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INTRA-CONFERENCE AND POST-CONFERENCE TOUR GUIDES

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D.J. Lowe (Editor)

Note: Throughout the text, Ma = millions of years before present, ka = thousands of years before present.

DAY 1: HAMILTON—RAGLAN—HAMILTON

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Outline of Day 1 (Wednesday 9 February)

8.30-9.00 am	Depart Bryant Hall, University of Waikato, and travel on SH 23 to Raglan Saddle
9.00-9.15 am	STOP 1 — Overview of Alexandra Volcanics from Raglan Saddle
9.15-9.30 am	Travel to Stop 2
9.30-10.30 am	STOP 2 — Woodstock Section: Kauroa and Hamilton Ash Fm.
10.30-10.35 am	Travel from Stop to Raglan
10.35-10.45 am	STOP 3 — Comfort stop, Raglan
10.45-11.00 am	Travel to Stop 4 on Wainui -Whaanga Roads
11.00-11.15 am	STOP 4 — Bryant Home Section, Manu Bay
11.15-11.30 am	Travel to Stop 5 (Te Toto Gorge)
11.30 am-4.30 pm	STOP 5 — Te Toto Gorge & Amphitheatre, Mt Karioi
	LUNCH at appropriate place and time
4.30-5.30 pm	Return from Te Toto Gorge to Hamilton
	Evening: Barbecue at Bryant Hall (all conference participants)

INTRODUCTION

Today's trip to the Raglan district, western North Island, is primarily an introduction to (1) the Alexandra Volcanics, a group of chiefly basaltic deposits of Plio-Pleistocene age, and (2) the Kauroa and Hamilton Ash formations, two groups of weathered, predominantly rhyolitic, tephra beds of Plio-Pleistocene age that, in places, are intercalated with Alexandra Volcanics. Buried paleosols are associated with both the Alexandra and Kauroa/Hamilton deposits. We plan on spending around half the day at one site — Stop 5 — on the Karioi edifice on the west coast, just south of Raglan (Figs. 1.1, 1.5). Here we will examine, in a relaxed and informal manner, outcrops in and near Te Toto amphitheatre and gorge, a critical locality for understanding the stratigraphic succession and petrologic evolution of Karioi (see Fig. 1.9 below).

Our trip westward initally crosses the surface of the Hamilton Basin, esssentially a fault-bounded basement depression of Pliocene and Pleistocene age (Fig. 1.2). Throughout the Quaternary, this basin has been infilling with terrestrial sediments and pyroclastic materials, derived mainly from extrabasinal sources to the southeast (especially the Central Volcanic Region), from Coromandel Volcanic Zone, and from erosion of the bounding ranges (Kear & Schofield 1978; Selby & Lowe 1992). Mesozoic basement is downfaulted ≈200-300 m on the western margins of the basin (Waipa Fault). Much Late Tertiary vertical displacement on the (mainly subsurface) Waipa Fault is inferred from the difference in elevation of basement across the basin, and drilling and gravity data suggests that the Mesozoic basement occurs at variable depth and, in places, up to ≈2000 m below the surface (Kear & Schofield 1978).

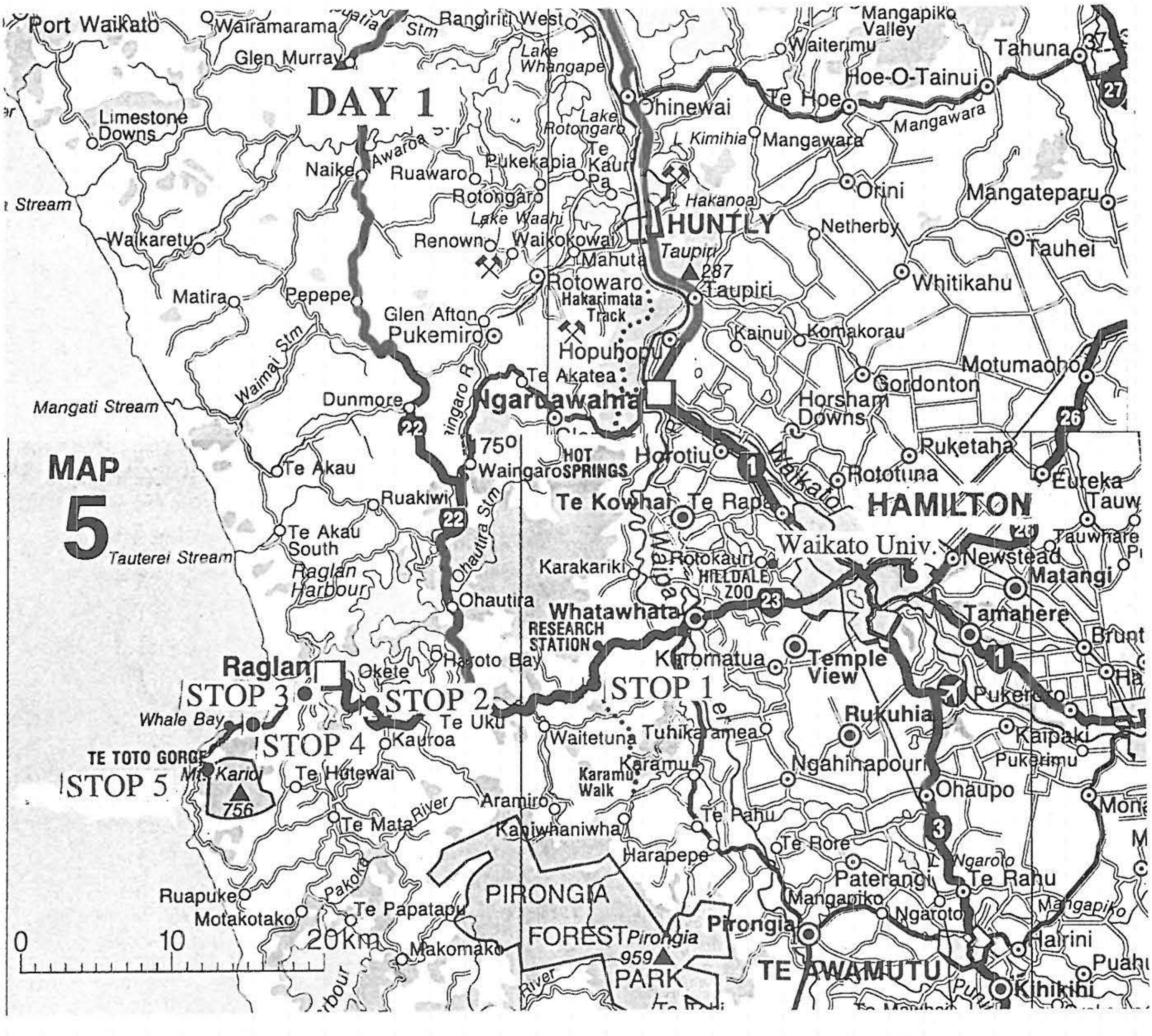


Figure 1.1: Route map for Day 1.

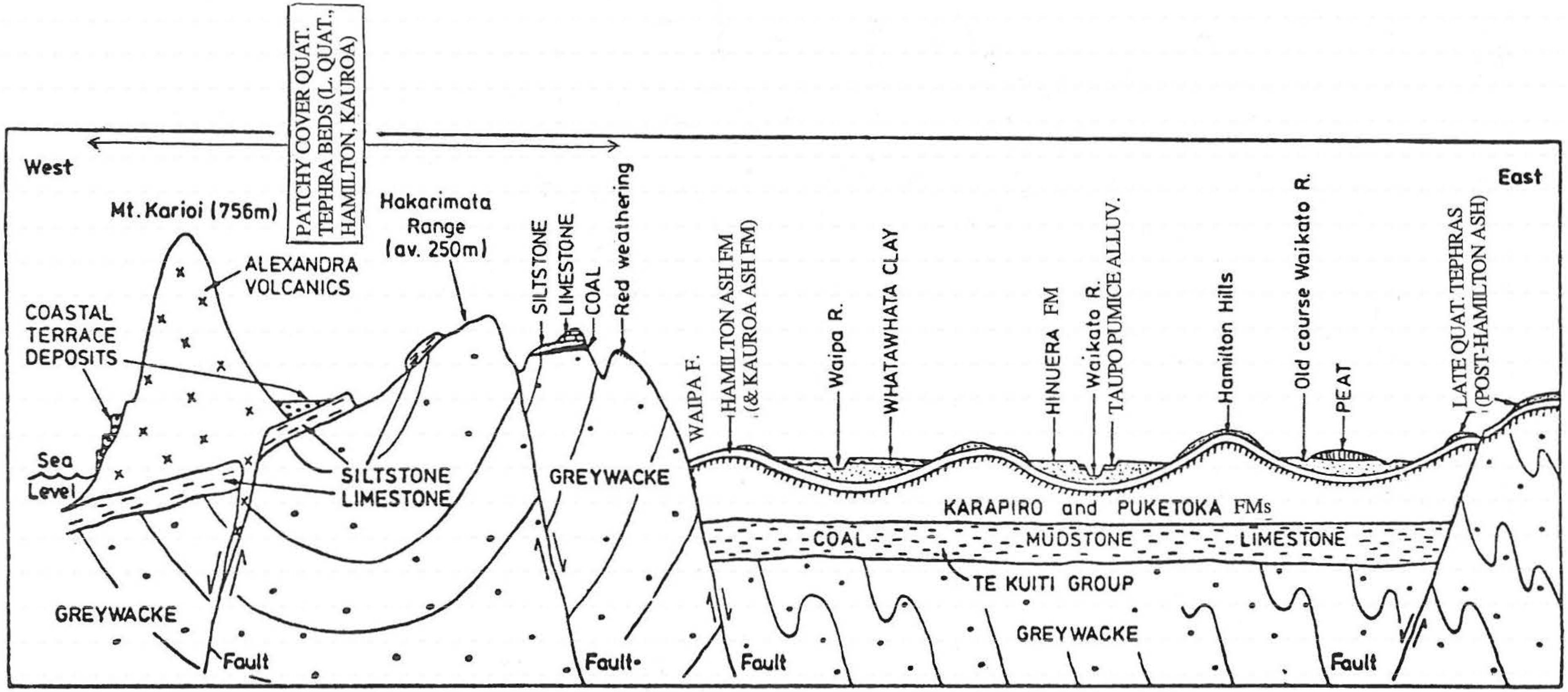


Figure 1.2: Schematic cross section across the Raglan Hills-Hamilton Basin (after Kear & Schofield 1978 and Selby & Lowe 1992).

A simplified stratigraphy of the Quaternary deposits in the basin is summarised in Fig. 1.2, and described in Selby & Lowe (1992). The soil pattern of the Hamilton basin was described by McCraw (1967).

In the Raglan Hills district, the geological pattern provides a basis for the recognition of several physiographic regions, each of which is characterised by an assemblage of distinctive landforms (Bruce 1978; Fig. 1.3). The soil pattern has been described by Bruce (1978).

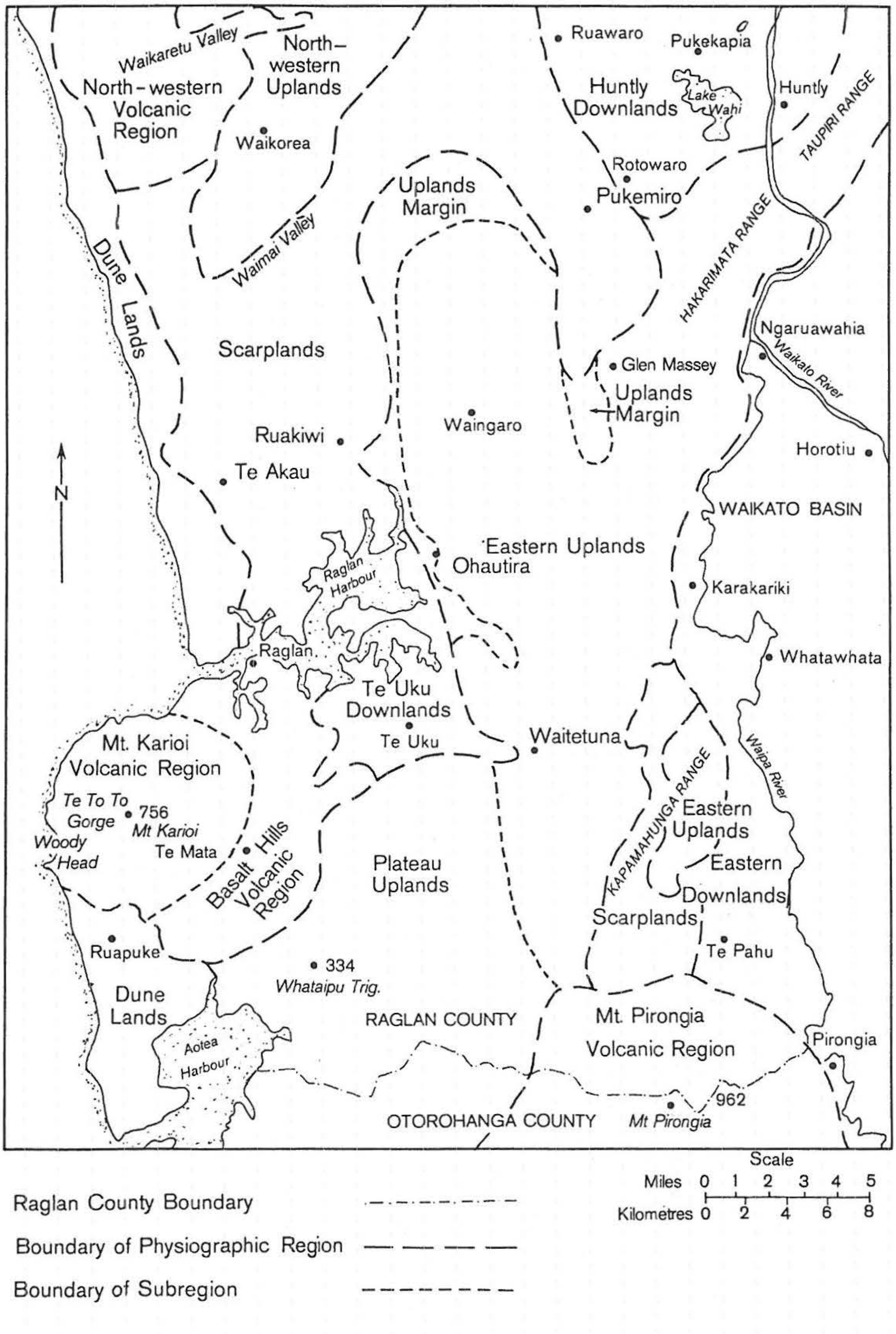


Figure 1.3: Physiographic regions of the Raglan Hills (part Raglan County), western Waikato (from Bruce 1978, p. 12).

ALEXANDRA VOLCANICS

The Alexandra Volcanics Group (AVG) is the southernmost of the Pliocene-Quaternary (2.7 to 1.6 Ma) basalt fields of northern North Island, northwest of the Taupo Volcanic Zone (TVZ) (Briggs et al. 1989; see Fig. 0.2). The most voluminous of the basalt fields (55 km^3), and covering an area of 450 km^2, the AVG forms a 65 km-long volcanic chain with a pronounced northwesterly alignment at right angles to the strike of the TVZ (Briggs 1983; Briggs & Goles 1984; Briggs & McDonough 1990; Fig. 1.4). The AVG has erupted two contrasting magma series: a convergent margin calc-alkalic magma (Pirongia and Karioi Volcanics), and an alkalic intraplate magma (Okete Volcanics), which are both closely spatially and temporally associated (Briggs & McDonough 1990). Field relationships indicate that these diverse magma types were contemporaneous, and thus their mantle source regions coexisted, in a single tectonic environment (Briggs & McDonough 1990).

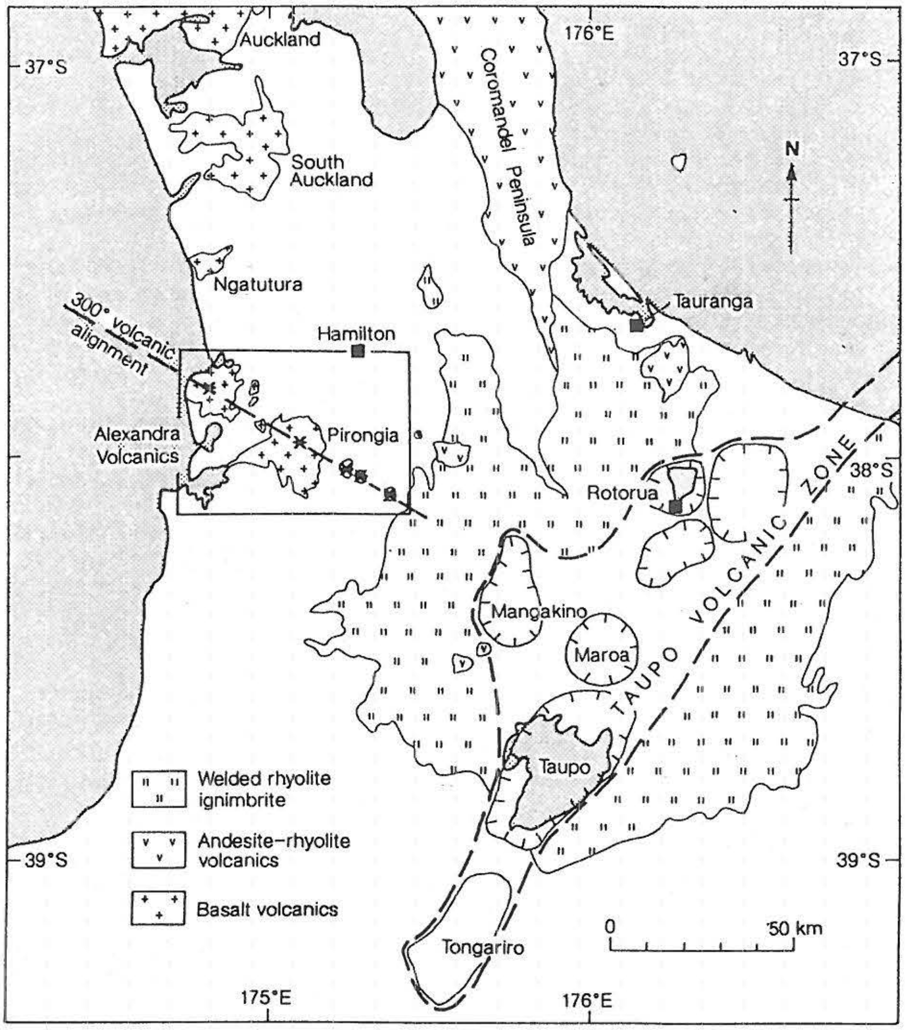


Figure 1.4: Map of the central North Island, New Zealand, showing the tectonic setting and volcanic alignment of the Alexandra Volcanic Group (in box) in relation to the Taupo Volcanic Zone (from Briggs & McDonough 1990). [The locations of recently-identified Whakamaru and Reporoa calderas in the TVZ are shown in Fig. 0.5.]

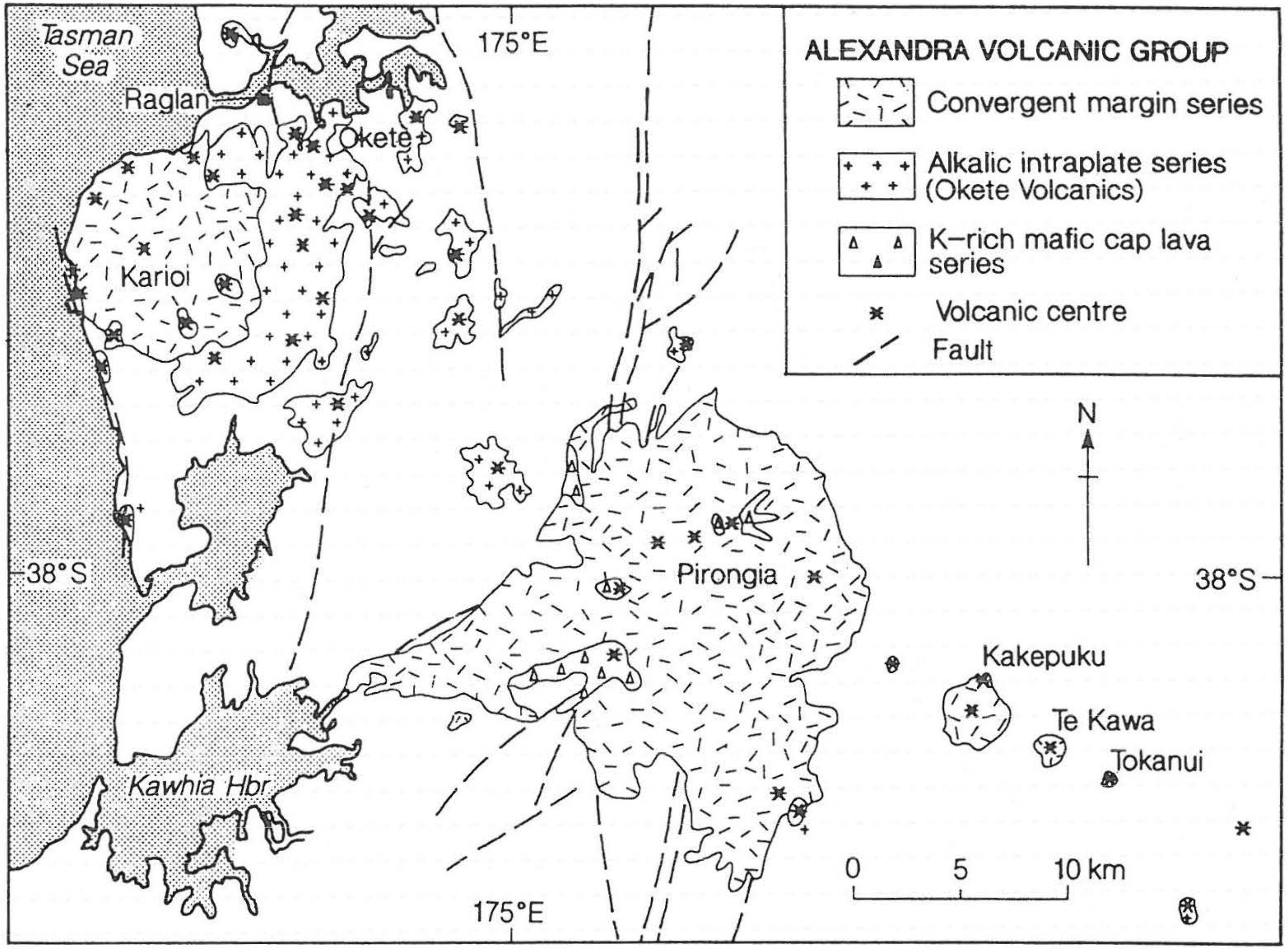


Figure 1.5: Distribution of the calc-alkalic lavas (Karioi, Pirongia, Kakepuku, Te Kawa, Tokanui) and alkalic lavas (Okete) of the Alexandra Volcanic Group (from Briggs & McDonough 1990).

The calc-alkalic convergent margin suite forms low-angle composite cones and shields constructed of lava flows, volcanic breccias, dikes, and minor lapilli tuffs and tuffs (Fig. 1.5). they are predominantly basaltic in composition but include high-K andesites. A K-rich mafic series (basanites and absarokites) form capping lavas on Pirongia, the largest of the stratovolcanoes.

The alkalic intraplate series has produced a volcanic field of monogenetic basaltic volcanoes consisting of lava flows, scoria cones, and tuff rings. Rock types range from basanites to alkali olivine basalts to hawaiites.

In contrast to the convergent margin volcanoes, the alkalic Okete suite shows no northwesterly structural alighnment, but instead is controlled by a system of N-S and NE-SW striking faults, typical of the trends of the extensional back-arc environment of western North Island.

KAUROA AND HAMILTON ASH BEDS

The Kauroa Ash Formation (locally referred to as 'K-beds') comprises a sequence of extremely weathered, clay-rich (av. 85% clay), rhyolitic tephra deposits recognised largely in the Waikato region (Ward 1967; Pain 1975; Davoren 1976; Salter 1979; Kirkman 1980). The beds are quite variable in character, ranging from friable to extremely firm in consistence, and with many colours and structures. Much of the sequence has been removed by erosion — in the Hamilton Basin it is seldom thicker than 1-2 m, but in western Waikato it may be up to 12 m thick — and outcrops are sparse (Selby & Lowe 1992). We will be visiting the type section at Woodstock near Raglan, where Salter (1979) identified 15 units, labelled K1 to K15 from bottom to top, respectively, and numerous associated paleosols (see Stop 2 below).

Stratigraphic interfingering of early Kauroa beds with K-Ar dated basalts of the Alexandra Volcanics enabled K1/2 to be dated at 2.3 Ma (Briggs et al. 1989; Fig. 1.6). New, provisional fission-track dates on zircons from several other beds are reported below. Where preserved, the youngest bed, K15 (also known as Waiterimu Ash), forms an extremely prominent dark reddish brown paleosol with usually a strongly developed blocky or prismatic structure. Not yet dated radiometrically, K15 may have been deposited c. 0.95 Ma (based on stratigraphic work in progress). If so, it represents the tiny remnants of an old land surface that apparently persisted for perhaps half a million years or so (Selby & Lowe 1992). The Kauroa Ash beds evidently represent distal airfall tephra and ignimbrite deposits from early TVZ eruptions, some probably deriving from Mangakino volcano (Fig. 1.4).

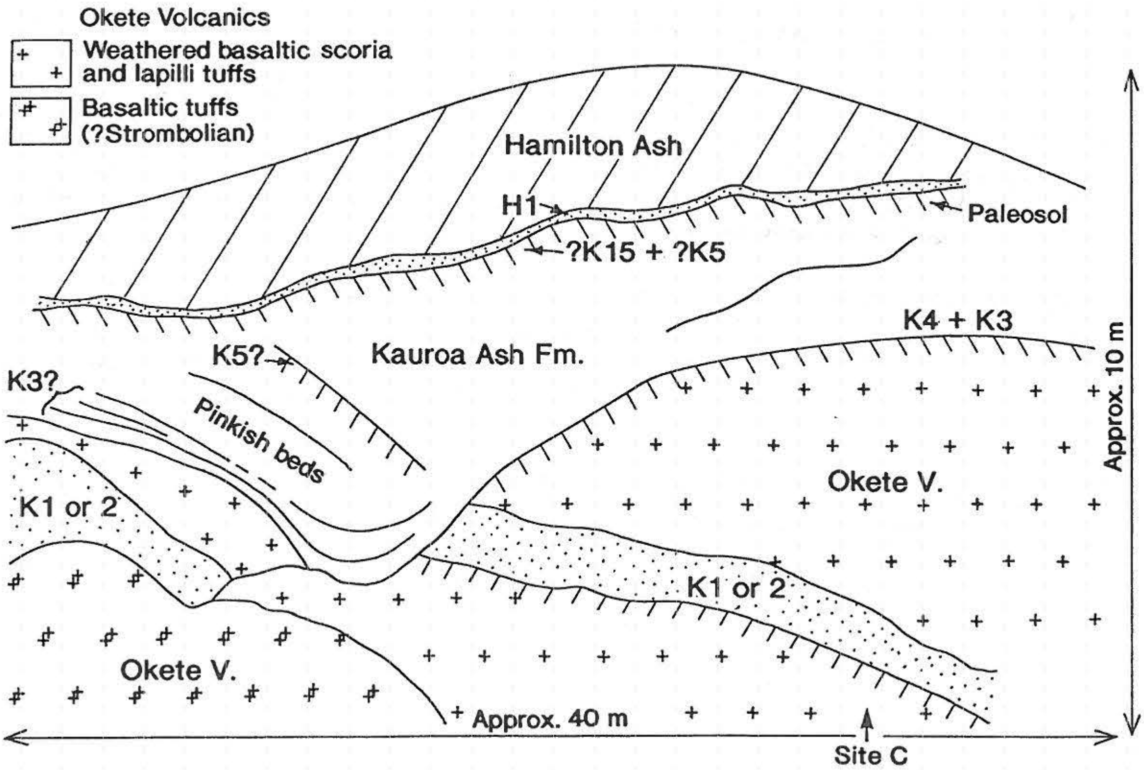


Figure 1.6: Sketch of section on Kauro-Te Mata Road (R14/787722) showing stratigraphic relationships of Okete Volcanics (Ohiapopoko cone, Maungatawhiri centre) and Kauroa and Hamilton Ash beds. 'Site C' is described in Briggs et al. (1989, p. 427).

The Hamilton Ash Formation, separated from the underlying Kauroa beds by a well defined erosional unconformity, comprises a sequence of strongly weathered, clay-textured tephra beds and paleosols well represented in the Waikato-South Auckland regions (Ward 1967; Pain 1975). Usually between 3 and 5 m thick, the beds are sometimes thin and patchy, presumably because of erosion (Selby & Lowe 1992). The sequence has been divided into eight units numbered H1 to H8 from bottom to top, respectively. The oldest bed (H1; also known as Ohinewai Tephra: Vucetich et al. 1978) is typically a pale yellowish brown colour with a sharp lower boundary marked by a coarse yellow, quartz-rich sandy layer forming a prominent marker bed. Based on correlations with other tephra deposits in central and southern North Island, and in deep sea cores, H1 (and perhaps H2) has been identified as the Rangitawa Tephra, which has an age (based on fission track analysis of zircons) of 0.35 ± 0.04 Ma (Nelson 1988; Kohn et al. 1992). Rangitawa Tephra is probably a distal correlative of the biotite and quartz-bearing Whakamaru-group ignimbrites erupted from Whakamaru or Taupo volcanoes (Kohn et al. 1992). The remaining Hamilton beds, all clayey in texture (≈60-85% clay), range from friable to firm in consistence with reddish-yellow to strong brown colours, and may well have originated from these sources too. Their ages are currently unknown, although Shepherd (1994) suggests that H8 was deposited probably during a glacial period at Stage 6 c. 150-120 ka. The presence of up to 7 paleosols in the sequence suggests that there were considerable periods without eruptions.

At some localities, halloysitic clay lobes with associated contorted stratification occur in basal beds; Tonkin (1970) suggested that such lobes were formed by deformation and plastic flowage into more sensitive overlying beds, perhaps during earthquake shocks. Where the Hamilton Ash materials are exposed at or near the surface, well-developed and strongly structured soils occur, usually Humults or Udults

The Hamilton Ash beds are evidently rhyolitic in origin (based on trace element analysis of titanomagnetites; Shepherd 1984). Their clay mineralogy has been documented by Hogg (1974) and Shepherd (1984) (summarised by Lowe & Percival 1993). The clays are dominated by halloysite with three common morphologies: large and small spheroids, long tubes, and short and medium-sized laths and tubes (Shepherd 1984); small amounts of allophane, goethite, gibbsite, and ferrihydrite also occur. In some beds (especially H2) a sand-sized golden platy mineral has been identified as a 2:1:1 partially random interstratified micaceous kaolinite intergrade (Shepherd 1984), probably the result of dissolution of biotite and recrystallisation of kaolinite at linear boundaries (Lowe & Percival 1993).

STOP 1 — Raglan Saddle (S14/920723*)

Here we stop briefly to overview the major composite cones of Pirongia and Karioi of the Alexandra Volcanics. Priongia (959 m a.s.l.) has a long and complex volcanic history with an age of 1.60 Ma at the summit and 2.74 Ma on its southern slopes — i.e. spanning the entire duration of the Alexandra Volcanics (Briggs et al. 1989). Karioi volcano (756 m) also has an involved volcanic history (see Stop 5), with reliable ages ranging from 2.40-2.16 Ma.

Based on the apparent decrease in degree of erosion from Karioi to Kawa (i.e. from NW to SE), it was suggested previously that the stratovolcanoes become progressively younger to the southeast. However, the K-Ar radiometric dates indicate that they have broadly similar ages and do not young in any direction, and, moreover, overlap in age with the Okete Volcanics (Briggs et al. 1989).

STOP 2 — Woodstock Section: Kauroa and Hamilton Ash beds (R14/783734) [Please be especially careful of traffic here]

This is the type section for the Kauroa Ash Formation (the name 'Woodstock' derives from the original name of the adjacent farm), and a reference site for the Hamilton Ash Formation (Ward 1967). Rainfall is ≈1400 mm p.a. (Bruce 1978).

* Grid references throughout the guide are based on the 1:50 000 New Zealand Map Series 260 with a 1000 m grid.

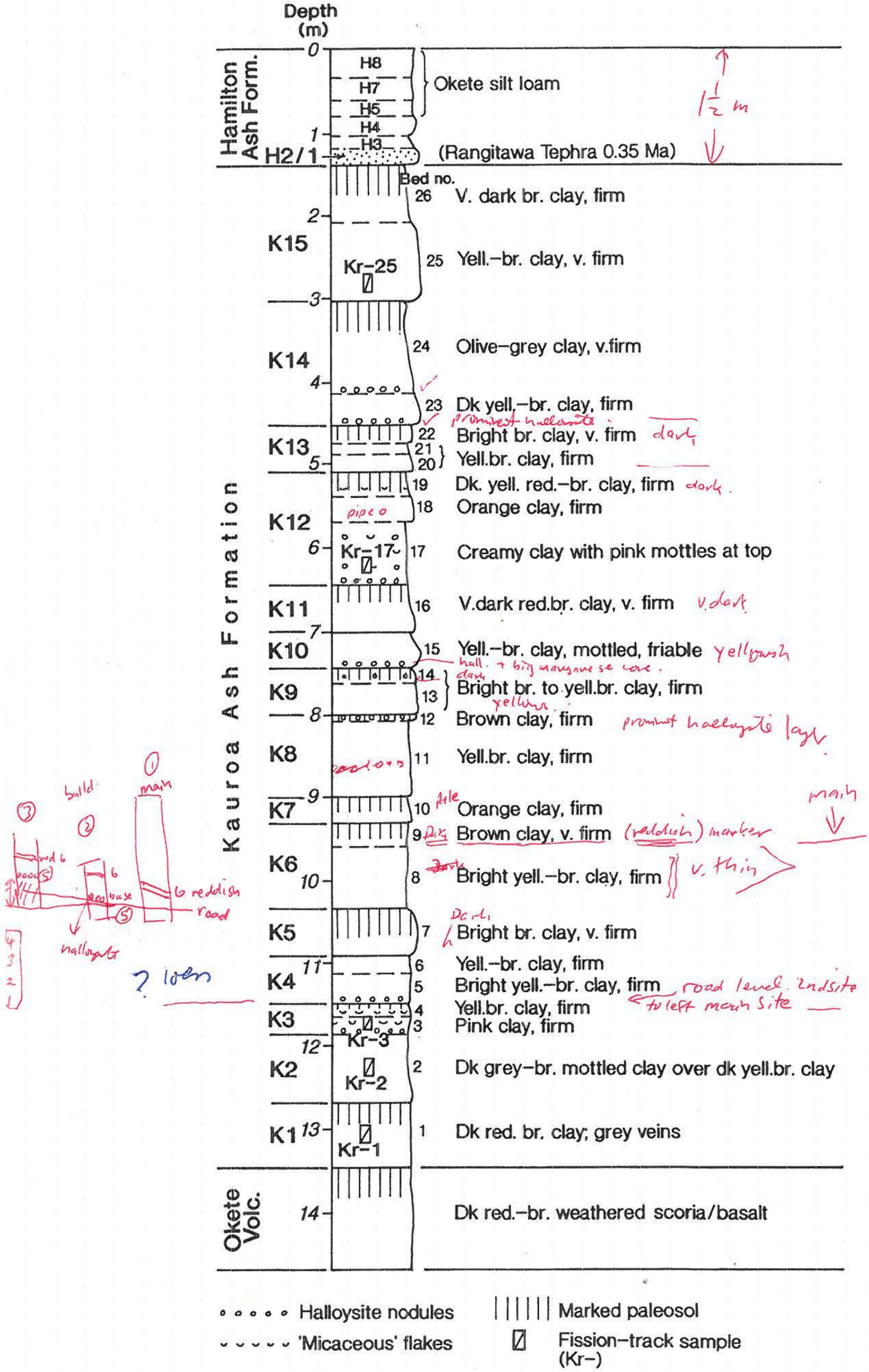


Figure 1.7: Stratigraphy of the Hamilton and Kauroa Ash beds at Woodstock near Raglan (mainly after Salter 1979; Hamilton Ash stratigraphy after Ward 1967).

The stratigraphy of the section is summarised in Fig. 1.7. Salter (1979) identified and analysed 26 beds within the section, enabling the sequence to be classified into 15 members (K1-15). This stratigraphy has been slightly modified by T.G. Shepherd (unpub. data). Provisional fission-track ages (subject to further counting) on zircons extracted from five beds (Fig. 1.7) are as follows (Table 1.1) (J. M. Tippett & P. J. J. Kamp unpub. data):

TABLE 1.1 Provisional fission-track ages, Kauroa Ash Formation, Woodstock

Sample	Member	Age ± 2 S.D. (Ma)
Kr-25	K15	nd (inadequate zircons)
Kr-17	K12	1.41 ± 0.26
Kr-3	K3	1.70 ± 0.32
Kr-2	K2	1.50 ± 0.44
Kr-1	K1	2.30 ± 0.56

The age for K1 (Kr-1) agrees with those obtained by Briggs et al. (1989) for this bed intercalated with two dated basalts at nearby Maungatawhiri volcanic centre (2.26, 2.25 Ma). K12, the prominent whitish marker bed, has been tentatively correlated with Ongatiti Ignimbrite (probably equivalent to Oparau Tephra; Pain 1975; Salter 1979) and the age of 1.41 ± 0.26 Ma (Kr-17), taking errors into account, is consistent with the Ar/Ar age of 1.23 ± 0.02 Ma obtained on Ongatiti Ignimbrite (Briggs et al. 1993). Briggs et al. (1989) demonstrated that K15 must be younger than 1.81 Ma, and the age on K12 supports this contention. As noted above, stratigraphic work suggests a possible age of c. 0.95 Ma(?) for K15; a minimum age is given by H1/2 (Rangitawa Tephra) of the overlying Hamilton Ash sequence (0.35 Ma; Kohn et al. 1992).

The Kauroa beds here have high clay contents, ranging from 69-92% (<2 μm fraction). The small amounts of primary minerals are dominated by quartz, cristobalite, (titano)magnetite, ilmenite, and zircon.

The clays have been analysed by Kirkman (1980), Salter (1979), and Shepherd (1994 and unpub. data). Table 1.2 summarises the latest data: the amounts of kandite (kaolinite plus halloysite) and gibbsite were determined by DTA (Whitton & Churchman 1987); halloysite and kaolinite were estimated by XRD analysis of formamide-treated samples (Churchman et al. 1984); allophane was estimated by the acid oxalate (Al, Si) and pyrophosphate (Al) extractions (Parfitt & Wilson 1985); ferrihydrite and goethite were estimated by oxalate, dithionite, and pyrophosphate (Fe) extractions (Childs 1987) (see Lowe & Percival 1993 for a summary of techniques).

The beds are dominated by kandite (60-95% whole sample basis) with smaller amounts of goethite (2-15%) and minor amounts of allophane (0.5-2%), ferrihydrite (0.1-1%), and gibbsite (<0.1-2%). Halloysite (50-95%) is by far the major component of the kandite mineral group, with kaolinite varying from 0-20% (Table 1.2). Bed K8IV has significantly more goethite than other beds (15%), while K10 has most gibbsite (2%). Salter (1979) additionally identified traces of montmorillonite-vermiculite intergrades in K2 and K4.

The predominance of halloysite throughout the entire Kauroa sequence is possibly a product of its relative stability in the current weathering environment where the ionic concentration of the various reactants for halloysite in solution (especially [Si]) is in equilibrium with its solubility product, a function in part of the age of the beds and their strongly weathered nature. It is possible that allophane would have formed in significant quantities in the past, but has since been 'converted' to halloysite either by the solid state transformation of Si-rich allophane (Al/Si = ≈1), or by the dissolution of Al-rich (proto-imogolite) allophane (Al/Si = ≈2) followed by its reprecipitation as halloysite.

The type of allophane that now remains is primarily of the Al-rich type, likely to be a function of its greater stability (depending on silica activity; Percival 1985). A remnant amount of Si-rich allophane occurs only in K8III and K4I (Table 1.2).

TABLE 1.2. Mineralogical composition[1] of the Kauroa Ash beds at Woodstock

Sample	Thickness cm	Kandite (%)	Halloy. (%)	Kaol. (%)	Alloph. (%)	Alloph. (Al/Si)	Alloph./ Kandite	Ferrihy. (%)	Goeth. (%)	Gibb. (%)
H2	35	85	85	0	1	a	0.01	0.2	4	<0.1
K15 III	38	60	55	5	1	a	0.02	0.5	7	<0.1
K15 II	29	65	60	5	1	a	0.02	0.5	8	0.5
K15 I	33	90	90	0	1	a	0.01	0.5	6	1
K14 VII	32	70	65	5	1	a	0.01	0.1	7	<0.1
K14 VI	29	75	70	5	1	a	0.01	0.5	8	<0.1
K14 V	18	75	70	5	1	a	0.01	0.5	7	0.5
K14 IV	58	85	80	5	1	a	0.01	0.5	6	0.1
K14 III	27	80	80	0	1	a	0.01	0.5	6	0.5
K14 II	14	90	90	0	1	a	0.01	0.5	5	<0.1
K14 I	16	95	95	0	1	a	0.01	0.5	2	0
K13 III	21	80	75	5	1	a	0.01	0.5	4	0.1
K13 II	15	85	80	5	1	a	0.01	0.5	5	0.5
K13 I	27	85	85	0	2	a	0.02	0.5	4	0
K12 IV	20	75	75	0	2	a	0.03	0.5	8	0.5
K12 III	39	75	70	5	0.5	a	0.01	0.5	5	0.1
K12 II	16	90	85	5	1	a	0.01	0.1	3	0
K12 I	57	95	90	5	0.5	3.2	0.01	0.5	2	0
K11	66	65	60	5	0.5	2.2	0.01	0.1	8	0.1
K10	49	75	70	5	0.5	3.3	0.01	0.5	8	2
K9 II	20	95	95	0	2	a	0.02	1	5	0.5
K9 I	38	85	85	0	0.5	2.0	0.01	0.5	6	0.5
K8 IV	6	70	70	0	0.5	2.2	0.01	0.5	15	0.5
K8 III	28	95	95	0	1	1.1	0.01	0.5	5	0.1
K8 II	9	90	75	15	1	3.6	0.01	0.5	5	0.5
K8 I	12	90	90	0	0.5	3.3	0.01	0.1	3	0
K7 II	8	90	80	10	1	a	0.01	0.1	4	0.1
K7 I	19	85	85	0	1	a	0.01	0.1	5	0.1
K6 II	24	75	70	5	1	a	0.01	0.5	5	0.1
K6 I	19	80	80	0	1	2.5	0.01	0.1	7	0.5
K5	70	60	50	10	1	a	0.02	0.5	10	0.5
K4 II	15	70	55	15	1	1.9	0.01	0.5	7	0.5
K4 I	20	80	70	10	1	1.0	0.01	0.5	7	0.5
K3	29	65	60	5	2	2.8	0.01	1	6	0.5
K2 III	16	80	70	10	1	3.6	0.01	0.5	5	0.1
K2 II	6	95	90	5	1	2.3	0.01	0.5	2	0
K2 I	18	85	80	5	1	a	0.01	0.1	5	0.1
Weathered basalt lapilli tuff ?	15	95	85	10	0.5	a	0.01	0.1	7	0.1
K1 III	25	70	60	10	0.5	a	0.01	0.1	6	<0.1
K1 II	30	70	50	20	1	a	0.01	0.1	8	0.1
K1 I	40	85	75	10	0.5	a	0.01	0.1	5	0.1
On weathered basaltic scoria (Alexandra Volcanics)										

[1] Mineralogical composition of the whole soil. ooooooo = White halloysite nodules a = insufficient silica present
Halloy. = Halloysite; Kaol. = Kaolinite; Alloph.= Allophane; Ferrihy. = Ferrihydrite; Goeth. = Goethite Gibb. = Gibbsite
Wavy line represents an unconformity. Shading signifies the presence of a paleosol.

An alternative explanation for the predominance of halloysite is that the drainage and leaching conditions at Woodstock have always been such that halloysite formation, rather than (Al-rich) allophane, has been favoured, i.e. the halloysite is relict. This contention requires that silica concentration has been relatively high (hence leaching of Si low, either because of low rainfall or slow drainage, or both) as halloysite is more stable than imogolite and Al-rich allophane only at high silica activities (Lowe & Percival 1993; Lowe 1994); kaolinite is the most stable mineral of those found in the Kauroa beds. The presence of halloysite concretions or nodules in some beds, typically with associated Mn nodules (Table 1.2; Salter 1979), indicates perhaps that silicon enrichment through wetting and drying and perching has occurred (Stevens & Vucetich 1985; Lowe 1986).

Both allophane (Al/Si = ≈2) (up to 60% whole sample) and halloysite (up to 66%) occur in a sequence of strongly weathered tephra beds near Te Kuiti, where Stevens & Vucetich (1985) suggested that the allophane-rich beds weathered under warmer, wetter (interglacial) conditions, and the halloysitic beds under colder, drier (glacial) conditions based on the leaching models of Parfitt et al. (1983) and Singleton et al.(1989). The Te Kuiti sequence probably has an appreciably greater andesitic component than that at Woodstock; if so, this would additionally favour the formation of allophane over halloysite (Lowe 1986).

Sand-sized 'micaceous' or platy minerals found in K3, K4, and K-12 were identified as b-axis disorded kaolinite books and stacks (Salter 1979). Sparse relict pumice fragments, coated with an iron oxide, were also identified in these beds (Salter 1979).

Numerous paleosols occur within the Kauora sequence — Salter (1979) identified around 10 and Shepherd (1994) 14 (Table 1.2). They are identified (not always easy in such strongly weathered materials) on the basis of various field properties including colour (darker and more reddish hue), consistence (very firm), and structure (strongly developed blocky/polyhedral), and occasional root traces or rodlet pseudomorphs.Their occurrence is supported by the distribution of total carbon, and by the increase of halloysite with depth from the top of the paleosol to the base of the tephra bed (T.G. Shepherd unpub. data).

STOP 3 — Toilet stop, Raglan

STOP 4 — Bryant Home Section, Manu Bay (R14/705737)

This section shows some of the TVZ-derived Kauroa Ash beds overlying laharic deposits derived from Mt Karioi (Fig. 1.8). The brief stop here is primarily to illustrate the contemporay activity of Mt Karioi and in TVZ. More sections, predominantly showing laharic material with one or two intercalated older K-beds, and paleosols, occur a little further along the road (around the corner). None of these sections has been studied in detail.

STOP 5 — Te Toto Amphitheatre and Gorge (Car Park at R14/665717)

The Te Toto area is a large scallop-shaped erosional amphitheatre that has formed on the northwestern flank of Karioi volcano (Figs. 1.9-10). The amphitheatre has exposed an Okete tuff ring, surge beds, and pillow lavas just above sea level, which are overlain by a thick sequence of Karioi lavas that form most of the upper cliffs.

The Okete Volcanic Formation has been divided into a stratigraphically lower Pauaeke Member that underlies Karioi lavas, which are exposed here at Te Toto (Figs. 1.11 & 1.13), and a stratigraphically upper Marumaruaitu Member that overlies Karioi lavas. The Karioi Volcanic Formation consists of three members, all of which are exposed in Te Toto amphitheatre and Gorge (Fig. 1.11). The Te Toto Member is stratigraphically lowest and consists of a series of three lava flows, separated from a thick sequence of shield-building Whaanga lavas by the prominent orange main marker horizon. The Whaanga Member consists of at least 15 sheet flows, and in the upper part of the stratigraphic succession exposed in road cuts in Te Toto Gorge, it is overlain in turn by Wairake Member lavas and lahars.

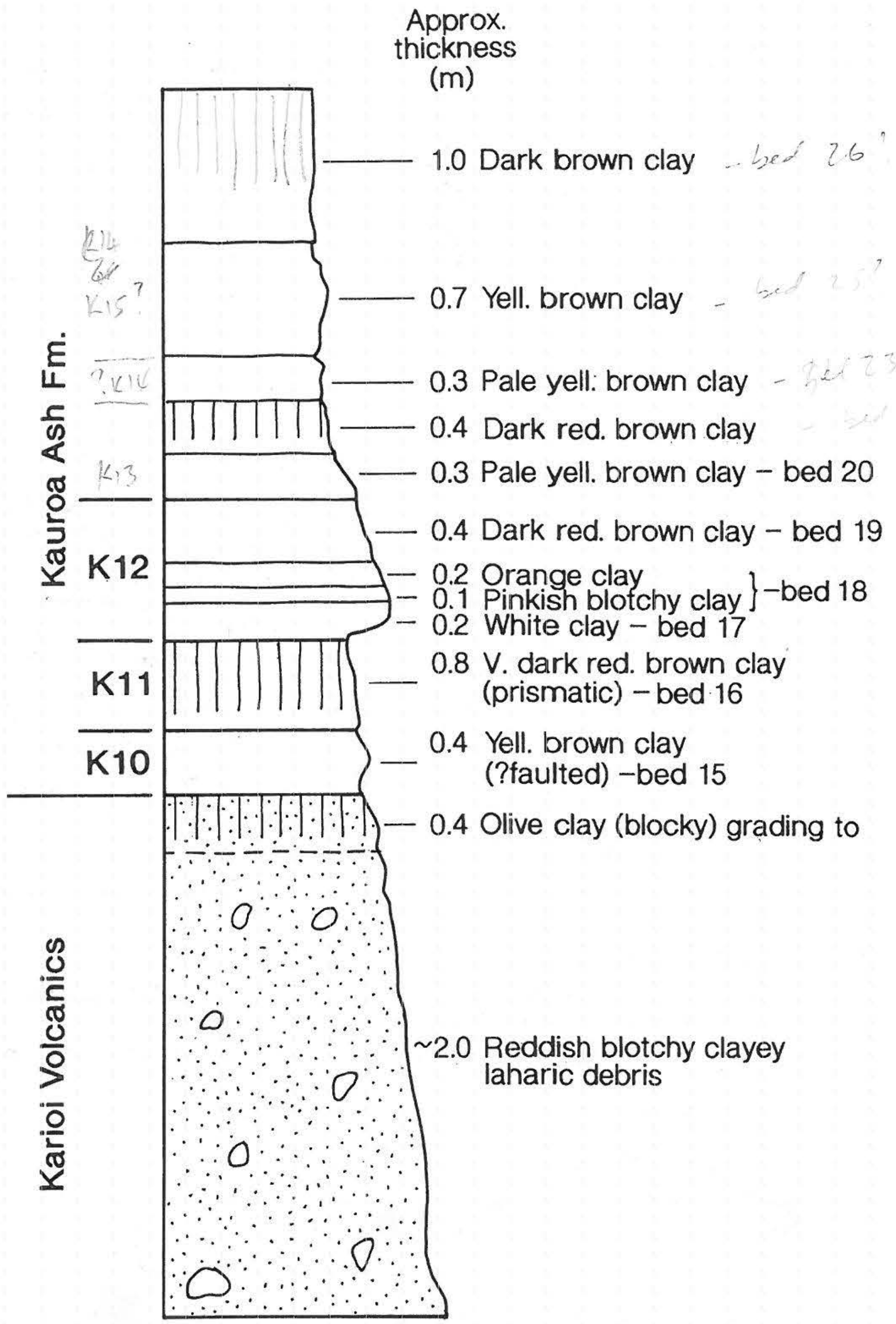
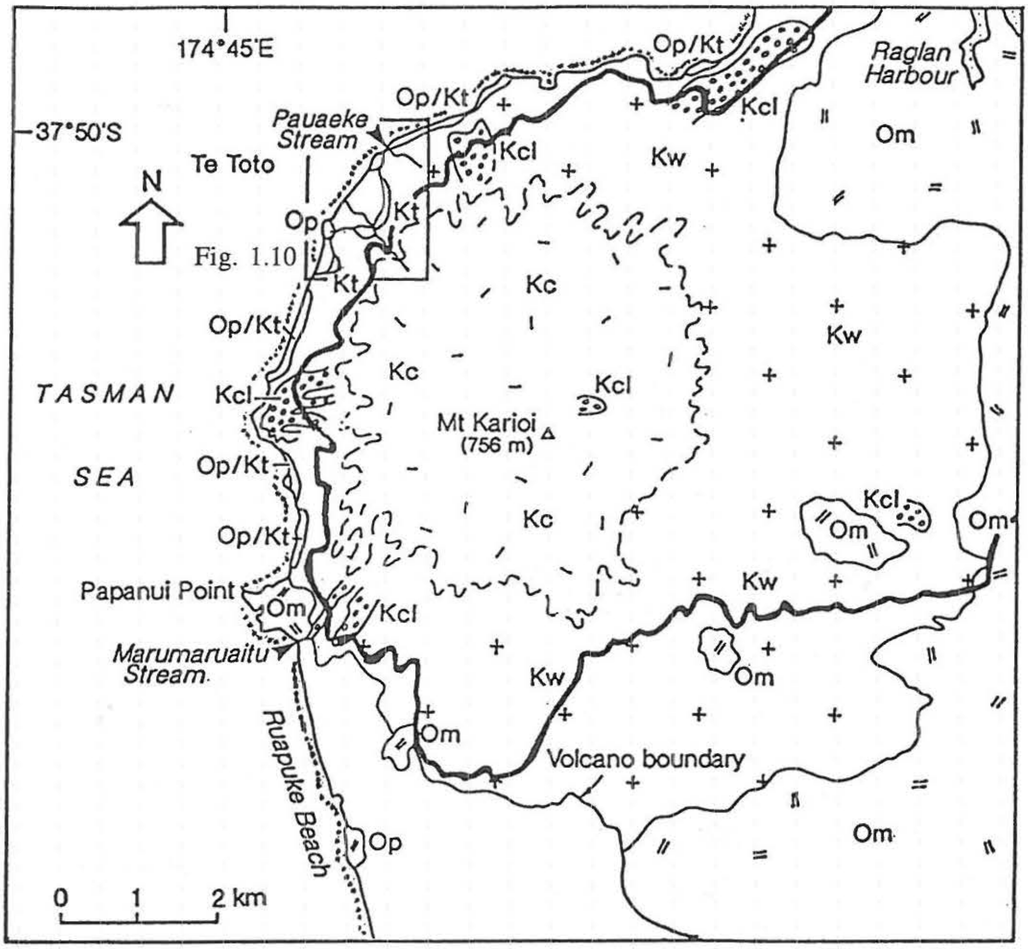


Figure 1.8: Stratigraphy of Kauroa Ash beds and Karioi laharic deposits at the Bryant Home Section, Manu Bay.

R14/705737



LEGEND

Karioi Volcanic Formation

Kc Wairake Member: Cone-building lavas, tuffs, dikes, volcanic breccias, laharic deposits (Kcl), and valley-filling lavas

Kw Whaanga Member: Sheet lavas, volcanic breccias, minor interbedded tuffs, and rare dikes

Kt Te Toto Member: Lavas, volcanic breccias, interbedded tuffs

Okete Volcanic Formation

Om Marumaruaitu Member: Lavas and interbedded tuffs postdating Karioi volcanics

Op Pauaeke Member: Lavas, lapilli tuffs predating Karioi volcanics

Figure 1.9: Map of Karioi volcano showing the distribution of volcanic formations and members. Some data from Matheson (1981) and Keane (1985).

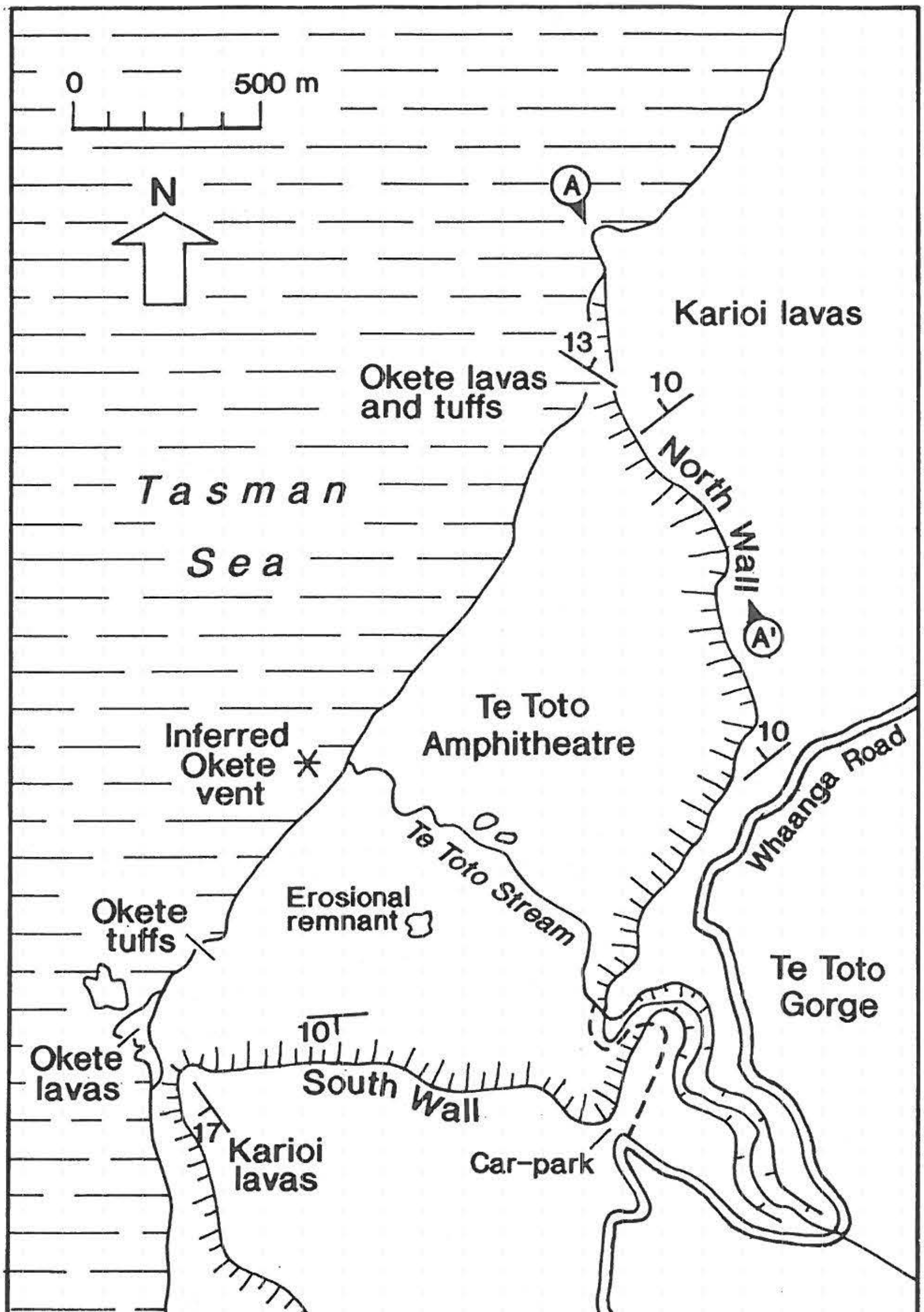


Figure 1.10: Map of Te Toto Gorge and amphitheatre, northwestern flank of Karioi volcano. A-A' is the line of the Pauaeke type section (Fig. 1.13), North Wall of Te Toto amphitheatre.

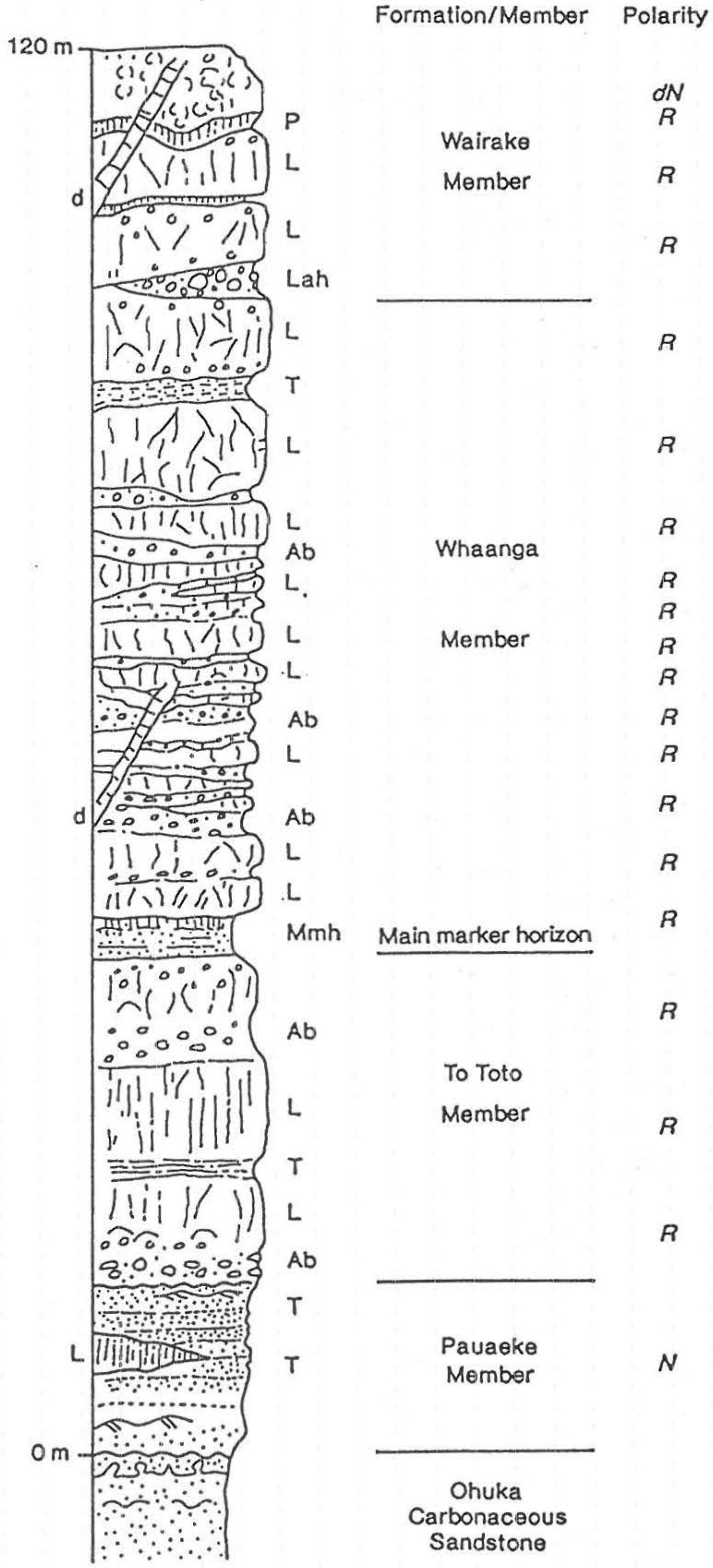


Figure 1.11: Composite stratigraphic section through the Karioi Volcanics exposed in the South Wall of Te Toto amphitheatre and in Te Toto Gorge. L = lava, Ab = autoclastic breccia, T = tuff and lapilli tuff, d = dike, Lah = laharic deposit, Mmh = main marker horizon, P = paleosol.

We shall begin with a general overview of Te Toto amphitheatre from the car park reserve of Whaanga Road. Then we shall examine the roadcut just east of the parking area, where there are exposed uppermost units of the Whaanga Member (including a strikingly plagioclase-phyric lava), the erosional unconformity that caps the Whaanga units, a basal Wairake lahar, and three Wairake lavas above that lahar (Fig. 1.12).

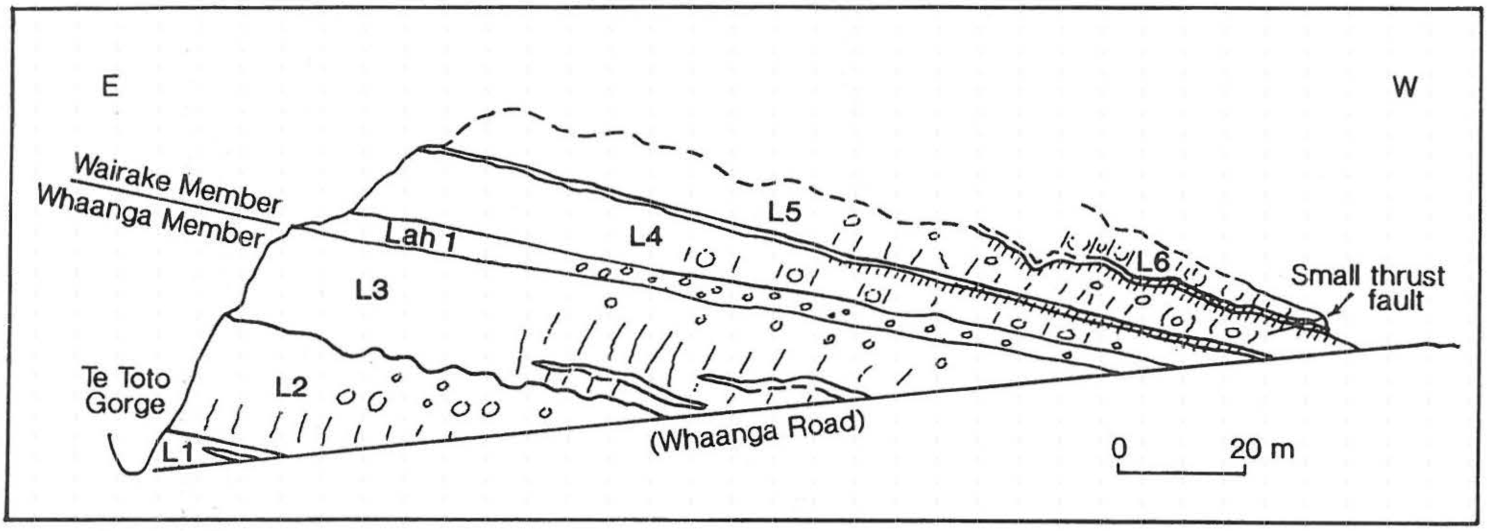


Figure 1.12: Sketch of lava flow sequence (L1-L6), with intercalated laharic deposits marking the local base of the Wairake Member, at the Whaanga Road section in Te Toto Gorge.

We shall then follow the trail down into Te Toto Gorge and amphitheatre, and examine:

(a) the vent-proximal facies of the Te Toto Member of thick calc-alkalic lavas and breccias;
(b) the Pauaeke type section (Fig. 1.13) at the seaward end of the North Wall of the amphitheatre (and archaeological features en route); and
(c) Okete (Pauaeke Member) lavas and enclosed mantle xenoliths, surge beds, and contacts with underlying Ohuka Carbonaceous Sandstone beds, near the end of the South Wall.

While in Te Toto amphitheatre, participants will see some of the indications of a close relationship between the alkalic Okete Volcanic Formation (Pauaeke Member) and the calc-alkalic Karioi Volcanic Formation (Te Toto Member). These indications include suggestions of a relatively short interval between cessation of eruption of Pauaeke magmas and beginning of Te Toto activity, and evidence that both sets of magmas were erupted from small central vent volcanoes under much the same kinds of structural control.

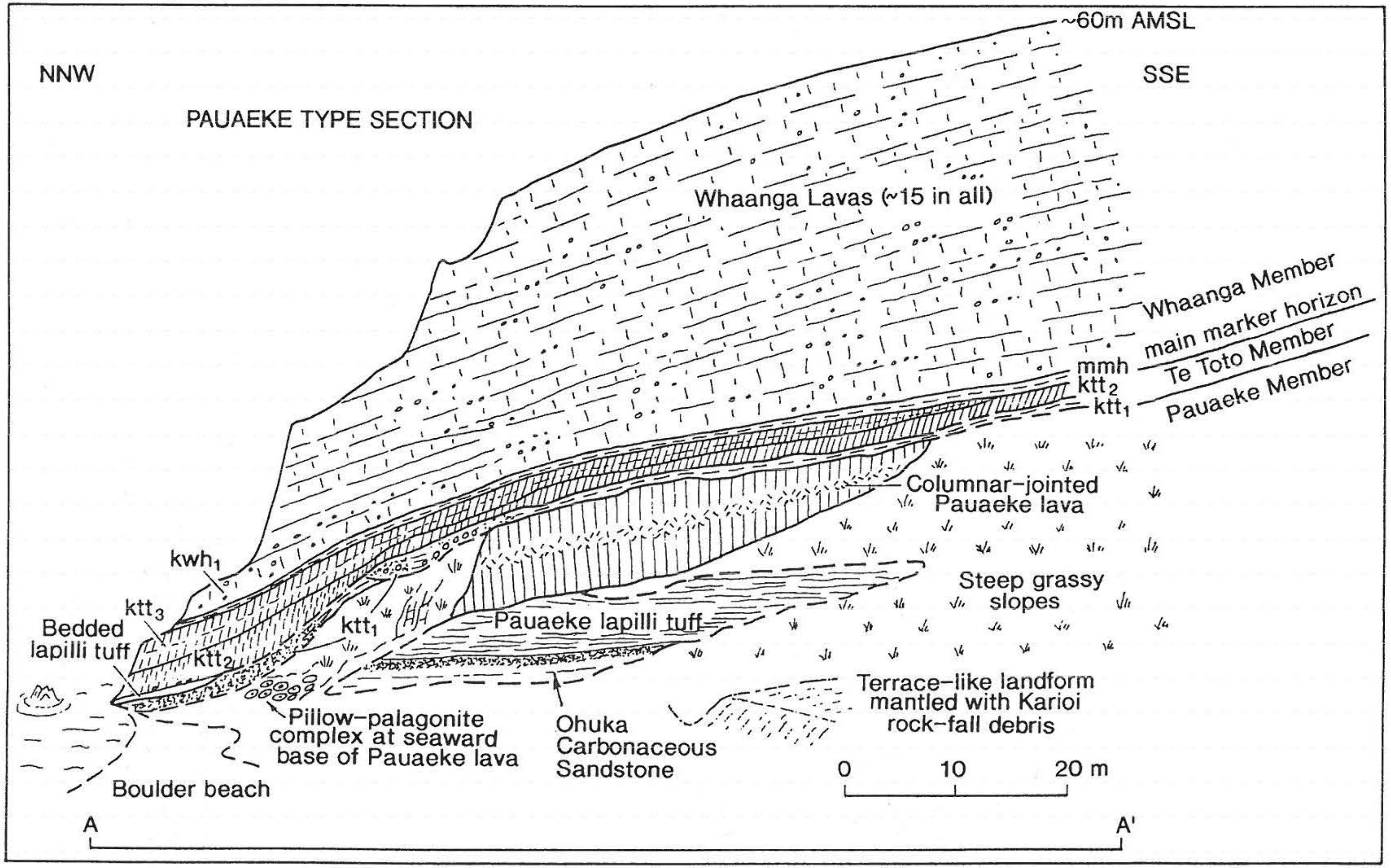


Figure 1.13: Sketch of Pauaeke type section at the North wall of Te Toto amphitheatre (A-A' in Fig. 1.10). Ktt_1-Ktt_3 are Te Toto Member lava flows overlying Pauaeke lava; mmh = main marker horizon; kwh_1 = basal Whaanga lava.

In Fig. 1.14, we show a spidergram for data on rocks from these two units. There is a tendency for some of the Pauaeke lavas to have greater Ba contents than Te Toto lavas, and there is a strong contrast in Nb abundance as commonly observed betwen these magma types. Pauaeke lavas also have greater contents of LREE, Sr, P, Zr, and Ti.

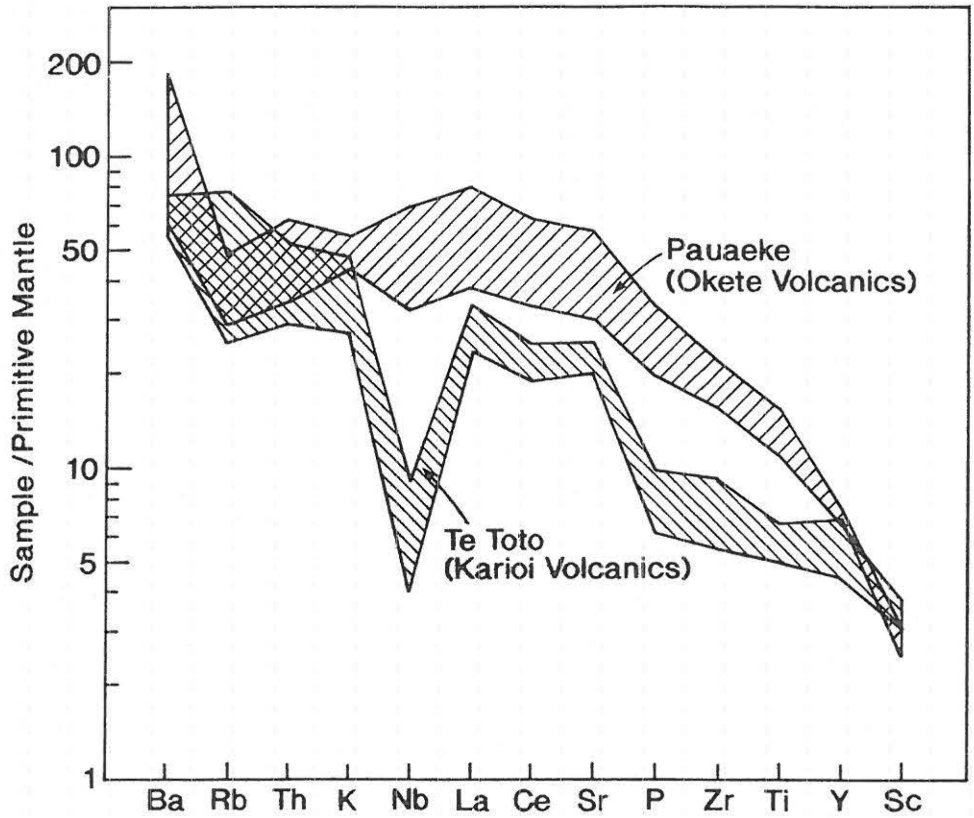


Figure 1.14: Primitive mantle normalized diagram for Pauaeke Member (Okete Volcanics Formation) and Te Toto (Karioi Volcanics Formation) lavas from Te Toto amphitheatre.

The Karioi ediface is only ≈70 km^2 in area, yet shows a remarkable diversity of magma types and physical volcanological processes. Early alkalic magmas brought an extraordinary array of mantle-derived xenoliths to the surface. The Pauaeke lavas and tuffs were succeeded after only a short pause by calc-alkalic augite-phyric Te Toto breccias and lavas. vents for both Pauaeke and Te Toto eruptions built all volcanic centres, with locations apparently controlled by regional-scale fault systems. After an hiatus (marked by the transgressive erosion surface beneath the 'main marker horizon', and by the 'main marker horizon' itself), the Whaanga shield was built by a series of fissure eruptions some of which are represented by dikes visible in the walls of Te Toto amphitheatre. Field evidence suggests that recurrence intervals between Whaanga eruptions initially were short, but became longer (allowing incision of the shield by streams) late in Whaanga times. A proto-Wairake composite cone may have been under construction before Whaanga eruptive activity had completely died away, but the exact temporal relationship between fissure eruptions that built the Whaanga shield and central vent eruptions that built the Wairake cone can only be determined by mapping in detail. The first clear indication of the existence of the Wairake cone in most locations is laharic debris. These same laharic deposits may afford the most complete record of Wairake volcanism, although, because of the alteration of most such deposits, deciphering that record would be difficult. Late in the history of the Wairake composite cone, it was intruded by at least one large hornblende andesite dike (exposed at the summit). That dike may have fed a flow of similar lithologic character, found on the western slopes of the ediface.

A curious feature of the volcanic history outlined here, as we presently know it, is that there seems to be an antithesis between alkalic Okete volcanism and calc-alkalic Karioi volcanism. We have found no instance of an alkalic eruption contemporaneous with, or interdigitating with, products of calc-alkalic eruptions, although more details of these temporal relations are required to confirm this.

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