death of the lessee, most were demolished in the 1970s and 1980s, but in 1990 this policy was stopped and the Rangitoto Island Historic Conservation Trust was established in 1997 to restore and promote the historic heritage values of these unusual bach communities.

Rangitoto Beacon (1887) on the northwestern corner was one of the first structures built on the

By 1937, 140 small baches like this one had been built around the southern shores of Rangitoto. Since then, many have been demolished, but those that remain are now being restored and their historic heritage values celebrated. PHOTO: 2010.

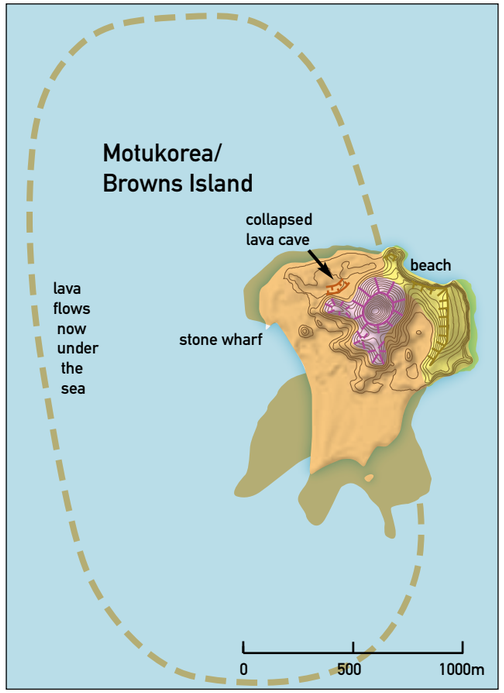
island. Initially lit by gas, it was electrified in 1929. Salt ponds were trialled unsuccessfully near McKenzie Bay in 1892–1896. The island's well-formed roads and distinctive stone structures were constructed in the 1920s–1940s by prisoners and army labour. During the Second World War a fire command post on the summit was used to co-ordinate Auckland's coastal defences. A controlled mine base and other military facilities were constructed at Islington Bay.

Motukorea/Browns Island

Motukorea Volcano was formed when the Tamaki Estuary and Waitemata Harbour were forested river valleys. It began life with a series of wet explosive eruptions that cleared its throat of debris and created a 1-kilometre-wide shallow crater. The ejected debris ripped from the walls of the vent, together with large volumes of magma-sourced ash, accumulated around the crater to form a tuff ring. The eroding remnants of part of this tuff ring form the cliffs around the northern and eastern side of the island. At the time of eruption the wind was probably blowing from the southwest and a more substantial rim was built up on the downwind side. Within the layers of tuff are numerous pieces of hard greywacke and Waitemata Sandstone. Both rock types underlie Motukorea and were pierced by the erupting throat of the volcano. More interesting, however, are the fragments of fossil shells that also occur in the tuff layers, having been thrown out with the eruptions. These fossils came from a shell bed that partly filled a former Tamaki Estuary channel that now underlies part of the volcano. Among the shells are specimens of the Sydney mud cockle, which lives in estuaries around Australia today but became extinct in New Zealand during the cold of the Last Ice Age around 20,000–100,000 years ago.

After the initial wet explosive eruptions, dry fire-fountaining built several scoria cones within the crater. Extrusion of lava flows from around the base of the cones appears to have rafted parts of their scoria ramparts away. The fluid basalt spread over the land forming an apron of flows extending 2 kilometres to the west and south, temporarily ponding the Tamaki Stream before it made itself a new course closer to St Heliers. These flows probably overtopped and removed the lower parts of the tuff ring around this sector of the volcano. The final phase of fire-fountaining produced the high scoria cone with its deep summit crater in the centre of modern Motukorea. Some of the scoria was blown northeast and forms a 5-metre-thick cap on top of the tuff ring, seen in the upper part of the cliffs above 'Crater Bay'.

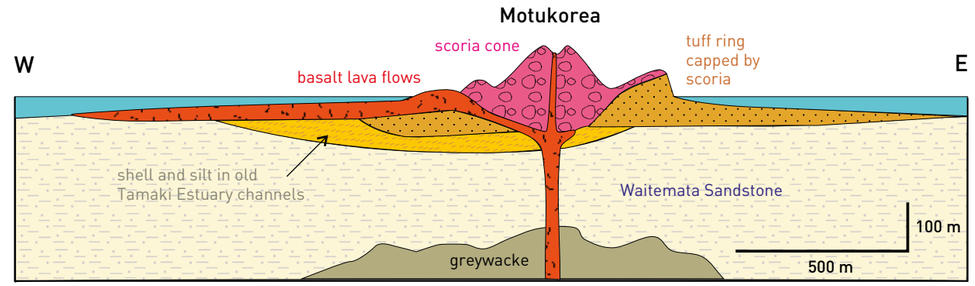
Aerial view of Motukorea Volcano from the south showing some of the lava flows forming coastal reefs. PHOTO: ALASTAIR JAMIESON, 2009.



The cliffs behind 'Crater Bay' on the north side of Motukorea are composed of bedded tuff overlain (top right) by loose, dark red scoria. This bay is not a crater but was formed by marine erosion of the soft tuff ring in the last 7500 years.

Thousands of years after the volcano was formed, sea level rose as the world's ice caps melted after the end of the Last Ice Age, reaching its present level about 7500 years ago. The Waitemata Valley was flooded creating the harbour, and Motukorea became separated from Musick Point by the sea creating an island. Three quarters of Motukorea's lava flows were drowned and now underlie the seabed west of the island. Marine erosion has had little effect on the hard basalt flows, but has carved away a large chunk of the softer tuff ring. This north side of the island was more exposed to wave attack prior to the formation of Rangitoto, 600 years ago. As a result, the tuff ring was severely eroded, with remnants now forming substantial offshore reefs to the northeast. Between 6000 and 2000 years ago, sea level was 1–2 metres higher than at present, and during this time an intertidal sand flat built up on top of the flows in the lee (south side) of the island. Now that sea level has dropped slightly, this sand flat has been left as an extensive flat terrace.

Motukorea is the only volcano in Auckland where the geological products and landforms of all three styles of eruption – tuff ring, scoria cone and lava flows – can be seen together in one reserve. It is also of scientific importance as the type locality from which the rare mineral motukoreaite was first described and



East–west cross-section showing the distribution of rocks beneath Motukorea Volcano – the source of some of the lumps thrown out by the initial wet explosive eruptions and found in the bedded tuff.

Vertical view of Motukorea's main scoria cone and central crater surrounded by numerous smaller scoria mounds formed by small secondary vents or by portions of scoria cone that were rafted away from the main cone by lava flows. Also visible is terracing and transverse ditches on the crest of the main cone and a secondary scoria mound (right). These are the remains of two pre-European pa. PHOTO: ALASTAIR JAMIESON, 2009.

named in the 1970s. This unusual, but unspectacular, hydrated carbonate and sulphate salt of sodium, magnesium and aluminium occurs as a cementing mineral within the ash layers of the tuff ring.

Motukorea, meaning 'island of the oystercatcher', was cleared of forest, settled and cultivated in pre-European times. Stone heaps and retaining walls mark the sites of early gardens on the flats, and earthworks from three defended pa remain. The largest of these is on the rim of the main cone, with smaller ones on the eastern cliffs and the western scoria knoll.

In 1840, Europeans William Brown and John Logan Campbell purchased the island from Ngai Tai chiefs. They lived in a large raupo whare constructed for them by Ngai Tai on the western flats and used the island as a trading base for a few months before moving in to the newly established Auckland township. Brown, after whom the island gets its European name, sold it in 1873, after which the island was farmed by the Featherstone (1879–1903) then Alison (1906–1946) families. The sites of their farmhouses are marked by introduced trees, building foundations and a stone-lined well on the northwestern flat near the stone wharf.

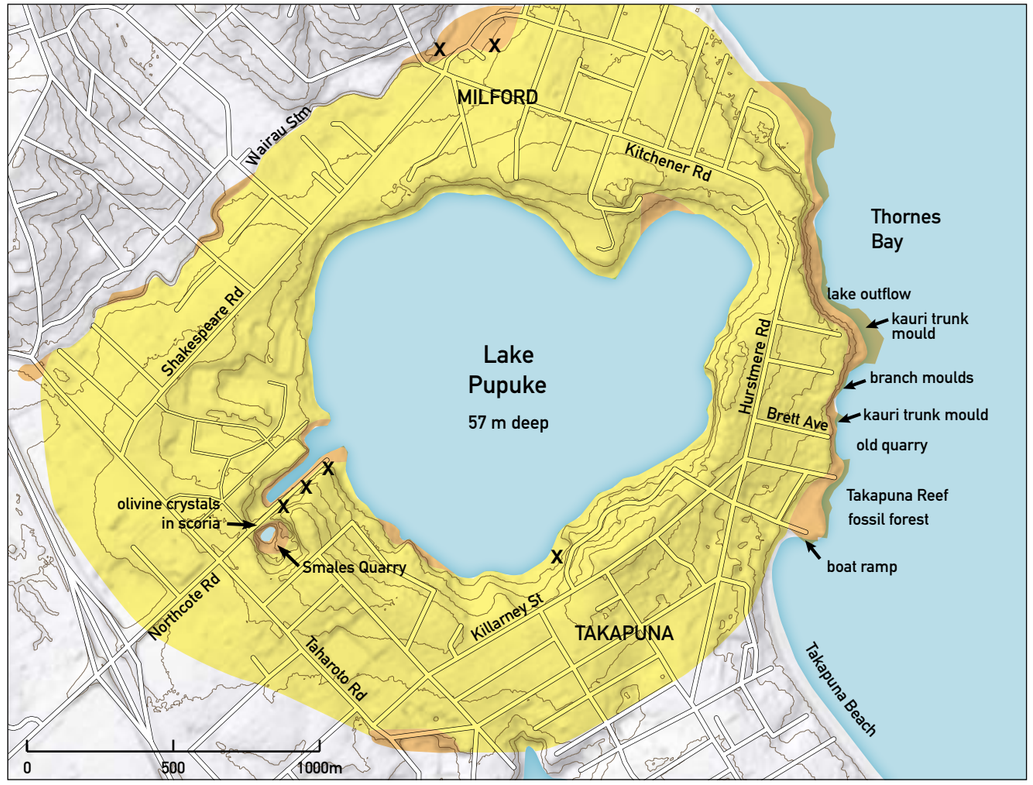
The Alisons were principal shareholders in the Devonport Steam Ferry Company, and Motukorea became a popular destination for ferry-loads of picnickers between 1900 and 1940. In 1946 the island was purchased by the Auckland Metropolitan Drainage Board as part of a plan for the disposal of the city's sewage. The scheme was switched to the Mangere area following a public outcry led by Dove-Myer Robinson. Subsequently, Sir Ernest Davis (Mayor of Auckland 1935–1941) purchased the island and gifted it to the people of Auckland in 1955.

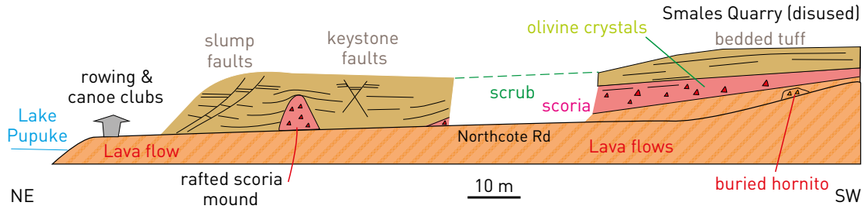
Profile of Motukorea from the north.

Pupuke Moana/Pupuke Volcano

The eruptive sequence of Pupuke Volcano differs from all the other Auckland volcanoes. Early activity built a low shield volcano of thin, overlapping basalt lava flows erupted from two vents. Some of these basalt lava flows can be seen exposed: a) inside the crater near the North Shore Rowing and Canoe clubs at the end of Northcote Rd; b) in the bed of Wairau Stream near the East Coast Rd bridge; c) in the car park under the Milford Shopping Mall; and d) between Takapuna and Milford beaches where it forms the rocky shoreline. Lava of slightly different composition erupted from each of the two vents: one was near the centre of the present lake; the other in the northeastern corner where there is now a bulge in the lake's otherwise circular outline. These dry eruptions possibly also produced small scoria cones directly above the vents, but any trace of these has gone. The initial eruptions were followed by wet explosive eruptions that blasted out the large double crater that is now Lake Pupuke. The ash that was thrown out by these explosive pulses built up a tuff ring on top of the shield volcano. Today, Killarney St, Shakespeare, Kitchener and Hurstmere Rds run along the approximate crest of this tuff ring.

The likely reason for this unusual sequence is that during the course of the eruptions water suddenly entered the active vents. Pupuke Volcano is thought to





Sketch of cliffed road cutting on the south side of the Northcote Rd extension that leads down to the North Shore Rowing and Canoe clubs on the western shore of Lake Pupuke. The exposed rocks illustrate the sequence of eruptions that formed Pupuke Volcano. The base of the sequence is underlain by a dark grey basalt lava flow, some of which was quarried away on the north side of the road. This old quarry is now flooded by Lake Pupuke and used for canoe-based sports. The deep hole in Smales Quarry up the road on the south side was also formed by quarrying into this lava flow which is part of Pupuke's early shield cone.

Overlying the lava flow and comprising most of the road cutting is bedded tuff erupted by the subsequent wet explosive eruptions. In one place there is a near-vertical-sided, 5-metre-high mound of scoria, which was probably part of a small scoria cone that was rafted along on the underlying lava flow. This hump has been draped and buried by later tuff. Some of the tuff layers are disrupted by small faults resulting from its compaction. Nearer the lake, small faults record a tendency for the tuff ring to slip down into the explosion crater. Further away, they form criss-cross compaction patterns (keystone faults). Displacements across the faults are generally only a few centimetres.

Within the tuff there are a number of cobble-sized lumps of sandstone that were ripped from the wall of the volcano's throat during the eruptions. The tuff layers sag beneath several of these projectile blocks of sandstone, depressed by the impact of the rock landing in the soft wet ash. Further up the road (to the west) a layer of fine scoria overlies the lava flow. This crumbly scoria contains light green crystals (up to 1 cm across) of olivine, a mineral that had crystallised out of the magma before it erupted and was ejected along with the semi-molten scoria in a fire-fountaining episode.

Aerial view of the two coalescing explosion craters of Lake Pupuke (one large, one small on left) and surrounding tuff ring from the north. PHOTO: ALASTAIR JAMIESON, 2009.

Exposure of steep-sided knoll of scoria within Pupuke tuff ring exposed in the road cutting near the end of Northcote Rd.

have erupted about the same time as nearby Onepoto and Tank Farm volcanoes, about 200,000–250,000 years ago. All three built low volcanic cones that would have blocked the ancient Wairau Valley that had drained south into Shoal Bay. This valley may have ponded and perhaps the fresh water overflowed into the Pupuke vents, reaching the molten rising magma resulting in a series of violent explosions.

Towards the end of Pupuke's eruptions, fire-fountaining of frothy lava built up a small scoria mound (34 m above sea level; mostly removed by Smales Quarry) on the southwestern flanks. The double crater subsequently filled with fresh water to form Lake Pupuke (105 ha; 57 m deep). The lake's name is a shortened form of Pupuke Moana, meaning 'the overflowing lake'. Its level is controlled by natural outlets that occur around Thornes Bay (between Milford and Takapuna beaches) where large volumes of fresh water flow from the lake through cracks in the basalt lava flows and discharge intertidally.

Like most of Auckland's volcanoes, Pupuke erupted during colder times of the Ice Ages, when sea level was below the present and the Waitemata Valley and its tributaries were clothed in forest. Early lava flows from Pupuke invaded some of these nearby forests, and the fossilised shape of some of these trees and branches can be seen within the solidified basalt lava flows between Takapuna Beach and Thornes Bay (see pages 18–21). Evidence of large gas blisters that formed beneath the cooled surface crust of some of the flows is also visible in this coastal section. As the flows were cooling and

The foreshore of Lake Pupuke before it was subdivided for houses and parks. PHOTO: 1880s, AUCKLAND MUSEUM, C8159.

LEFT Overflow water from Lake Pupuke flows through cracks in the basalt lava flows all the way from the lake to emerge at Thornes Bay on the coast.
ABOVE Ropey pahoehoe on the surface of a Pupuke lava flow exposed on the coast near the end of Brett Ave, Takapuna.

ABOVE LEFT Seen in the coastal rocks near the end of Brett Ave, Takapuna, these small elongate globs of lava are stalagmites on the floor of a gas blister in a lava flow. They have dropped off stalactites above while they were still hot and plastic. Width of photo, 20 centimetres.
ABOVE RIGHT Sea-rounded knobs of basalt lava flow, Thornes Bay.

solidifying, small gas bubbles within the still-molten lava rose towards the surface where they coalesced with other bubbles to form the blisters (1–3 m across and 50 cm high) that were trapped beneath the glassy surface crust. On the ceilings of some of these blisters are small lava stalactites (1–5 cm long) that were formed by the heat of the trapped gas which partially re-melted the overlying basalt crust which dribbled down before solidifying again.

Hochstetter (1864) was the first to describe Lake Pupuke and its volcanic origins. His writings are the source of the oft-quoted myth that the water in Lake Pupuke comes through an underground aquifer from Rangitoto. These days we know that this is impossible and that all the lake water is purely derived from rain that falls on the lake and the surrounding inside of the tuff ring which slopes towards it. The clear fresh water of the lake was used to provide the first reticulated water supply for Devonport Borough from 1894. The old brick pumphouse in Killarney Park housed steam engines that pumped water to a reservoir on Mt Victoria. For a time, Lake Pupuke also supplied water to Northcote and Birkenhead boroughs.

Te Kopua o Matakamokamo/ Tank Farm (Tuff Crater)

Tank Farm gets its name from the fuel storage tanks that were dug into the north wall of the explosion crater to camouflage them from potential aerial attack during World War II. The local council subsequently relabelled it Tuff Crater, a nineteenth-century descriptive term that was written beside it and a number of other explosion craters on Hochstetter's 1864 map of Auckland's volcanoes. The earlier Maori name is Te Kopua o Matakamokamo, meaning 'the basin of Matakamokamo', derived from the oral traditional story of Te Riri a Mataaho or 'the wrath of Mataaho' (see pages 43–44).

Today, Tank Farm is a well-preserved explosion crater and high surrounded tuff ring that were formed by explosive eruptions about the same time as neighbouring Onepoto Crater. Exmouth Rd, College Rd and Akoranga Drive run along the crest of the tuff ring. After its eruption the crater became a freshwater lake that was breached by rising sea level about 7500 years ago after the end of the Last Ice Age. It filled up with marine mud to become a tidal lagoon. Unlike many of Auckland's breached explosion craters, it still contains its original pre-human mangrove forest with a narrow fringe of salt marsh.

A portion of the tuff ring, where The Warehouse's head office now stands, was removed to provide fill during construction of the Northern Motorway.

Aerial view from the northwest across Tank Farm explosion crater and surrounding tuff ring, with Onepoto explosion crater and tuff ring beyond to the right. PHOTO: ALASTAIR JAMIESON, 2009.