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Field Trip 3

Mount Pirongia – North Island's largest basaltic volcano

28th November 2019

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MOUNT PIRONGIA – NORTH ISLAND'S LARGEST BASALTIC VOLCANO

Itinerary and route

This is an all-day scenic geological excursion to investigate the newly discovered (and mapped) volcanic history of Mt Pirongia, North Island's largest basaltic volcano. The morning will involve an uphill tramp to Ruapane Trig which requires moderate fitness. We will have lunch in Pirongia township. The afternoon involves a drive to investigate deposits on the southwestern side of Pirongia.

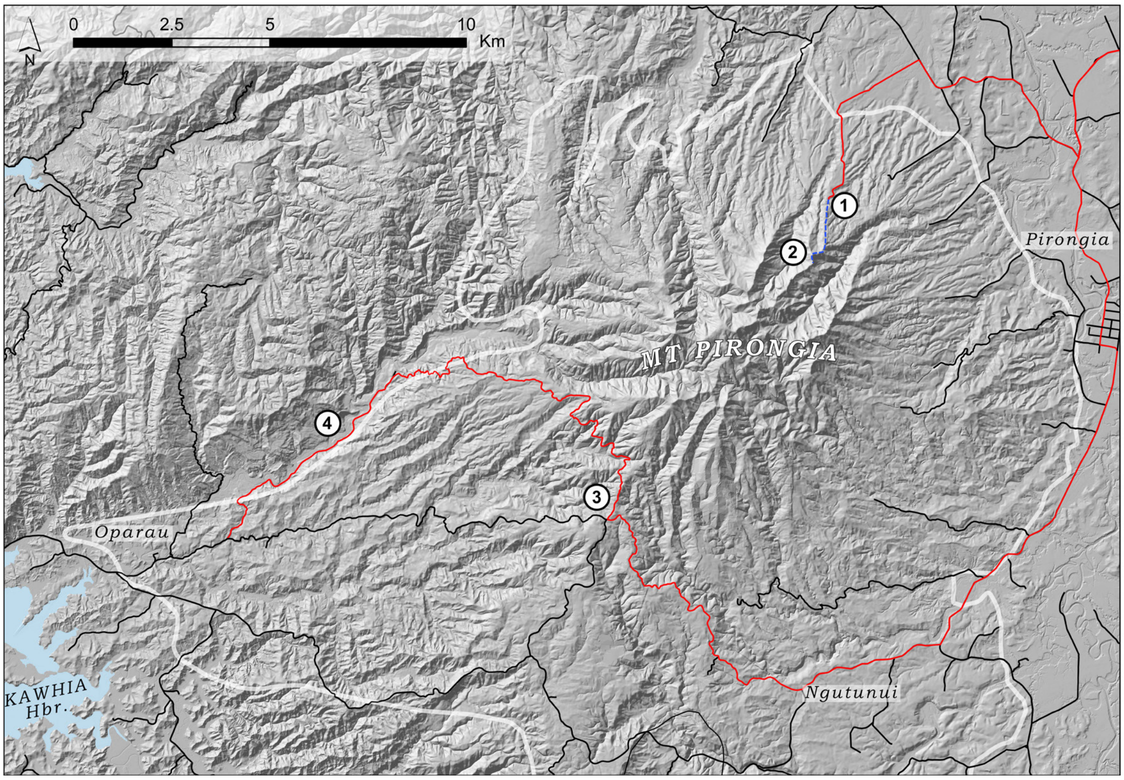


Figure 1. Field trip route map on hill-shaded base map. Symbols: numbered circles = field stops; red line = driving route; blue dashed line = walking track to Ruapane Peak; thick white line = approximate extent of Pirongia volcanics.

8:30 am – Depart Hamilton

Drive to STOP 1

9:30 am Stop 1 – Corcoran Rd car park:
brief introduction (*basic DoC toilet available*)

Walk to STOP 2 – approx. 1-hour tramp upslope to Ruapane Trig. The tramp involves sections of steep and rocky ground, and large tree roots; take care with your footing.

10:50 am Stop 2 – Ruapane Trig: extended discussion, landscape views and outcrop examination. Walk back to Corcoran Rd car park (*basic DoC toilet available*) by 12:45 pm; drive to Pirongia township

1:00 pm Lunch – Pirongia township *(30 mins, toilets available)*

Drive to STOP 3

2:00 pm Stop 3 – Intersection Pirongia West and Okupata roads: brief discussion, landscape views

Drive to STOP 4

3:00 pm Stop 4 – Pirongia West Rd (lower):

extended discussion and outcrop examination

Return (via Kawhia Rd/Hwy 31; Ngutunui Rd; Ormsby Rd/Hwy 39 via Pirongia – *toilet stop if needed*) via Hamilton Airport

5:00 pm – Return to Hamilton

Introduction

Mount Pirongia is the eroded landform of the largest basaltic volcano in North Island, New Zealand (Fig. 2) and is the most prominent landmark in the Waikato region. The mountain is a broad cone (13 km wide, 175 km^2 area) that rises from a piedmont to several jagged summit peaks, the highest at 959 m above sea level (asl). The edifice lies east of the Kawhia Harbour, where it mantles the Kapamahunga Range and prevails over the skylines of Hamilton city (30 km northeast) and Te Awamutu (20 km east). The Waipa River, which is the largest tributary of the Waikato River, flows around the volcano's northern slopes. Pirongia formed initially around 2.5 Ma, during a flare-up of regional basaltic volcanism across the wider Alexandra Group, which was associated with the rapidly transitioning Hikurangi subduction front and back-arc spreading in western North Island. The last eruptions of Pirongia, around 1.6 Ma, were contemporaneous with the first super eruptions of the Mangakino caldera in the early development of the Taupo Volcanic Zone (TVZ).

Geological setting

The Alexandra Volcanic Group (AVG, Kear 1960) is a Quaternary volcanic field in western North Island that produced ~55 km^3 of mainly basaltic eruptive material over a total area of 1100 km^2. It includes an extinct chain of subduction-related volcanoes (Fig. 2), comprising two large stratovolcanoes (Pirongia and Karioi) and two smaller cones (Kakepuku and Te

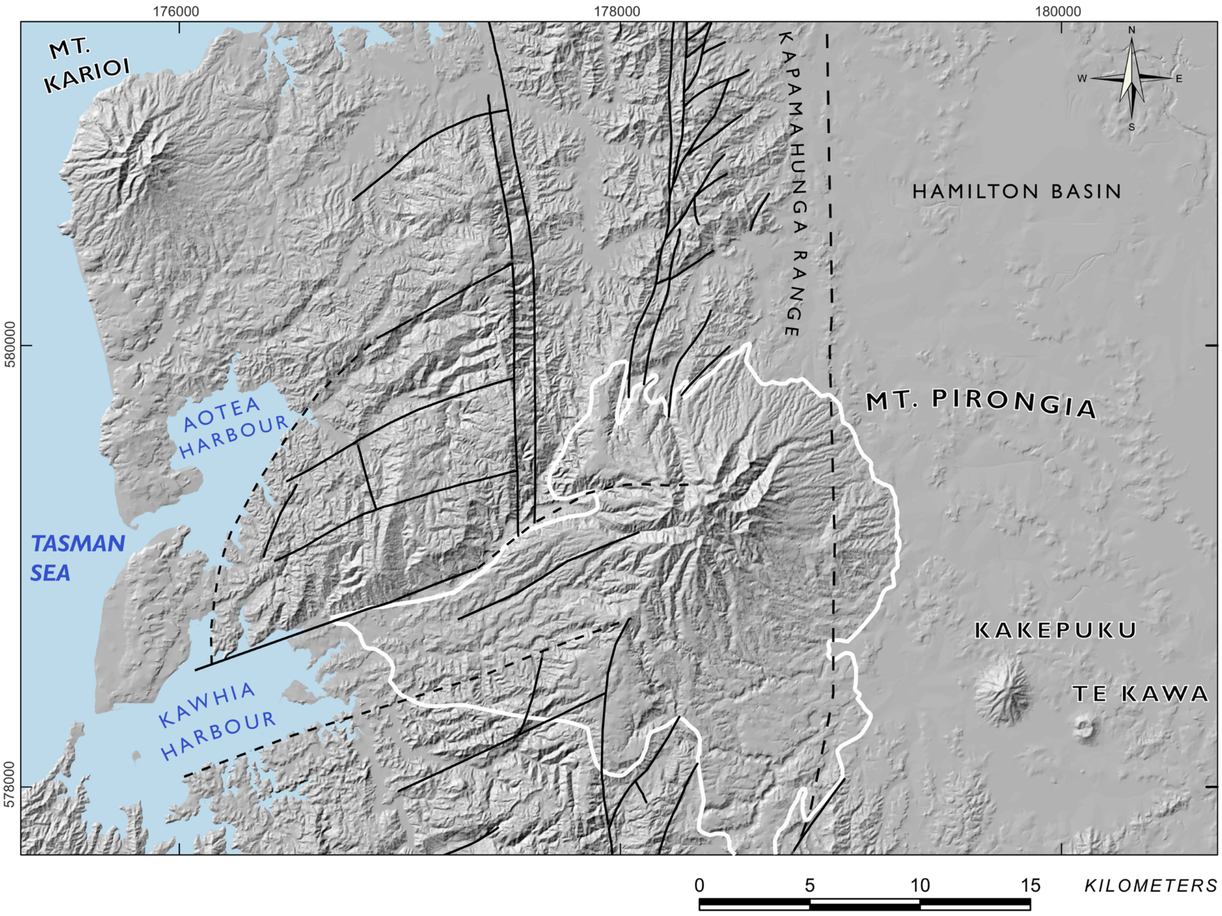


Figure 2. Location map for the Alexandra Volcanic Group, Waikato. The main physiographic features are the extinct volcanic cones of Mts Pirongia, Karioi, Kakepuku and Te Kawa. The Hamilton Basin is separated from the coastal harbours of Aotea and Kawhia by the Kapamahunga Range. Local faults are shown in black solid (outcropping) or dashed (concealed) lines.

Kawa), termed the 'convergent margin' group (Briggs & McDonough 1990), that were active between 2.74 and 1.60 Ma (Briggs et al. 1989). Interspersed with the larger volcanoes is the intraplate monogenetic Okete volcanic field (2.69 to 1.80 Ma), a group of alkaline basaltic scoria cones, lava flows and tuff rings (Briggs 1983, 1986; Briggs and Goles 1984). The convergent margin volcanoes form a volcanic lineament oriented (NW-SE, 120°; Henderson and Grange 1926; Kear 1964; Briggs 1983, 1986) perpendicular to the modern TVZ, located 70–120 km to its east. Most eruptions within the AVG were subaerial except for several coastal vents near Raglan Harbour and Mt Karioi. The AVG produced large volumes of ankaramite, an extremely clinopyroxene porphyritic basalt.

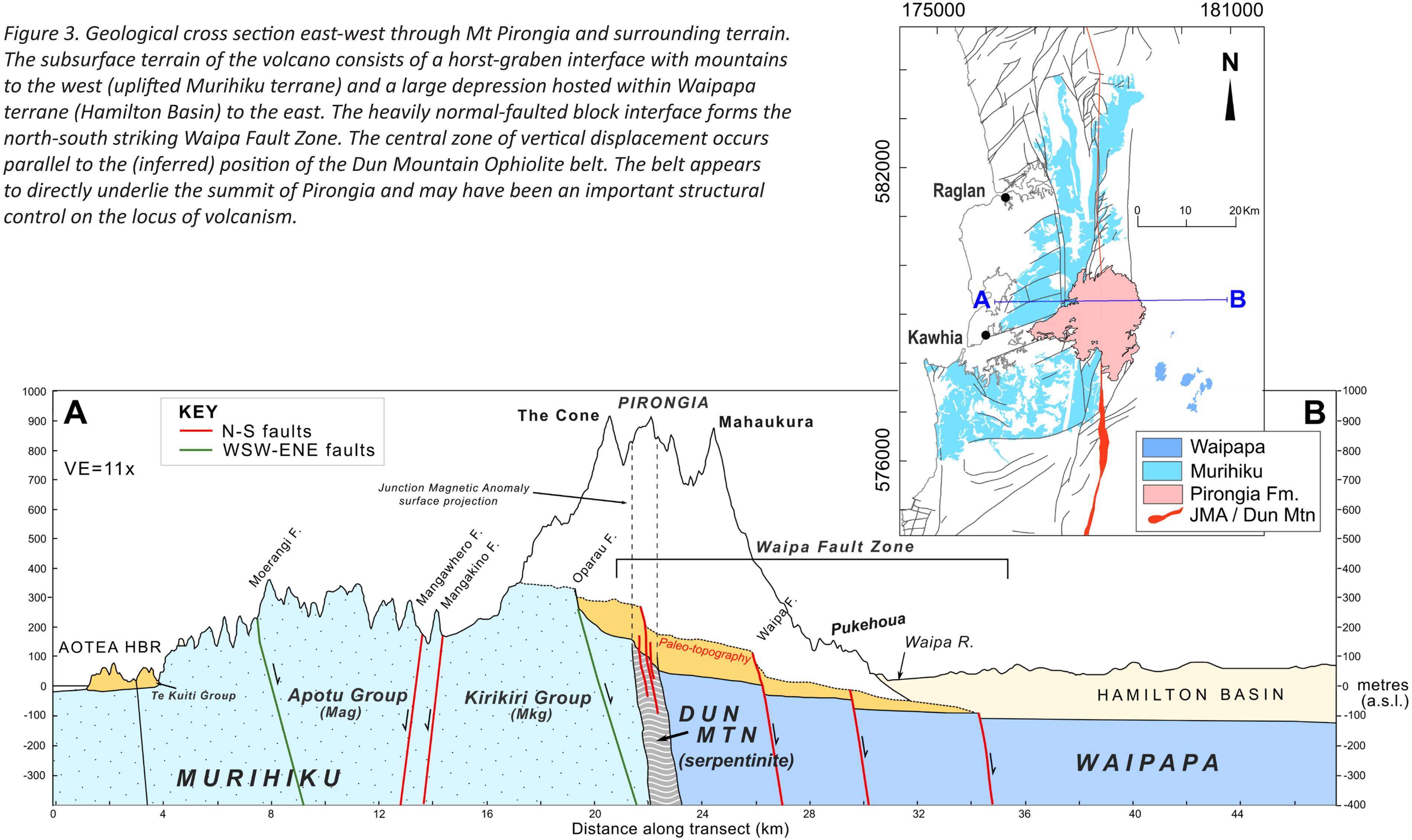
The eruptive history of the AVG (2.7–1.6 Ma) overlaps with the termination of activity of the Coromandel Volcanic Zone (CVZ, 2.69–1.95 Ma rhyolites and dacites at Tauranga; Briggs et al. 2005) and initiation of major caldera-forming eruptions centred east along strike of the Alexandra volcanic lineament at Mangakino caldera (1.68–1.53 Ma; Houghton et al. 1995; Wilson et al. 2009). Activity of the AVG was also coeval with that of other small, predominantly andesitic stratovolcanoes west of the arc front, including Maungatautari (1.8 Ma; Robertson, 1983; Prentice et al. 2019), Pureora and Titiraupenga (1.89 Ma; Stipp 1968). It is, therefore, proposed that the subduction-related AVG represents an arc-perpendicular chain of basaltic stratovolcanoes situated within the back-arc zone of the CVZ-TVZ transitional arc.

Mt Pirongia is the largest volcano of the AVG (Figs. 2, 3). The volcanic edifice lies above the uplifted Triassic to Jurassic Murihuku, Dun Mountain and Waipapa basement terranes, and the overlying Late Eocene to Oligocene Te Kuiti Group siltstones, sandstones and limestones, including the lowermost Waikato Coal Measures (Henderson and Grange 1926; Kear and Schofield 1959; Nelson 1978; Tripathi et al. 2008). Highly magnetic serpentinites of the Dun Mountain Terrane form a linear (mostly <10 km wide) belt, inferred in the subsurface as the Junction Magnetic Anomaly through the western North Island (e.g. Spöorli et al. 1989) that projects into field area beneath the summit of Mt Pirongia (Fig. 3).

Pirongia Volcano was constructed over a period of approximately one million years. Growth of the edifice occurred from numerous central and flank vents and was characterised by sporadic flare ups in activity separated by long periods of repose (up to 500,000 years). Fluctuations between active and repose periods were probably controlled by the regional tectonic environment, where heightened vent activity corresponded with periods of extension in the western Waikato. The volcanic history of Pirongia has been subdivided into six main stages of growth and collapse (Fig. 4). Each stage is separated temporally by an unconformity and is associated with a shift in the main vent centre on the volcano.

The volcanic lithologies of Pirongia and the AVG are dominated by basalts, subordinate volumes of basaltic-andesite, and rare andesites (Fig. 5). The most characteristic rock type of Mt Pirongia and the wider AVG is ankaramite, a highly porphyritic variety of basalt abundant in clinopyroxene and olivine (mega-) phenocrysts. Elsewhere in Zealandia and the wider southwest Pacific area, ankaramites are rare– Patrick Marshall commented that ‘the rocks differ markedly from all other volcanic material of the North Island’ (Marshall 1907, p.96). Ankaramites found across the AVG are melanocratic rocks with large, euhedral phenocrysts of clinopyroxene. On Pirongia, clinopyroxene is typically dull black, although some crystals have a dark greenish tinge. Olivine is typically subordinate in abundance to clinopyroxene and has been altered to orange “iddingsite” (likely made up of nanocrystalline forms of smectites and iron oxides ± silica: Churchman and Lowe 2012). The groundmass ranges from dark purple and very-fine grained to paler-grey with abundant, tabular plagioclase. Rarely, the phenocryst content is so high that the rocks display an apparent doleritic texture. Most ankaramites are weakly to non-vesicular, except for scoria, which are also glassy, and near-vent lavas.

Figure 3. Geological cross section east-west through Mt Pirongia and surrounding terrain. The subsurface terrain of the volcano consists of a horst-graben interface with mountains to the west (uplifted Murihiku terrane) and a large depression hosted within Waipapa terrane (Hamilton Basin) to the east. The heavily normal-faulted block interface forms the north-south striking Waipa Fault Zone. The central zone of vertical displacement occurs parallel to the (inferred) position of the Dun Mountain Ophiolite belt. The belt appears to directly underlie the summit of Pirongia and may have been an important structural control on the locus of volcanism.



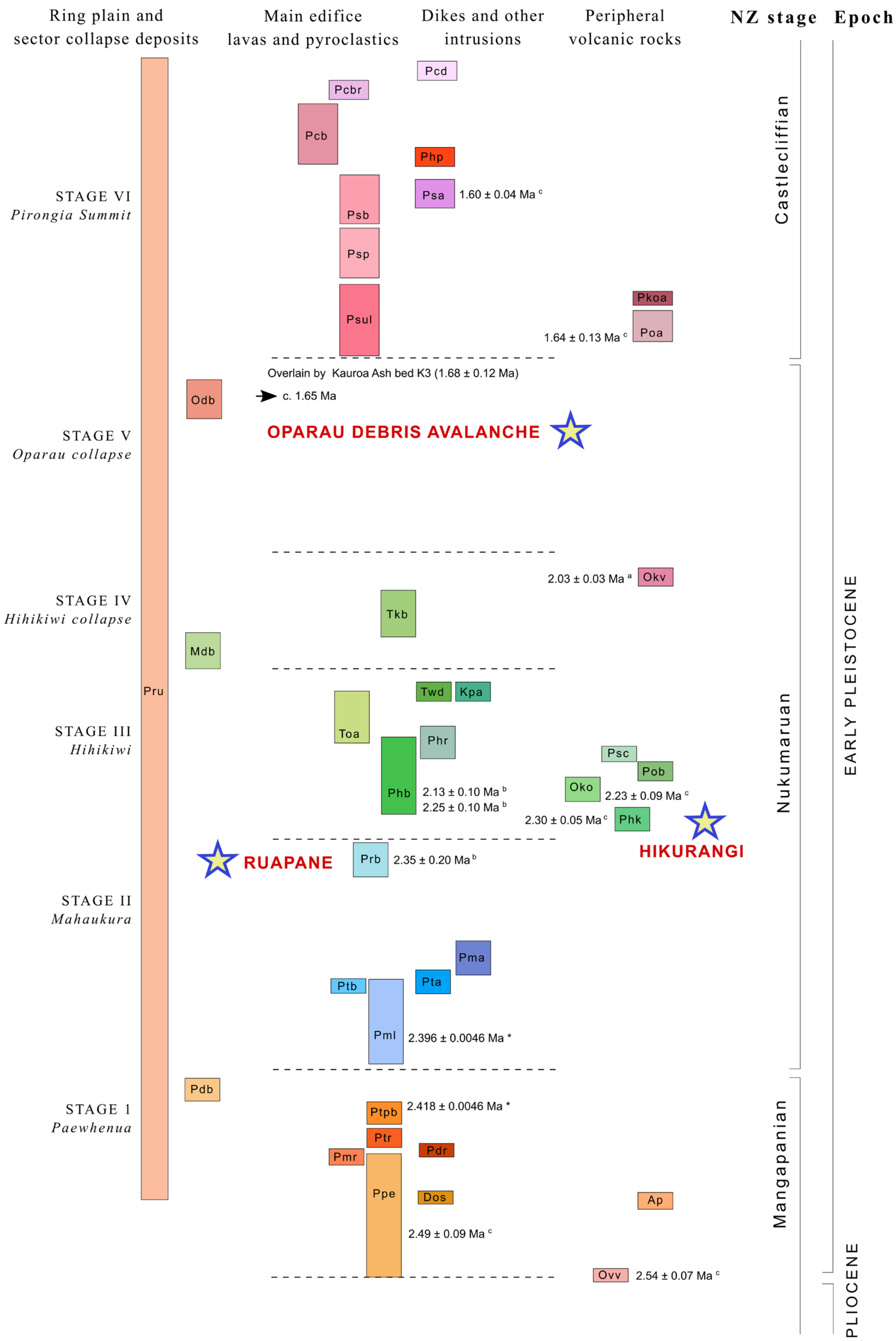


Figure 4. Stratigraphic correlation chart for Pirongia Volcano, based on the Pirongia Geological Map. The volcano is subdivided into six main constructional/destructive stages (I-VI) spanning c. 1 million years. Volcanic units corresponding to field trip stops are marked by star symbols.

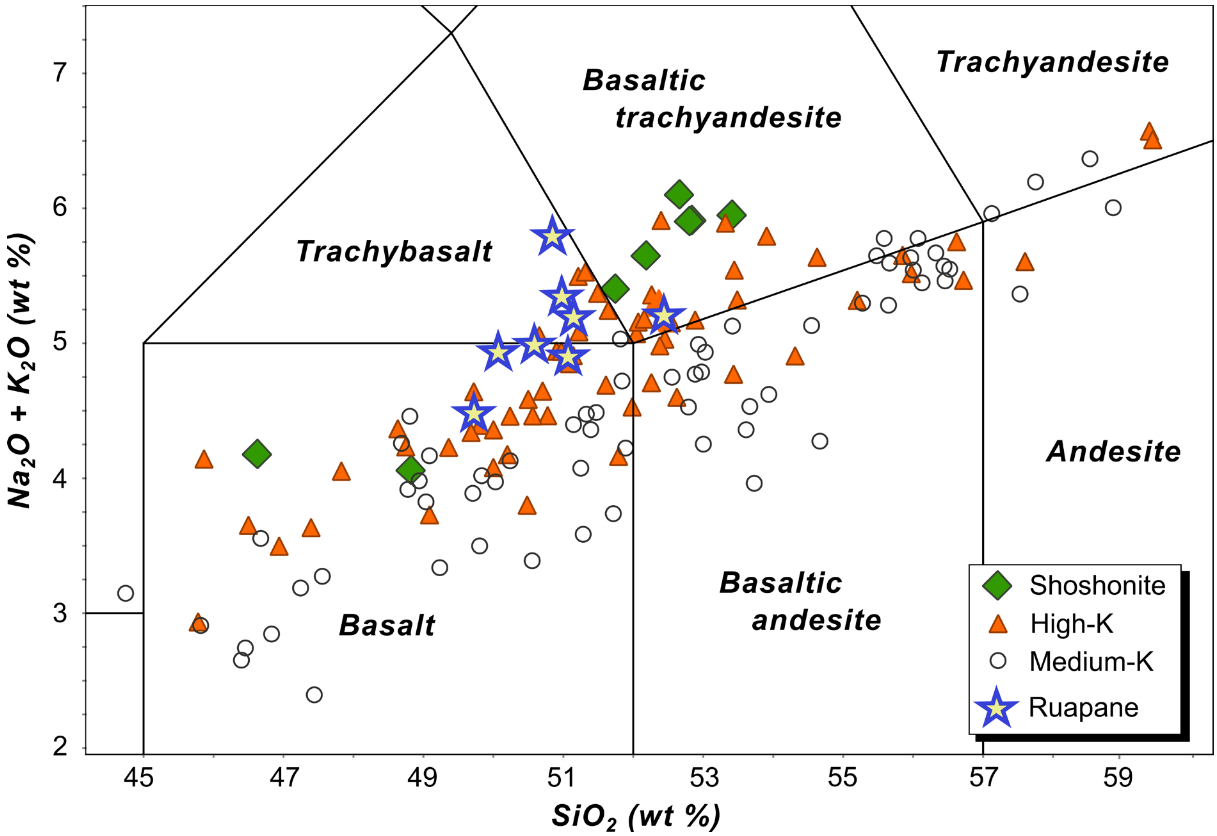


Figure 5. Total alkali ($Na_2O + K_2O$)–SiO_2 classification diagram (Le Bas et al. 1986) for Pirongia volcanics. Rock compositions are relatively alkalic and range from basalt and trachybasalt to andesite and trachyandesite. Symbols show sub-classification according to the SiO_2–K_2O diagram (Le Maitre 1989). Ruapane rocks (Stop 2) are highlighted with star symbols.

STOP 1 – Corcoran Rd car park

The drive from the university to Pirongia crosses the Hamilton Basin, a large extensional graben that has accumulated volcaniclastic sediment and primary pyroclastic deposits mainly from the TVZ (Kear and Schofield 1978; Edbrooke 2005). The basin is bordered by two ranges of uplifted basement rocks, the Western Ranges (Hakarimata) and Eastern Ranges. The Pirongia ring plain is buried by basin deposits and extends at least 10 km northeast of the mountain. The exposed surface of the ring plain appears south of the Waipa River, near Pirongia township. The Corcoran Rd car park is located on the outer ring plain. Here we will stop at the look out that provides a brief overview of Pirongia Volcano and its surrounds.

The car park marks the beginning of the one-hour hike to a peak at Ruapane Trig through dense native forest.

STOP 2 – Ruapane Trig

The Ruapane Trig is a surveying mark centred on the highest of three basaltic peaks of the Ruapane dyke swarm (Figs. 6a-c). The swarm marks a prominent flank vent on the northern side of the volcano. From this view point, there are panoramic views:

- to the northwest, of Mt Karioi, the sister volcano of Pirongia;
- to the north, of the Kapamahunga-Hakarimata ranges; and
- to the east, of the Hamilton Basin, the Kiwitahi volcanoes (6.2–5.8 Ma), the Eastern Ranges, and Maungatautari Volcano (1.8 Ma).

The immediate views of the nearby peaks and ridges of Pirongia are part of the Stage 2 edifice (Mahaukura Member) erupted between 2.4 and 2.35 Ma. The pinnacle just south of Ruapane is Tirohanga Peak, an andesitic dyke complex (Fig. 7) that marks the central vent of Stage 2 activity. Observe the radial valleys, up to 300 m deep, of Mangakara and Rangitukia streams. These valleys incise the oldest shield of Pirongia (Paewhenua Member). Across the valley is the most prominent outcrop succession: the 'Mahaukura Bluffs' (Fig. 8). These bluffs consist of another andesitic dyke swarm, oriented radially to Mahaukura Peak that marks the location of a Stage 2 flank vent. Associated with these dykes are domes at Mahaukura (Fig. 8) and Wharauroa (Fig. 9) Peaks. The dykes cross cut basaltic-andesite lavas of similar age. The southernmost dyke is the most silicic volcanic rock of the Alexandra Group. A spectacular monolith (called here as Mangamauku Peak) below Wharauroa Peak appears to be an andesitic plug with a truncated face.

Ruapane Peak (723 m asl) is satellite vent of Stage II fed by two dyke swarms and includes remnants of spatter cones represented by agglomerates and lavas (Fig. 6a). The best exposures of ankaramite on the mountain occur at Ruapane Peak (Figs. 6b,c; Table 1).

As we approach the peak, we will walk across lapilli-tuff deposits that form the basal succession. Outcrops north and east of Ruapane Peak are matrix-supported deposits with coarse angular lapilli of vesicular ankaramite and finer-grained red scoria (7-10% clasts) set within a reddish-brown matrix of clay and loose clinopyroxene and plagioclase crystals. These deposits are intercalated with red crystal-rich tuffs containing clinopyroxene.

The ankaramite dykes intrude and mantle older Paewhenua flank lavas, and are typically 1 to 1.5 m wide with undulating, brecciated margins, and display platy jointing. They comprise abundant clinopyroxene (glomero-) phenocrysts (1–3 mm; 6–13% of the rock) and plagioclase (mostly 1 mm), and subordinate olivine set within dark-grey (or purple) groundmass, with similar minerals. Some dykes are moderately vesicular, and the southernmost dyke is a finer-grained basaltic andesite.

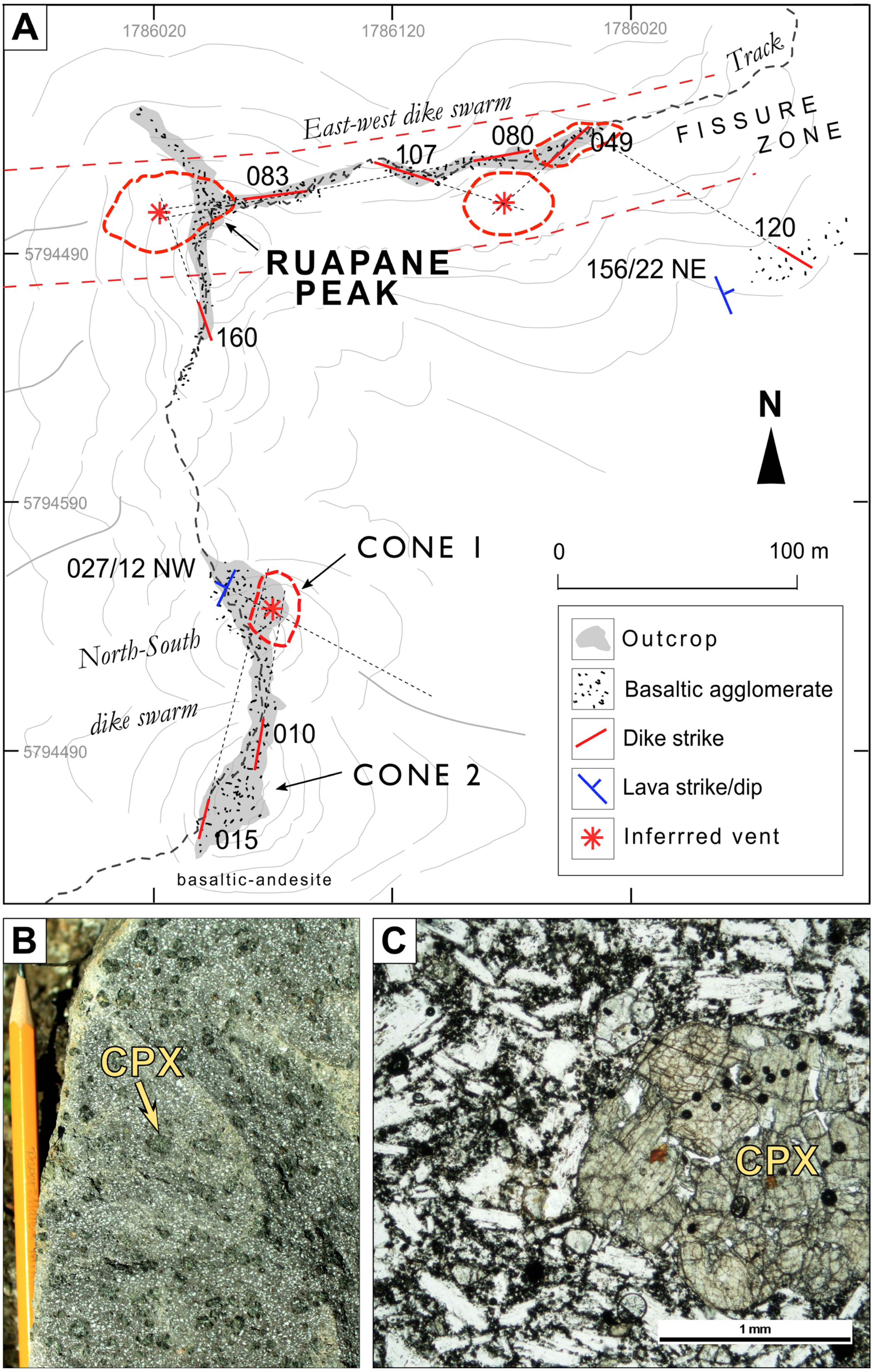


Figure 6. Ruapane Peak (Stop 2). (A) Ridge map showing the location of key volcanic outcrops and dyke orientations. The peak lies within a cluster of dykes that once formed a fissure zone on the flank of Pirongia. (B) Ankaramite-type basalt characteristic of Ruapane. The rock contains large phenocrysts of diopside and abundant microphenocrysts of plagioclase (for composition, see analysis #1, Table 1). (C) Photomicrograph of Ruapane ankaramite, showing the same texture as in photo B.

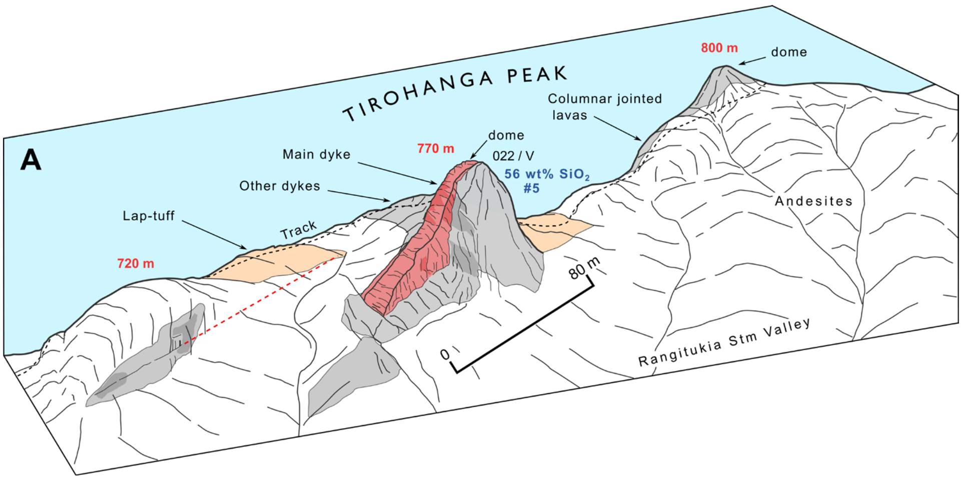


Figure 7. Sketch of Tirohanga Peak, located 800 m southwest of Ruapane. Tirohanga consists of an andesitic dyke swarm cross cutting lavas of similar composition (~56 wt% SiO_2, see analysis #5, Table 1). The main dyke (in red) feeds a small dome at the peak.

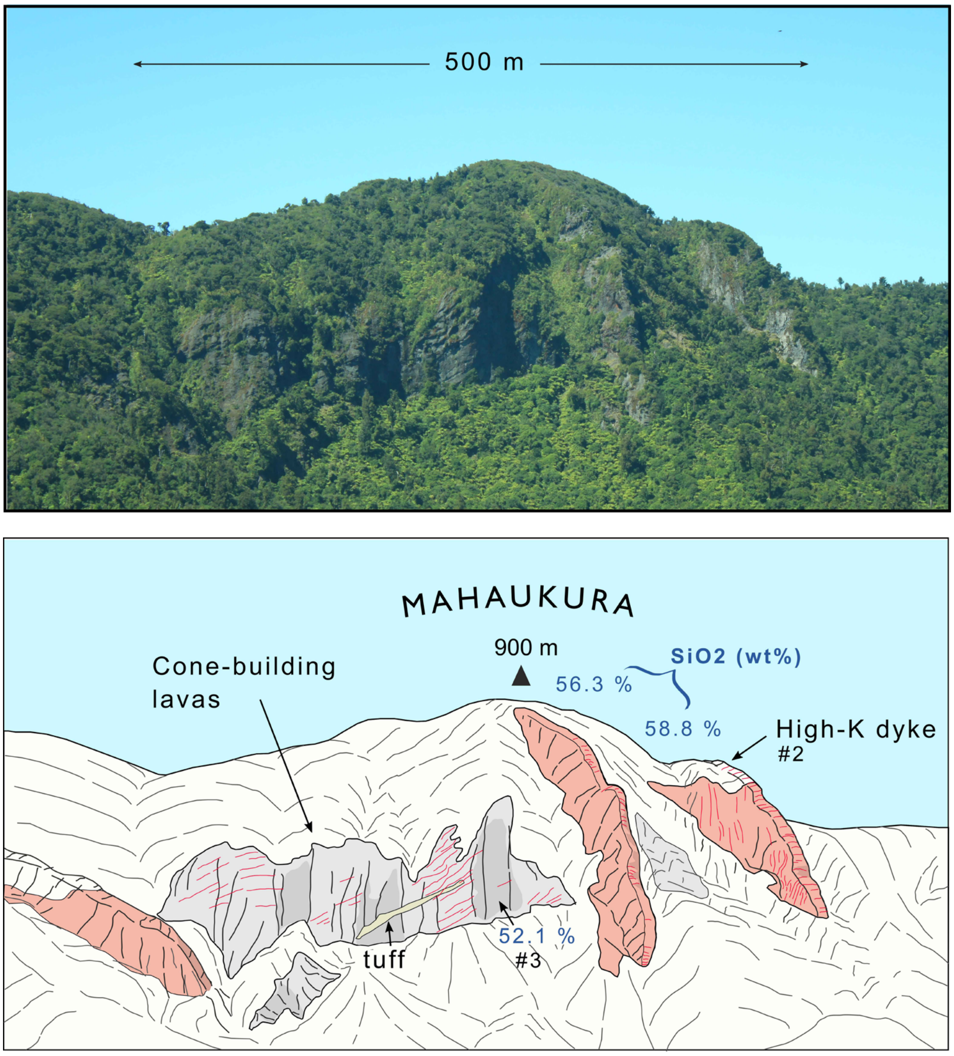


Figure 8. Panoramic photo (top) and geological sketch (bottom) of the 'Mahaukura bluffs'. The bluffs are situated 2 km south of Ruapane, across Mangakara valley. They consist of three prominent dykes that cross cut autobrecciated lava flows (analysis #3, Table 1) and tuff. The southernmost dyke is the most silicic (58.76 wt %; see analysis #2, Table 1) rock on Pirongia Volcano and has a high-K composition. The dykes and lavas relate to Stage II activity and represent flank eruptions of the Tirohanga Volcano (centred on Tirohanga Peak).

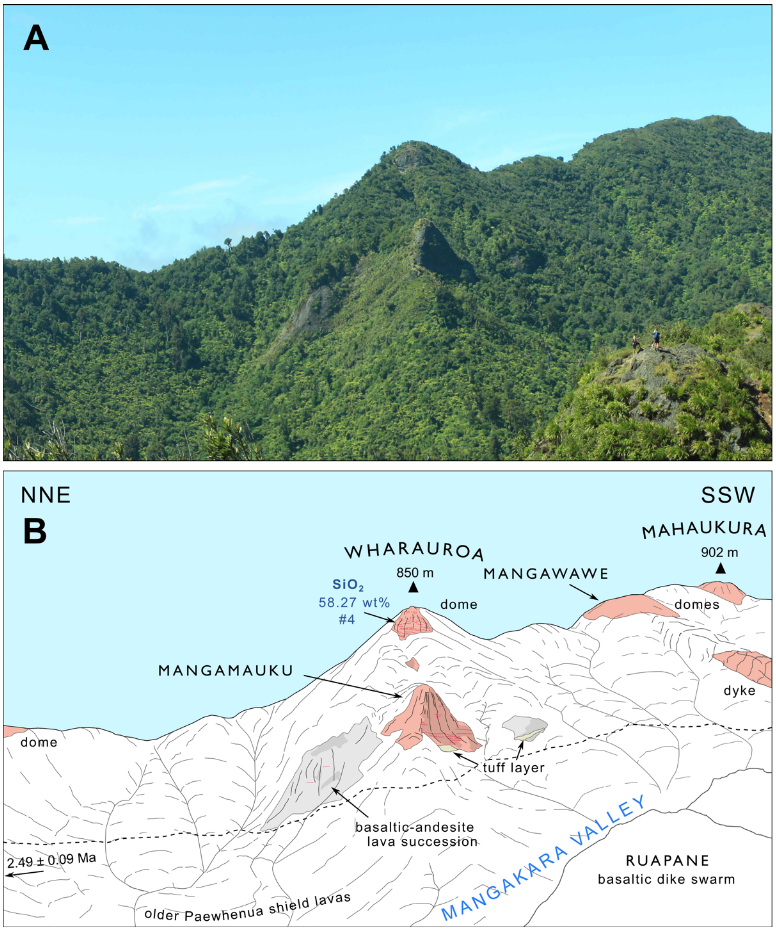


Figure 9. Wharauroa Peak, (A) as viewed from Ruapane Peak, and (B) geological sketch of the same view. The peak (see analysis #4, Table 1, for composition) and surrounding ridges consist of andesitic dykes and domes belonging to volcanic Stage II. In the foreground is the Mangamauku monolith, an andesitic body that cross cuts and overlies lavas and tuffs. The contact between Stage II lavas and older Stage I shield lavas is shown by the dashed line.

Table 1. Major element analyses of selected lavas and dykes of Pirongia Volcano.

	1	2	3	4	5	6
Wt% oxide	**Ruapane**	**Mahaukura Dyke**	**Mahaukura Lava**	**Wharauroa Dome**	**Tirohanga**	**Hikurangi**
	High-K basalt	High-K trachyandesite	High-K basaltic trachyandesite	Med-K trachyandesite	Med-K basaltic andesite	Shoshonitic bas-trachyandesite
SiO_2	49.38	58.76	52.39	58.27	56	52.48
Al_2O_3	16.12	18.47	18.5	17.24	17.49	16.55
TiO_2	1.33	0.58	1.03	0.76	0.83	1.13
MnO	0.19	0.10	0.15	0.13	0.16	0.18
Fe_2O_3	10.88	6.58	9.55	6.72	8.22	9.18
MgO	6.61	1.63	3.62	2.42	3.49	4.53
CaO	9.74	5.64	9.18	7.13	7.12	8.88
Na_2O	2.99	4.07	3.45	4.47	3.89	3.54
K_2O	1.53	2.45	1.85	1.90	1.80	2.38
P_2O_5	0.39	0.38	0.36	0.27	0.25	0.35
LOI	1.19	1.29	0.41	0.45	0.85	0.62
Total	100.52	100.17	100.64	100.01	100.28	99.98

Ankaramitic agglomerates consist of dense, sub-rounded blocks or scoriaceous to non-vesicular bombs. At Ruapane peak, the clasts are strongly vesicular with mineral assemblages and textures similar to those of the dyke rocks. At cone 1 (Fig. 6a), the observed succession consists of (1) relatively thick (>5 m) agglomerate, overlain by (2) a thin (<1 m thick), northwest-dipping lava flow that is further overlain by another more coarsely porphyritic lava flow towards the top of cone 1. The lavas are mantled by (3) agglomerate containing weakly vesicular, finer-grained clasts.

Lunch

We will descend Ruapane Peak and return to the Corcoran Rd car park, then drive to Pirongia township for lunch.

STOP 3 – Intersection Pirongia West and Okupata roads

From Pirongia township we will drive around the southern ring plain, passing by Pukehoua flank vent, today marked by a low hill on grassy farmland. The rolling hills around Ngutunui School, at the beginning of Pekanui Rd, are in the middle of the Mangakiekie Breccia, one of the mapped debris avalanche deposits of the Pirongia ring plain. After turning into Pekanui Rd, we ascend along a fluvially-dissected plateau. Road cuttings on the left-hand side show examples of similar breccias that are stratigraphically older. Stop 3 is at the end of Pekanui Rd at the intersection with Pirongia West Rd.

The view from Stop 3 includes Pirongia Peak to the northeast, and Karioi volcano on the horizon to the northwest. The immediately adjacent hill at Stop 3, to the south, is the Hikurangi Dome (Fig. 10a,b), a flank vent of Pirongia that erupted lava to the west across the Pekanui Breccia (Fig. 10b). The lavas have a shoshonitic composition (Table 1) with characteristic phlogopite phenocrysts (Fig. 10c).

The lowlands in the foreground form the Oparau Graben (Figs. 11, 12) bound on the far side by the Oparau Fault and uplifted Jurassic basement hills of the Murihiku Terrane. Infilling the graben from the base of Pirongia Peak through to Kawhia Harbour is the Oparau Breccia, on which we will focus at Stop 4.

STOP 4 – Pirongia West Rd (lower)

From Stop 3, along the Pirongia West Rd, we will drive across the Pekanui ring plain, across a lava flow, then onto the Oparau Breccia, which we will follow downslope to Stop 4 (Fig. 12).

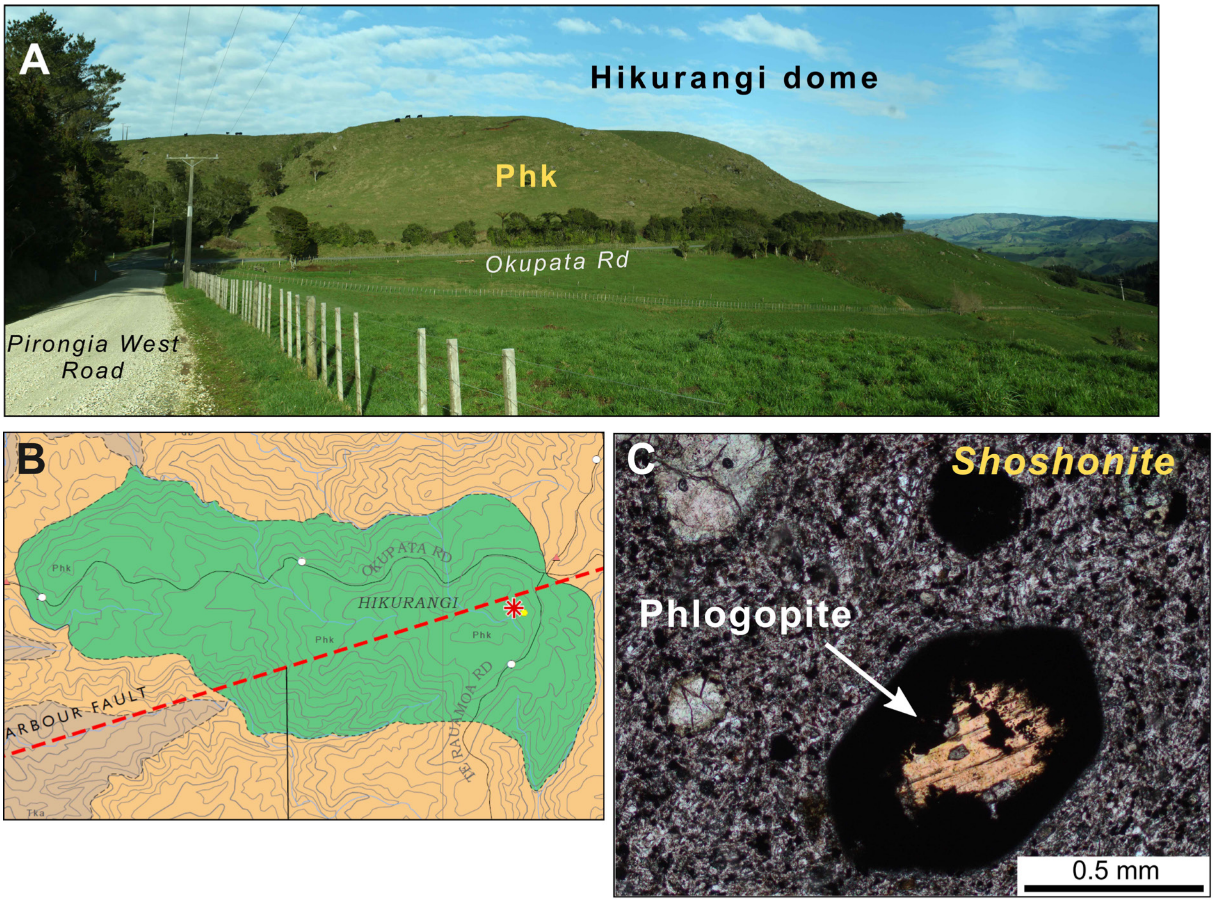


Figure 10. Hikurangi dome, southern Pirongia. (A) Photo of the dome from Pirongia West Road, at Stop 3. (B) Westward distribution of lavas from Hikurangi, taken from the Pirongia Geological Map. (C) The dome is a peripheral vent of Pirongia Volcano and erupted unusual shoshonitic basaltic-trachyandesite (see analysis #6, Table 1). The rock is weakly porphyritic but with relatively abundant phlogopite that occurs within resorbed phenocrysts of hornblende. Phlogopite is rare in Pirongia lavas and always associated with resorbed hornblende.

Undifferentiated volcaniclastic breccia (Odb, Fig. 4) covers the southwestern flanks of Pirongia. The voluminous Oparau breccia, which covers an area of at least 31 km^2, is interpreted as a debris avalanche deposit derived from collapse of the western flank. Deposits of the unit extend ~20 km southeast of the volcano to Kawhia Harbour, where volcanic breccia crops out at Kaiwaka Point (Tiritirimatangi Peninsula). The Oparau breccia is confined to the Oparau Graben, where it partially overlies Murihiku basement rocks, Te Kuiti Group sedimentary rocks and older Pirongia Formation breccias. The breccia is overlain in the northeast by younger lavas of Pūāwhe/The Cone.

The composition of proximal deposits is known from limited outcrops on the upper planeze surface of the Oparau breccia, which consist of large (1–2 m) blocks of basalt and basaltic-andesite weathered from the underlying breccia. Hydrothermal alteration (clay-altered plagioclase) is evident in some boulders. Two radiometric dates for boulders from this area

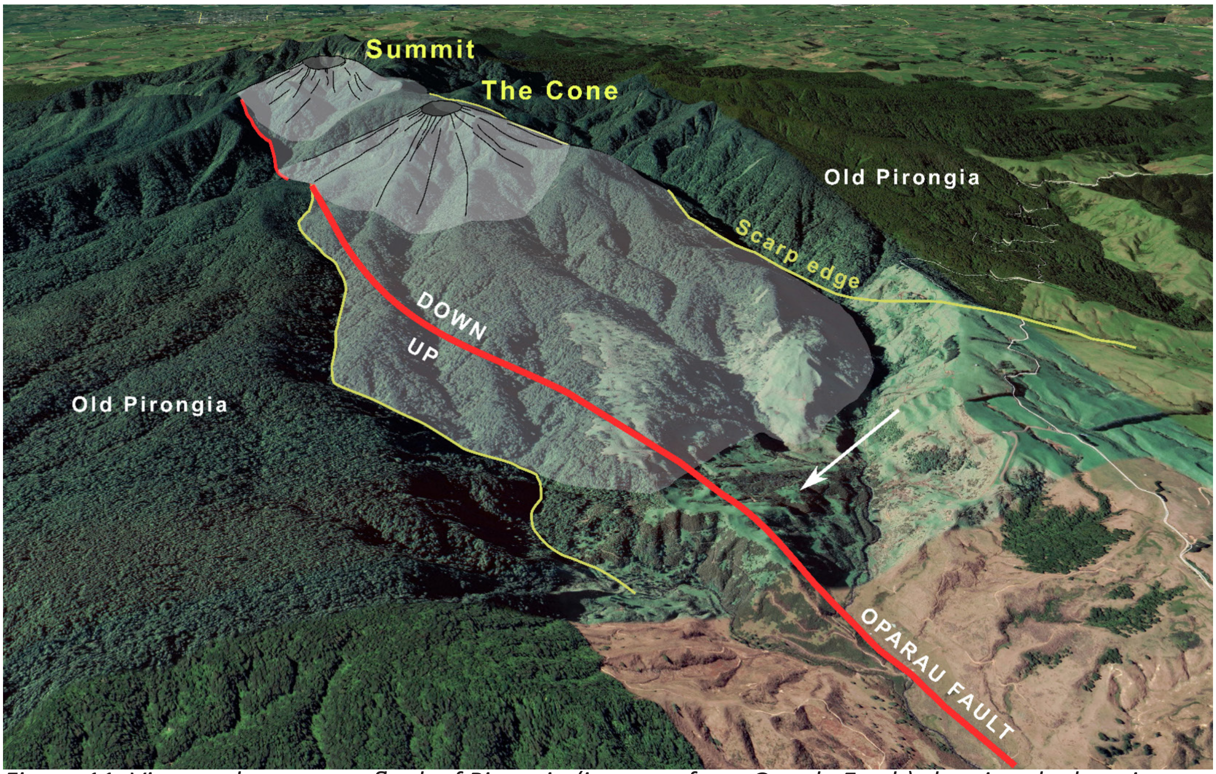


Figure 11. View to the western flank of Pirongia (imagery from Google Earth) showing the location of a large sector collapse scarp (yellow line) associated with the Oparau debris avalanche. The scarp edges mark a major unconformity between older shield lavas (~2.5 Ma, 'Old Pirongia') and younger (1.6 Ma) lavas of The Cone and Pirongia Summit that subsequently infilled the scarp. The northern edge of the scarp coincides with the projected trace of the Oparau Fault (heavy red line). The summit vents are aligned roughly parallel to the Oparau Fault.

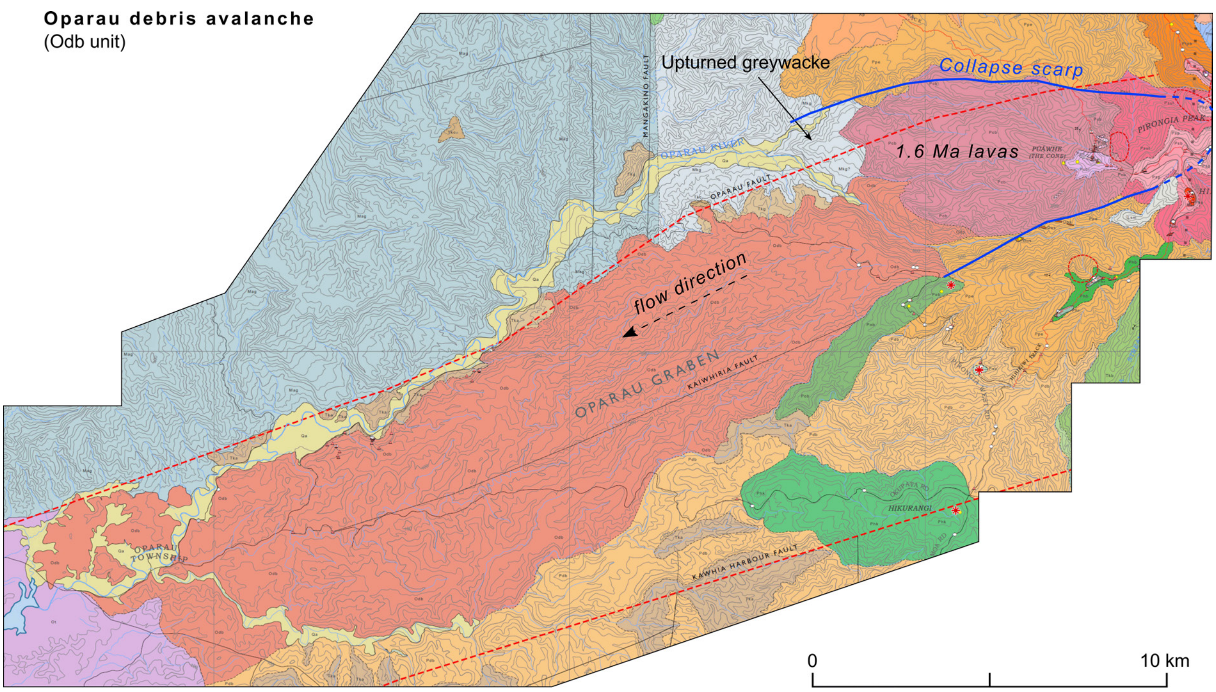


Figure 12. Geological map of the Oparau Breccia (Odb, Fig. 4) debris avalanche deposit (shown in red). The approximate boundary of the collapse scarp is shown by the blue line. Also labelled are the 1.6 Ma lavas that infilled the scarp, and a large block of greywacke at the foot of the scarp that was rotated during the collapse event.

yield ages of 2.13 ± 0.10 Ma and 2.25 ± 0.10 Ma (Robertson 1976). The boulders are correlated stratigraphically to lavas from the Hihikiwi volcanic centre, 2.6 km east and upslope. Finer-grained basanites are found as clasts in the breccia, indicating that intraplate basalt exists in the lower edifice succession of Pirongia.

Distal portions of the Oparau breccia (Fig. 13a-f) form prominent crags (below 70 m asl) along the Oparau River valley where the unit overlies Aotea Formation sandstone (Fig. 13a,c). At the best exposed bluff (base height ~38 m asl), the breccia is vertically continuous over 42 m (Fig. 13b) and forms scattered outcrops to the top of the ridge line (~95 m asl). Deposits in this area consist of poorly sorted, matrix supported diamictons of volcanic rock (Fig. 13d). Clasts range from angular, coarse lapilli up to large, metre-sized, blocks. Many of the blocks show jigsaw fracturing (Fig. 13e) infilled by matrix material. The clastic component is polymict and dominantly basaltic in composition. Lithologies range from ankaramite to finer-grained basaltic-andesite. Andesite is relatively uncommon and occurs mainly as lapilli, including pale-coloured pumice. Hydrothermal alteration is prevalent in many clasts (e.g. zeolite amygdales). Deformed blocks of Te Kuiti Group sandstone and angular basement (metasedimentary) clasts are relatively common in the breccia (Fig. 13f).

Concluding Remarks

On this field trip we have shown a selection of key landforms and deposit types that capture the main characteristics of Pirongia Volcano. In the morning, we focussed on proximal vent systems (e.g. dykes, vent structures and deposits) and the volcanic cone reconstruction, and highlighted the characteristic ankaramites of Pirongia. In the afternoon, we focussed on aspects of the volcanic ring plain (e.g. flank vents and debris avalanche breccias). A new Geological Map of Pirongia Volcano and its associated bulletin, soon to be published, will provide a more comprehensive overview of the volcanic structure and stratigraphy.

Acknowledgements

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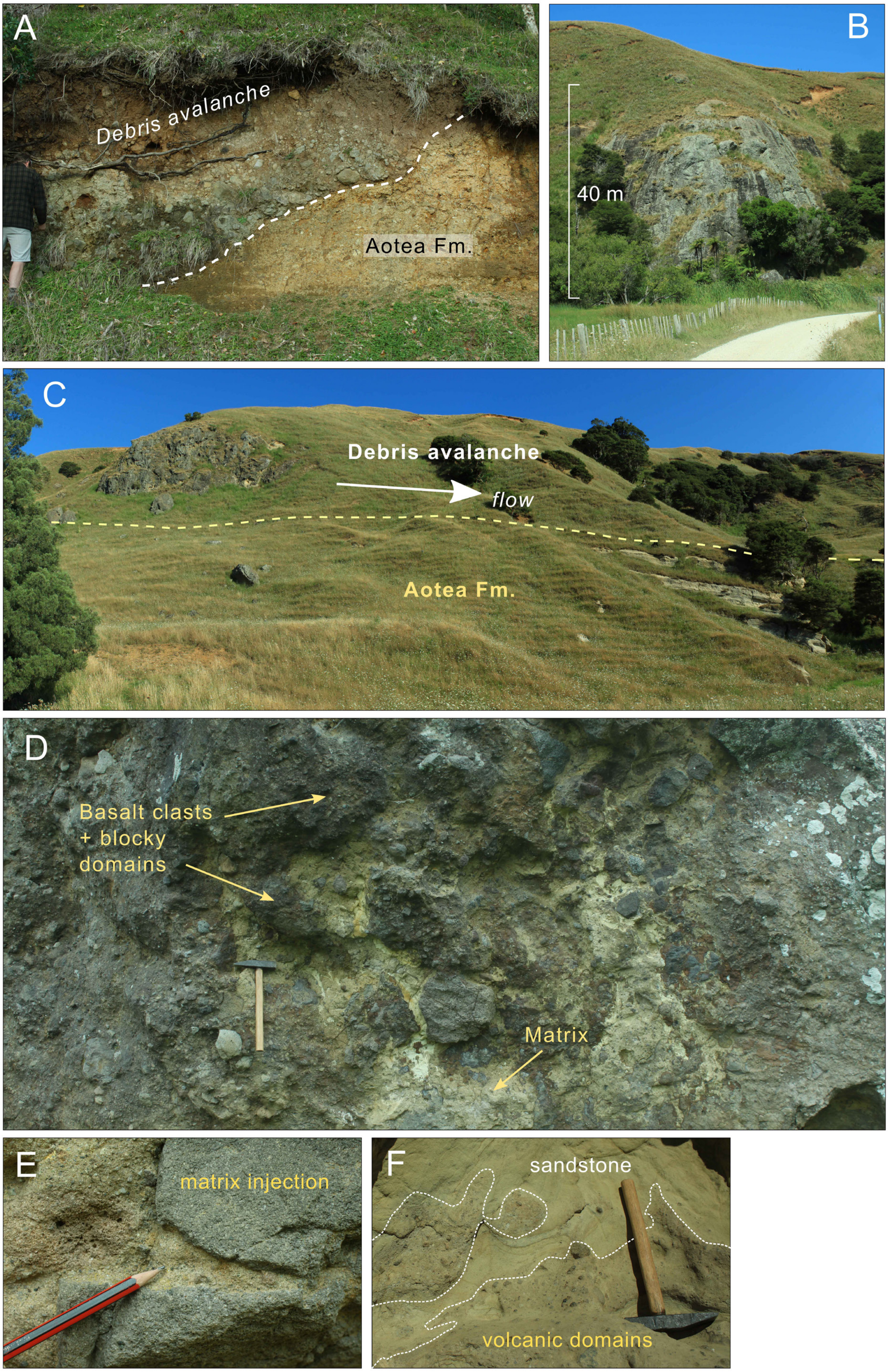
A
Debris avalanche
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Basalt clasts
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E
matrix injection
F
sandstone
volcanic domains

Figure 13 (facing page). Clastic features of the Oparau Breccia. (A) Outcrop at Stop 4, where the debris avalanche overlies Aotea Formation (dashed line is contact, person for scale). (B) Prominent outcrop of breccia on Pirongia West Road, near to Stop 4. (C) Panoramic view of the contact (dashed line) between the breccia and Aotea Formation sandstone near stop 4. (D) Clastic texture of the deposit, with hammer for scale. (E) Matrix injection into jigsaw fractured clast within the deposit. (F) Plastically deformed sandstone clast with volcaniclastic matrix domain of the breccia.

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