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Excursion Guide C-1

The Taupo Volcanic Zone, central North Island, New Zealand

30 September - 4 October, 1990

by

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Bureau of Mineral Resources, Geology and Geophysics
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ICOG7

FIELD TRIP C1

THE TAUPO VOLCANIC ZONE, CENTRAL NORTH ISLAND, NEW ZEALAND

Sunday 30 th September 1990

to

Friday 5th October 1990

Leaders:

J. A. Gamble (Dept Geology, Victoria University)

P. C. Froggatt (Dept of Geology, Victoria University)

I. J. Graham (Nuclear Sciences Group, DSIR)

SYNOPSIS OF TOUR C1

DAY 1 Sunday 30 th September 1990

Assemble at Auckland International Airport.
Travel by coach to Rotorua
Accommodation at Princes Gate Hotel, Rotorua
Evening: Introductory Lecture on Volcanism and Tectonic setting of Taupo Volcanic Zone.

DAY 2 Monday 1 st October 1990

Visit to Rotorua Offices of Geological Survey of New Zealand.
Tephrostratigraphy of Rotorua and Okataina Calderas.
Rhyolite Domes, Ignimbrites and pyroclastic deposits associated with these calderas.
Geothermal Systems of Rotorua District.
Evening: Maori Concert.

DAY 3 Tuesday 2 nd October 1990

Rotorua Geothermal Fields
Domes and Physical Volcanology of Mt Tarawera.
Evening: Free

DAY 4 Wednesday 3 rd October 1990

Travel between Rotorua and Lake Taupo.
Paeroa Fault Scarp and associated Geothermal Features.
Older Ignimbrites (230 ka and pre 230 ka) in Waikato River hydro dam sites.
Wairakei Geothermal Field and Geothermal power.
Tauhara Dacite Dome Complex.
Taupo ~1800 and 22 ka eruption products.
Evening: Tokaanu, THC Hotel. Talk on Taupo Tephra Formation.

DAY 5 Thursday 4 th October 1990

Ruapehu Volcano and Related Vents.
Evening: Free

DAY 6 Friday 5 th October 1990

Tokaanu to Auckland and end of Tour C1 at Auckland International Airport.

INTRODUCTION

The Taupo Volcanic Zone (TVZ) in the Central North Island, New Zealand is an active subduction related continental magmatic zone and an extension of the oceanic Tonga-Kermadec volcanic arc into continental crust (Cole, 1984; 1986; Wright, 1990). TVZ is characterised by voluminous rhyolitic deposits, subsidiary andesites and dacites and rare basalts, all of which have been erupted over the past 1.1Ma.

Tectonically the region is widening at a rate of ~7 mm/a^{-1} as demonstrated by geodetic studies and recent earthquake studies (Beanland et al, 1989). Geothermal fields associated with volcanic and fault activity attest to the very high heat flow (total natural heat output calculated at $4 \pm 1 \times 10^9$ W with heat flow ~800 W/m^2, Stern, 1987). These fields are particularly well developed in the axial part of TVZ between Rotorua and Taupo and are major tourism and energy resources. The latter derives from the geothermal power stations at Wairakei (the world's first "wet steam" geothermal power station) and the recently commissioned station at Broadlands - Ohaaki, both of which contribute electricity to the National Grid System.

The central part of TVZ is dominated by rhyolites which were erupted through thin crust (~15 km in thickness) to yield extensive ignimbrite sheets, rhyolite dome complexes and associated air fall deposits. Andesite volcanoes, which dominate the skyline at the south end of the TVZ, also occur in the axial zone but are largely buried beneath a mantle of ignimbrite. Basalts erupted along fault controlled fissure systems form monogenetic scoria cones which result from the variable interaction between magma and groundwater. The summit rift zone of Mount Tarawera is the location of New Zealand's last major basaltic eruption, (June 1886) which resulted in the loss of more than 150 lives.

Objectives of Tour

The objective of this tour is to overview the various styles of volcanism and range of volcanic products in a major continental volcanic arc system.

The tour will visit Mt Tarawera, the Rotorua Geothermal System, a number of sections through the Taupo Tephra Formation produced by New Zealand's last major ignimbrite eruption and Mount Ruapehu, New Zealand's largest active andesite volcano.

After assembling at Auckland International Airport, the party will travel by coach to Rotorua via the regional centres of Hamilton, Cambridge and Tirau. The journey south from Auckland will take us through the Auckland (< 100 ka) and South Auckland (1.6 - 0.5 Ma) volcanic fields. These are intraplate volcanic fields and the eruptive products mainly alkali basalt - basanite with minor nephelinite and tholeiite. These magmas have formed low lava shields and pyroclastic cones. Phreatomagmatic activity is a feature of some centres.

From near Tirau, those seated on the left side of the coach should be able to see the Mamaku Plateau forming the horizon. This is composed of variably welded ignimbrite sheets which were erupted from the TVZ around 140 - 150 ka, (Wilson et al, 1984).

Rotorua is a major centre of Maori cultural activity and will be our base for the first 3 nights. There our hosts will be Mr and Mrs Marvelly at the Princes Gate Hotel. The last two nights will be spent in the village of Tokaanu at the south end of Lake Taupo. There we will stay at the THC hotel where our host will be Ms Shirley Barnett.

Day two will comprise a coach tour of rhyolitic volcanism associated with the Rotorua and Okataina Caldera Complexes. Day three will be more strenuous and will involve a hike to the summit of Mt Tarawera and a tour of the Whakarewarewa Thermal Park. Day four involves travel from Rotorua to Taupo and on to Tokaanu with study of ignimbrites, rhyolites, and dacites associated with the Taupo Volcanic Centre. Day five is a circuit of the andesite massifs of the Tongariro National Park.

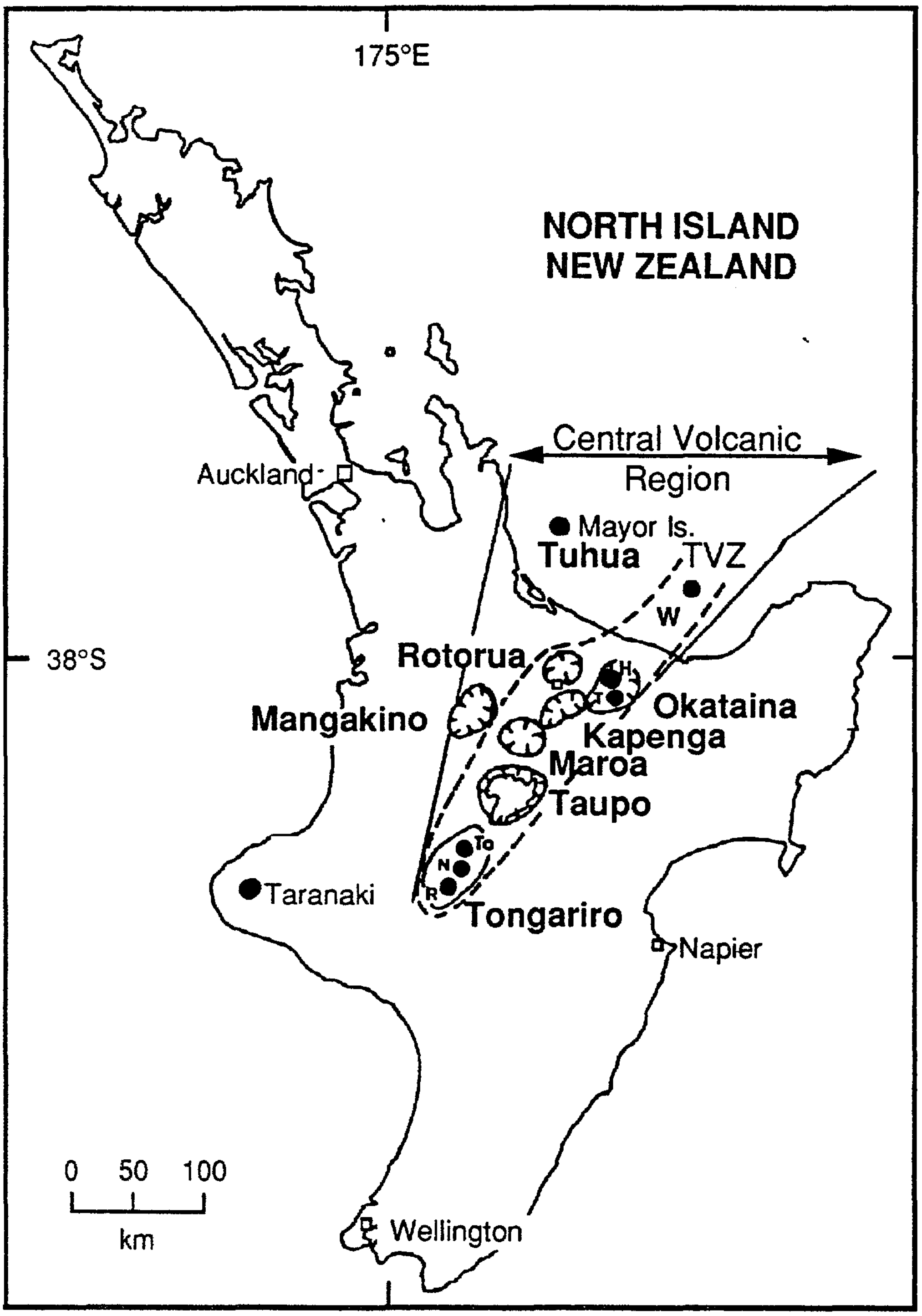


Figure 1. Location map of major volcanic centres in Taupo Volcanic Zone (TVZ), Central North Island, New Zealand.

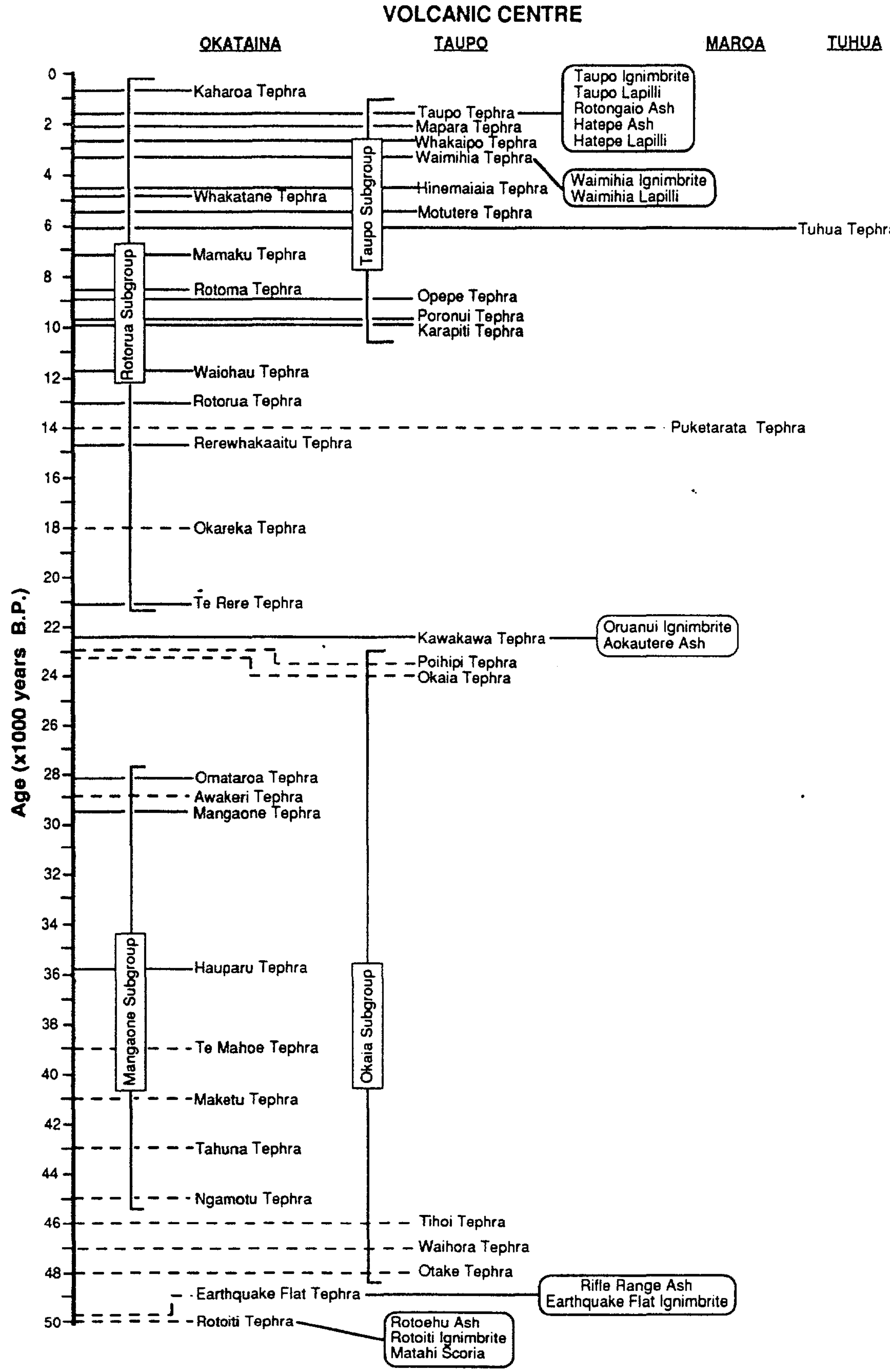
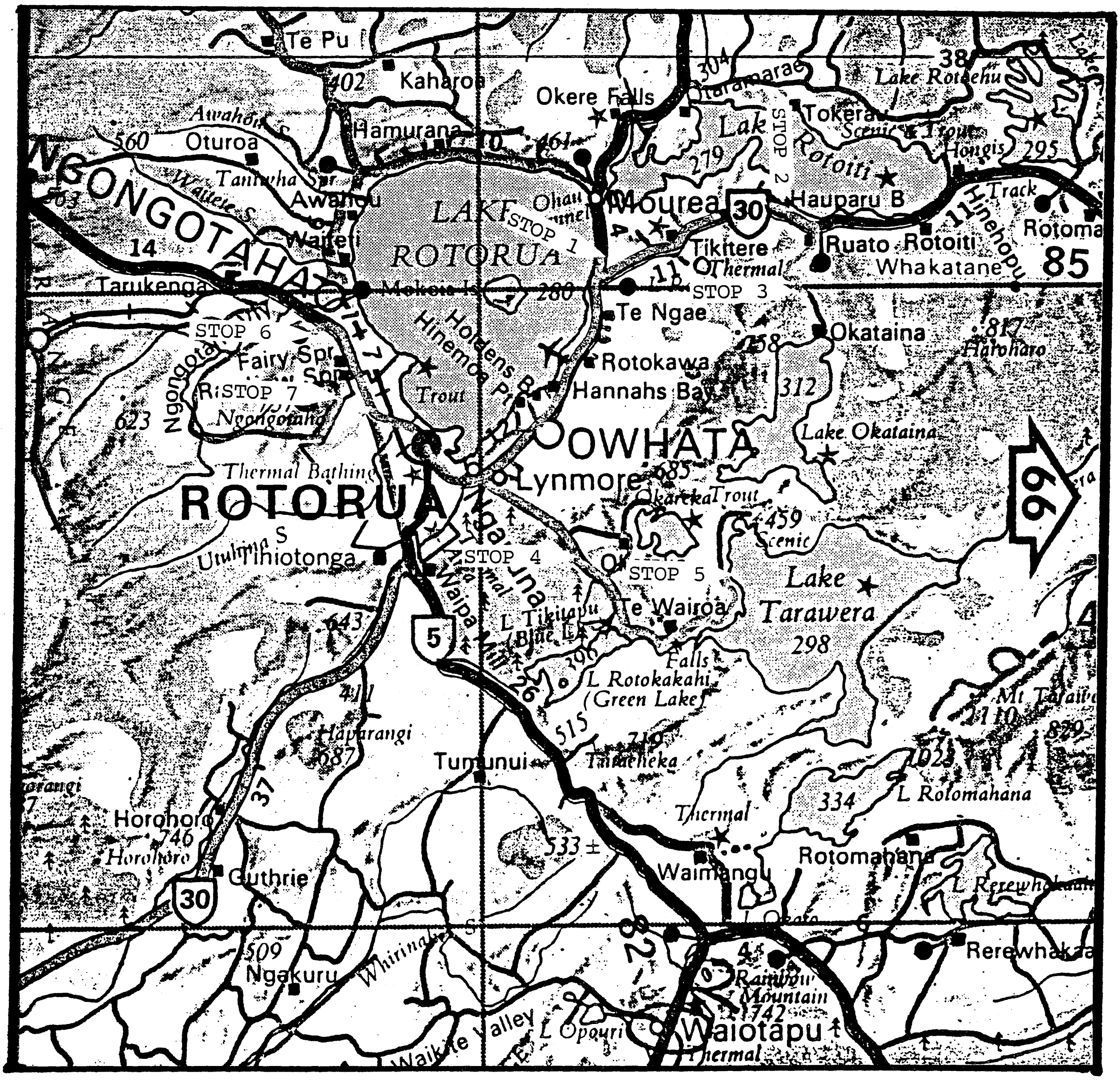


Table 1 Stratigraphic relationships of late Quaternary silicic tephras from the Okataina, Maroa, Taupo and Tuhua (Mayor Island) volcanic centres. Solid horizontal lines are based on mean conventional radiocarbon ages. Dashed lines indicate that no radiometric data are available, correlation is based on the tephrostratigraphic record. (Data from Froggatt & Lowe, 1990)



Route Guide, Day 2
Rotorua-Okataina Caldera
Volcanology and Tephrostratigraphy

DAY 2 Tephrostratigraphy and Physical Volcanology of the Rotorua - Okataina Calderas.

N.B. All map references refer to Dept. Survey & Land Information, Topomap series 1 : 50,000.

Route Guide

From Rotorua drive north east on SH 33 along the east shore of Lake Rotorua to Te Ngae and stop 2.1 (12 km), Section exposes a tephra section from ~22 ka pertaining to eruptions from Okataina and Taupo volcanic centres. Retrace route to junction with SH 30, turning left onto SH 30. Take SH 30 east to the shores of Lake Rotoiti and stop 2.2 (21 km), Mamaku Ignimbrite. Continue east for a further 2.5 km to the junction with Lake Okataina Road and follow this road for 2.5 km, Stop 2.3 Rotokawau Basalt (26 km). Retrace route to Rotorua and take road for Lake Okareka. Stop 2.4 (56 km) is in a quarry into one of the Okataina centre Rhyolite Domes. From the Okareka quarry, follow the Okareka Loop Road to Lake Okareka, then Lake Tikitapu and on to the west shore of Lake Tarawera (70 km). Stop 2.5 Mount Tarawera view point. Take the route back to Rotorua and from there along the West shore of Lake Rotorua to Stop 2.6 in the quarry at Ngongotaha (km). From stop 2.6 take coach to top of Ngongotaha Dome and scenic view over Rotorua Caldera at Stop 2.7. From here coach returns to Rotorua.

FIELD GUIDE

Stop 2.1 Te Ngae Road Section. (U15/019422)

This section exposes airfall tephras from both the Taupo and Okataina Volcanic centres. Rhyolitic tephras predominate but a number of basaltic markers are present. The majority of the rhyolite tephras are associated with dome emplacement in the Okataina Volcanic centre but some are airfall deposits associated with ignimbrite. The top of the section is marked by basaltic and phreatic (Rotomahana Mud) products from the 1886 Mt. Tarawera eruption. The base of the section is a paleosol dated at around 22 ka. Between these two marker beds a number of distinctive tephra layers can be identified, they include: Kaharoa Tephra (770 ± 20); Taupo (1850 ± 10); Rotokawau (3440 ± 70); Whakatane (4830 ± 20); Mamaku (7250 ± 20); Rotoma (8530 ± 10); Waiohau (11,850 ± 60); Rotorua (13,080 ± 50) and Rerewhakaaitu (14,700 ± 110). The distinctive tephra layers are separated by a number of paleosol horizons which delineate time breaks Full details as to where these units occur within the local stratigraphic framework can be assessed from Table 1 which is taken from Froggatt and Lowe (1990).

Stop 2.2 Mamaku Ignimbrite. (U15/097449)

This roadside locality exposes a section through the Mamaku Ignimbrite. This pale brownish - pink ignimbrite, with an erupted volume > 300 km^3 is thought to have erupted from and been responsible for collapse of the Rotorua Caldera. Stratigraphic relationships elsewhere suggest that it may be the youngest of three named, large volume ignimbrites, dating from around 140 ka and named Matahina, Kiangaroa and Mamaku ignimbrites (Healy et al, 1964; Murphy & Seward, 1981). Petrographically at this locality the ignimbrite is rather poorly welded, with sparse pumice clasts; phenocrysts are quartz, plagioclase, hypersthene, augite, hornblende and Fe-Ti oxides. A chemical analysis is contained in Table 2, analysis 1.

Stop 2.3 Rotokawau Basalt. (V15/103422)

At this stop phreatomagmatic and strombolian airfall deposits from the ~3000 bp eruption east - west Lake Rotokawau fissure system are exposed in road cuts. The exposures are restricted in areal extent and are typical of many of the basaltic

TABLE 2

Representative Chemical Analyses of Rhyolitic Rocks from Taupo Volcanic Zone

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	72.15	71.30	78.5	68.89	77.96	75.32	74.74	77.0	72.49	74.44	78.97	74.31
TiO_2	0.29	0.34	0.23	0.36	0.15	0.19	0.20	0.27	0.28	0.20	0.13	0.29
Al_2O_3	14.30	13.11	12.21	14.56	12.25	13.01	13.10	12.6	13.64	13.20	12.18	13.55
Fe_2O_3*	2.44	2.16	1.21	2.40	1.08	1.53	1.70	1.31	2.26	1.82	1.33	2.53
MnO	0.09	0.08	-	0.07	-	0.06	0.05	0.06	0.07	0.05	-	0.09
MgO	0.24	0.53	0.22	0.56	0.16	0.27	1.11	0.20	0.46	0.43	0.12	0.43
CaO	1.34	1.98	1.34	1.93	1.04	1.40	1.26	1.30	2.02	1.43	1.06	1.74
Na_2O	4.24	3.87	3.20	3.79	3.70	3.59	4.47	4.20	3.90	4.31	3.16	4.18
K_2O	2.94	2.58	2.95	2.38	3.54	3.32	3.20	3.20	3.30	3.22	3.18	2.84
P_2O_5	0.09	0.07	-	0.04	-	0.05	0.02	0.08	0.07	0.02	-	0.05
LOI	-	3.57	-	4.68	-	0.75	0.82	0.28	-	1.05	-	2.98
Total	98.12	99.58	100.00	99.66	100.00	100.23	99.67	100.50	98.49	99.93	100.00	100.12
Sc	-	5	-	7	-	4	-	4	5	5	-	-
V	-	13	-	14	-	14	-	-	17	12	4	3
Cr	-	1	-	1	-	2	-	-	2	3	-	-
Ni	-	2	-	1	-	1	-	-	-	2	11	4
Cu	-	2	-	2	-	2	-	1	8	1	5	7
Zn	-	42	-	46	-	33	-	-	-	36	41	73
Ga	-	14	-	16	-	13	-	18	18	13	-	-
Rb	-	85	-	78	-	105	-	107	128	100	100	90
Sr	-	156	-	154	-	114	-	99	128	106	127	152
Y	-	24	-	25	-	19	-	-	-	28	22	30
Zr	-	212	-	233	-	124	-	110	155	181	151	217
Nb	-	6	-	8	-	7	-	-	-	11	-	-
Ba	-	723	-	754	-	772	-	875	977	643	598	570
La	-	19	-	22	-	21	-	-	-	24	-	-
Ce	-	42	-	39	-	41	-	-	-	46	-	-
Pb	-	14	-	14	-	16	-	-	-	14	11	14
Th	-	9	-	11	-	12	-	-	-	12	10	10
U	-	2	-	2	-	2	-	-	-	3	3	3

1. Mamaku Ignimbrite, Grange (1937).
2. Rotorua Ash, Stancorp Quarry, whole pumice, base of succession, P.C. Froggatt (unpub.)
3. Rotorua Ash, Stancorp Quarry, glass (electron microprobe), base of succession, P.C. Froggatt (unpub.)
4. Rotorua Ash, Stancorp Quarry, whole pumice, top of succession, P.C. Froggatt (unpub.)
5. Rotorua Ash, Stancorp Quarry, glass (electron microprobe), top of succession, P.C. Froggatt (unpub.)
6. Rhyolite, Stancorp Quarry, P.C. Froggatt (unpub.)
7. Rhyolite, Ngongotaha Quarry, Grange (1937).
8. Rhyolite, Tarawera Volcanic Complex, Ewart & Healy (1965).
9. Whakamaru Ignimbrite, average of 19 major and 7 trace element analyses, Reid (1982).
10. Puketarata Rhyolite, Maroa Volcanic Centre, Brooker (1988).
11. Oruanui Ignimbrite, glass (electron microprobe for major elements), Froggatt (unpub.)
12. Taupo Ignimbrite, pumice clast, P.C. Froggatt (unpub.)

deposits in the TVZ. The basalt is sparsely porphyritic with micro-phenocrysts of olivine (Fo 82 - 71), plagioclase (An 89 -72) and clinopyroxene (Mg/Mg + Fe = 82 - 80). The dip of the deposits at this locality is variable and probably controlled by pre-existing topography. The strombolian air fall layers are composed of lapilli sized scoria, with occasional larger bombs. Many of the clasts are cored by older rhyolite fragments. The glassy often palagonitised phreatomagmatic deposits contain ballistic blocks of non vesicular basalt and rhyolite obsidian. A chemical analysis of Rotokawau Basalt (from Gamble et al, 1990; Gamble, Smith and Graham, 1989) is included in Table 3, analysis 2.

Stop 2.4 Stancorp Quarry, Okareka (U16/015316 - 022315)

At this locality we first study landscape draping air fall deposits of the 13 ka Rotorua Ash. Note the well sorted nature of the deposits and the manner in which they drape over the existing topography. The Rotorua ash is one of very few TVZ rhyolitic tephras to show vertical chemical zonation. Chemical analyses of whole pumice and glass are contained in Table 2, analyses 2-5. The deposits rest on an older paleosol which is underlain by poorly sorted glassy obsidian deposits which are probably rhyolite dome carapace breccias or block and ash flow deposits associated with nearby rhyolite domes. The direction of their emplacement cannot be inferred at this outcrop.

In the main quarry dome rhyolite is extracted for road metal. This rhyolite is one of a large number of rhyolite domes within the Okataina Caldera, Table 2, analysis 6. It's age is not accurately known but it is presumed to be between 17 and 20 ka. The rhyolite is a vitric vesicular rock containing phenocrysts of quartz and plagioclase. Note the cooling joints in the rhyolite.

Stop 2.5 Mount Tarawera view point, west shore of Lake Tarawera. Photographic stop. (U16/073296)

This is a brief photographic stop but it is particularly instructive in demonstrating the steep-sided rhyolite domes which make up the Tarawera Volcanic Complex, Nairn (1990). These domes date from ~ 150 ka but the youngest are around 700 yr and these form the present day summit domes. An analysis is contained in Table 2, analysis 8.

Stop 2.6 Ngongotaha Rhyolite Dome. (U15/916402)

This locality offers the opportunity to examine rhyolite in the core of a rhyolite dome. The locality is noteworthy for the range in textural varieties of rhyolite showing various stages in devitrification from porphyritic obsidian, to spherulitic and lithophysal varieties. These occur in definitive zones in the rhyolite. The rhyolite is sparsely porphyritic with phenocrysts of plagioclase, quartz and minor pyroxene. This rhyolite dome and a number of others were associated with the Rororua Caldera formation episode and the associated Mamaku Ignimbrite eruption ~ 130 - 140 ka. A chemical analysis is given in Table 2, analysis 7.

Stop 2.7 Ngongotaha View Point. (U16/916384)

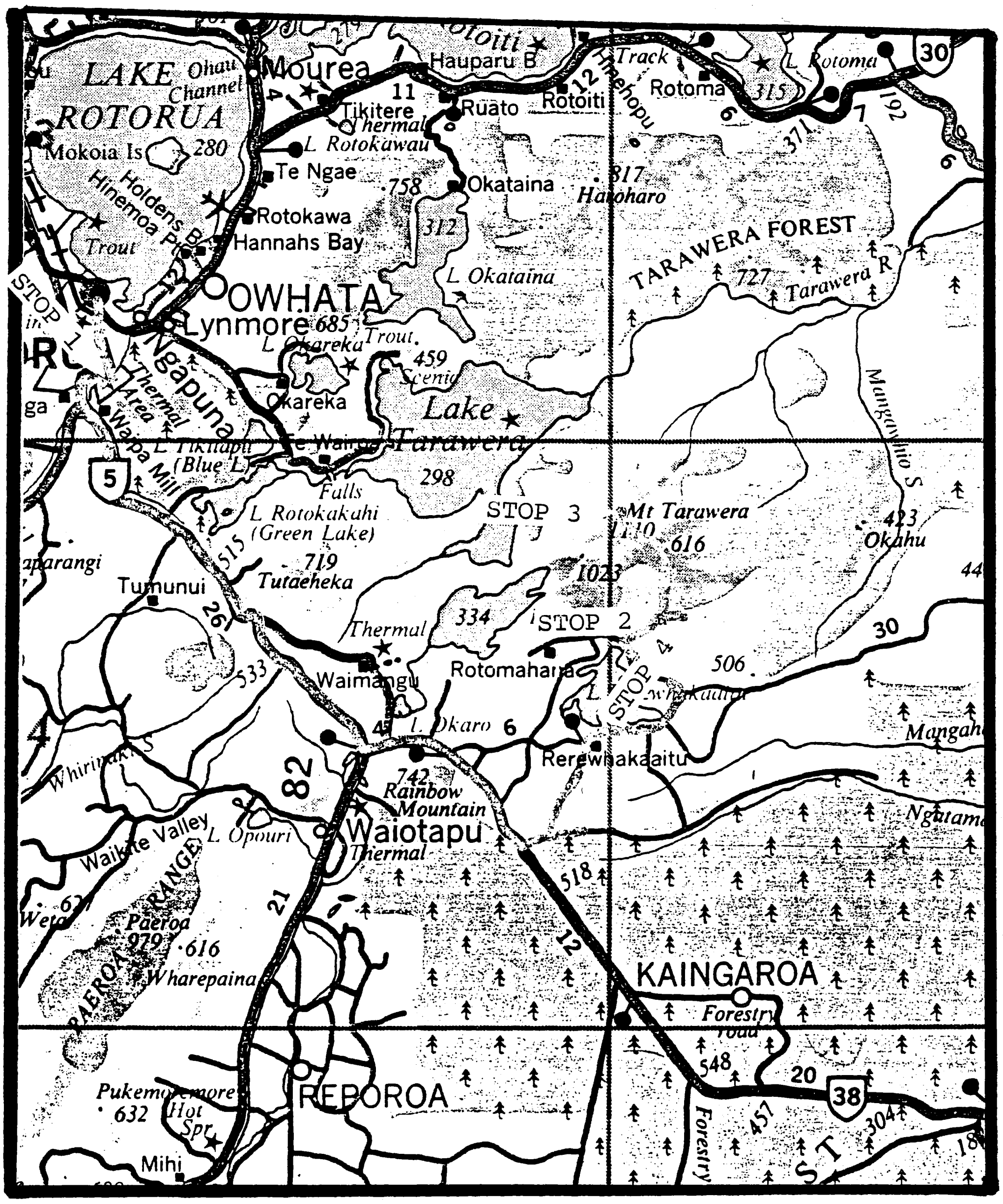
From this vantage point an excellent panorama of the Rotorua Caldera and the Rotorua district can be viewed. To the north west, ignimbrites form the Mamaku Plateau, (Ewart & Healy, 1965). Across Lake Rotorua the caldera bounding fault cuts a distinctive rhyolite dome on the north shore of the lake. Mokoia Island within Lake Rotorua is an example of a number of younger rhyolite domes which were emplaced within the caldera. Unlike the early domes these rhyolites are crystal rich with phenocrysts (plagioclase, quartz, hypersthene, hornblende and biotite) making up 15 - 30% by volume. To the east, the view takes in the domes of the Tarawera Igneous Complex and in the background the ignimbrites of the Kaingaroa Plateau.

TABLE 3

Representative Chemical Analyses of Basalts and Dacites from Taupo Volcanic Zone

	1	2	3	4
SiO_2	50.63	51.06	48.52	67.55
TiO_2	0.83	0.80	0.89	0.38
Al_2O_3	17.17	17.75	18.09	14.81
Fe_2O_3*	10.42	9.54	8.81	4.26
MnO	0.17	0.19	0.13	0.09
MgO	6.17	6.31	9.12	2.49
CaO	11.34	11.86	11.16	4.54
Na_2O	2.12	2.34	2.49	3.61
K_2O	0.55	0.55	0.27	2.20
P_2O_5	0.10	0.10	0.14	0.07
LOI	0.25	-0.22	0.20	0.30
Total	99.75	100.28	99.82	100.00
Sc	40	37.1	28	10
V	256	277	191	74
Cr	55	79	85	42
Ni	14	27	113	25
Cu	25	38	56	18
Zn	94	83	70	48
Ga	18	15	14	17
Rb	15	13	4	70
Sr	318	372	350	324
Y	19	19	19	20
Zr	82	52	79	117
Nb	2	1.3	2.9	5
Ba	-	212	70	495
La	6.33	6.1	5.7	21.5
Ce	15.94	14	14.9	48
Nd	10.45	10.8	12.7	23
Sm	2.83	2.53	2.65	5.4
Eu	0.97	0.83	0.91	1.25
Gd	3.04	3.06	4.38	5.8
Tb	0.50	0.41	0.40	0.80
Tm	0.33	0.33	0.33	-
Yb	1.87	1.58	1.6	3.2
Lu	0.30	0.24	0.23	-
Hf	1.87	1.36	1.89	-
Th	0.17	1.3	0.51	9
U	-	0.24	0.1	-
$^{87}Sr/^{86}Sr$	0.70520	0.705064	0.703878	-
$^{143}Nd/^{144}Nd$	0.512762	0.512791	0.512913	-
ΣNd	+2.2	+2.7	+5.1	-

1. Tarawera Basalt, summit rift, Mt Tarawera, Gamble et al., 1989, Gamble et al., 1990.
2. Rotokawau Basalt, eastern crater of Rotokawau fissure system, Gamble et al., 1989, Gamble et al., 1990.
3. Kakuki Basalt, Kakuki Stream, Gamble et al., 1989, Houghton et al., 1987, Gamble et al., 1990.
4. Hornblende Dacite, Hipaua Dome, Mt Tauhara (mean of 27 analyses), REE from Reid, 1982, sample 30007.



Route Guide, Day 3
Tarawera Volcanic Complex

DAY 3 The Rotorua Geothermal Field and Tarawera Volcanic Complex.

N.B. This will be a long day with a long (~7km) walk to the summit of Mt Tarawera. The walk is strenuous, but not over demanding and well worth the effort as the view is fantastic. Wear stout and comfortable footwear, bring protective rain wear and a warm sweater.

Route Guide

From Rotorua SH 5 south to the geothermal area at Whakarewarewa, Stop 3.1. Whakarewarewa is the largest geyser field in New Zealand and a major tourist attraction for the Rotorua District. In an area of ~ 1km^2 in excess of 500 hot springs discharge at the surface. Please keep to the pathways in the thermal area as the ground is unstable. From Whakarewarewa we take State Highway 5 south (km) to the intersection with SH 38. From here take SH 38 and follow road signs to Rerewhakaaitu and from here via Ash Pit road to the foot of Mt Tarawera. By foot we scale the rhyolite domes (~ 770 ± 20 y) of Mt Tarawera to the rim of the rift formed during the 1886 eruption. Stop 3.3 Following descent from the crater rim we will examine pyroclastic deposits associated with the growth of the 700 yr dome building event. Stop 3.4 Disused quarry on Crater Road.

FIELD GUIDE

Stop 3.1 Whakarewarewa Geyser Field. (U16/955325) and Figure 2.

This locality is New Zealand's only active geyser field and also a major location for Maori cultural activity. Concerns over declining geothermal activity, attributable to increasing exploitation, in the Rotorua Field as a whole led to a government sponsored monitoring programme being initiated in 1982. The research associated with this programme led to refinement of the hydrological plumbing system and refinement of an outflow model from the the subterranean aquifer. According to Wood (1985) outflow is confined by the permeable Rotorua Rhyolite and Mamaku Ignimbrite and faults, such as the Ngapuna and Roto-a-Tamaheke Faults, (Simpson, 1985) which connect to a deep geothermal reservoir. Inferred temperatures in this reservoir are greater that 230°C.

The natural activity at Whakarewarewa takes a variety of forms, determined by the local vertical permeability and the supply of groundwater. A state of high vertical permeability allows upward flow of alkali chloride water to form clear hot springs (close to boiling), frequently with precipitated sinter margins. Where vertical permeability is restricted, flashing of the superheated fluid produces steam, CO_2 and H_2S and associated acid sulphate features. An excellent review of New Zealand geothermal systems can be found in Hedenquist (1986).

Stop 3.2 Ash Pit Road, Mt Tarawera. (V16/173197)

The 10 June 1886 eruption of basalt at Mt Tarawera is the last major eruptive event to have occurred in New Zealand. The following account is compiled from the work of Cole (1970), Cole and Nairn (1975), Nairn (1979), Nairn and Cole (1981), Walker et al (1984), Nairn et al (1986) and the unpublished work of Nairn, Houghton and Wilson.

The June 1886 eruption of Tarawera is noteworthy for the apparent lack of precursor activity and the short duration and violence of the eruption. Peculiar waves, approaching 0.3m high, were reported on the west shore of Lake Tarawera on 1 June 1886. Earthquake activity was reported at Te Wairoa and Rotorua, beginning about 00.30 hours on 10 June. These increased in intensity until the eruption commenced around 01.30. According to the accepted eruption narrative (reconstructed from eye witness accounts; Grange, 1937) the eruption began near

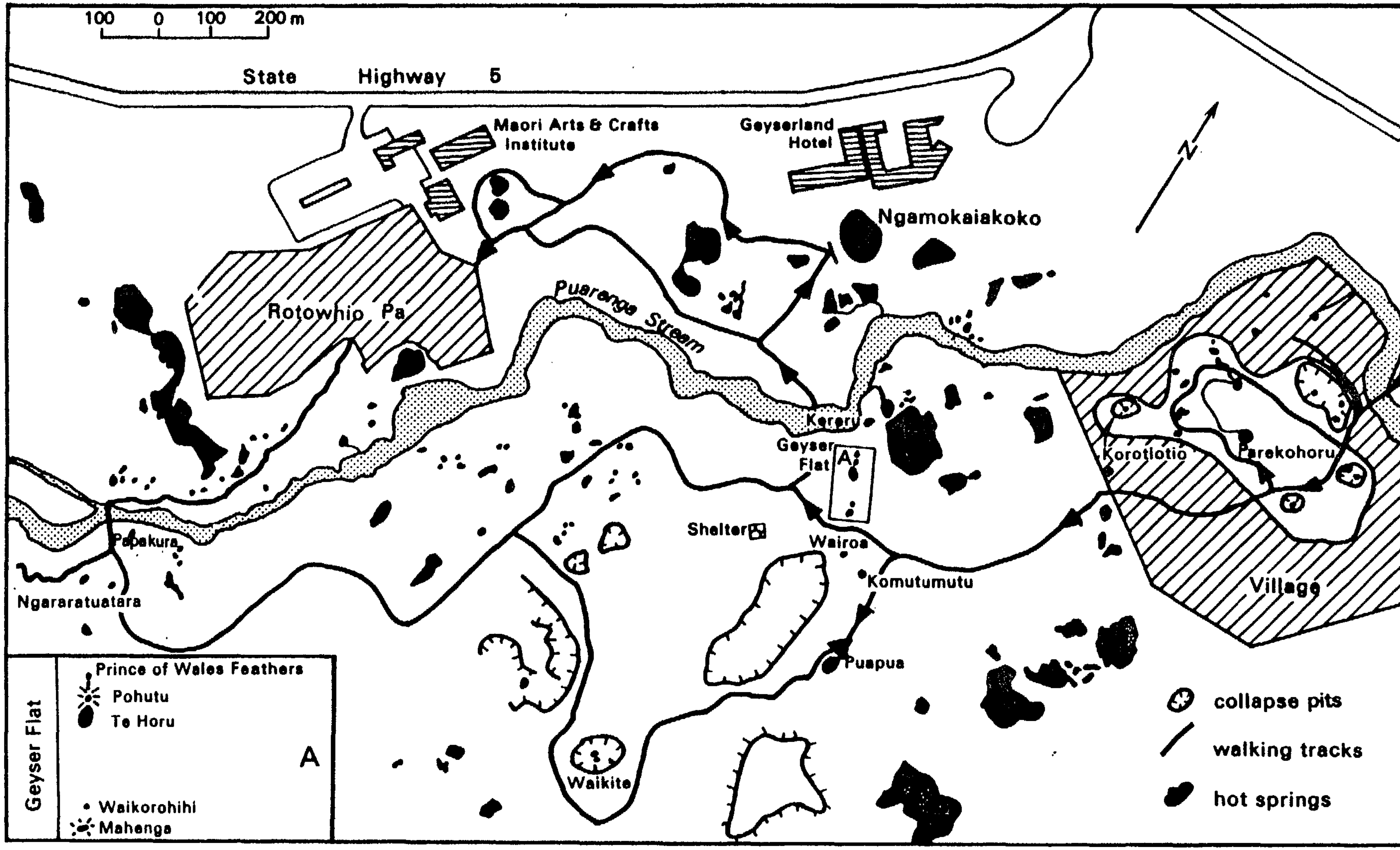


Figure 2. Recommended route for Whakarewarewa Geothermal Field (arrowed). Taken from Houghton (1982).

Wahanga Dome (Figure 3) and extended to the south west. At 02.10 a violent earthquake was accompanied by the rise of an eruption column from Tarawera Dome. This column was estimated to extend to a height of 9.5 km. At this time phreatomagmatic and hydrothermal eruptions began in Lake Rotomahana (the site of the world famous Pink and White Terraces which were destroyed in the eruption) and by 03.30 the entire 17 km fissure system from Wahanga Dome to Waimangu (= black water) was in eruption. The eruptive episode was all but complete by 06.00 on 10 June. Estimates of the total volume of ejecta differ, a recent estimation of ~ $2km^3$ for the basalt (equivalent to ~0.7 km^3 magma) being from Walker et al, 1984.

The character of the eruption products varied with the availability of groundwater. In the Tarawera rift, at Waimangu and also probably at Lake Rotomahana en-echelon dikes, (Nairn & Cole, 1981) and Figure 3, acted as feeders for the magma rather than a single fissure system. From detailed stratigraphic mapping of the layers in the Tarawera Rift (Houghton & Wilson, pers comm) it is apparent that a number of fire fountains interplayed from different fissures at any given time, leading to a complex overlapping of tephra layers. Within the Tarawera Rift, Nairn et al, (1986) recognise 3 parts to the eruption sequence:

a) A discontinuous basal zone rich in rhyolitic wall rock clasts and containing conspicuous cauliflower bombs.

b) A thick middle zone of red and black often intensely welded scoria. Fragments of rhyolitic wallrock in these deposits often show signs of rheomorphism.

c) An upper zone rich in ballistic blocks and lithic ash.

Away from the rift, exposures on the flanks of Tarawera show a basal zone of basaltic lapilli sized scoria which passes up into a zone characterised by mudlumps and accretionary lapilli.

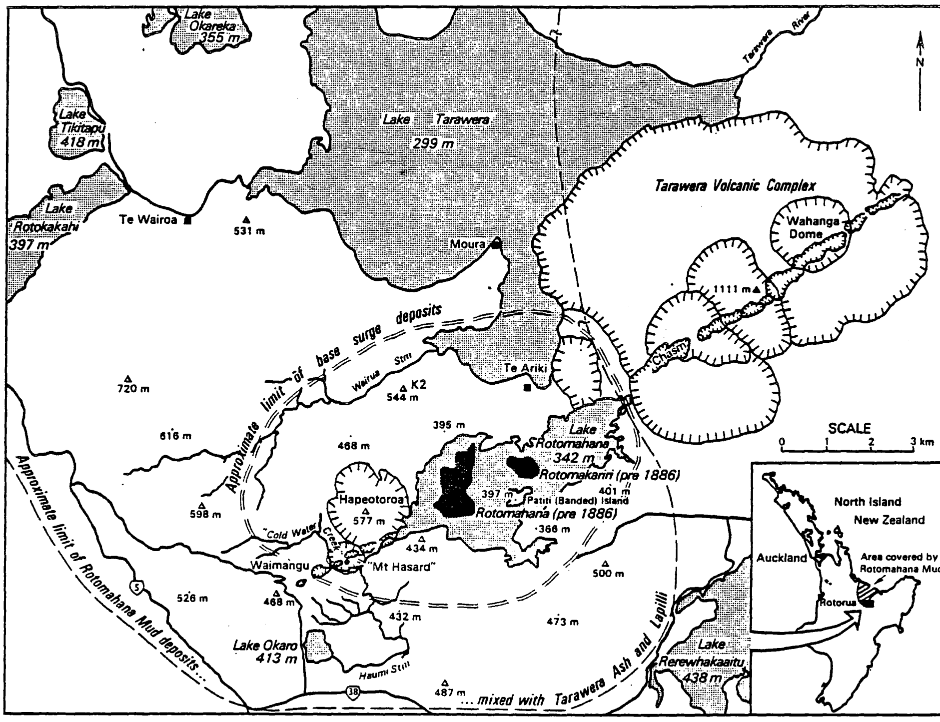
The eruption products from the Lake Rotomahana and Waimangu segments of the fissure system reflect the explosive interaction of hot basaltic magma with groundwater and the geothermal system. The resulting phreatomagmatic and hydrothermal explosions generated the Rotomahana Mud phase of the eruption (Nairn, 1979). Deposits include ground-hugging surge deposits which topped adjacent hills up to 360m above the lake level and travelled more than 6 km west of the main source in Lake Rotomahana. It was these deposits and the associated mudfall which brought about the major loss of life (estimated at more than 150) during the eruption.

A chemical analysis of the Tarawera Basalt is given in Table 3, analysis 1 and additional details are to be found in Cole, (1973) and Gamble et al, (1990). The basalt is fine grained and vesicular with phenocrysts of plagioclase and rare clinopyroxene and olivine. Examination of hand specimens show that fragments of dome rhyolite are thoroughly disseminated throughout the basalt, no doubt a function of the explosive nature of the eruption.

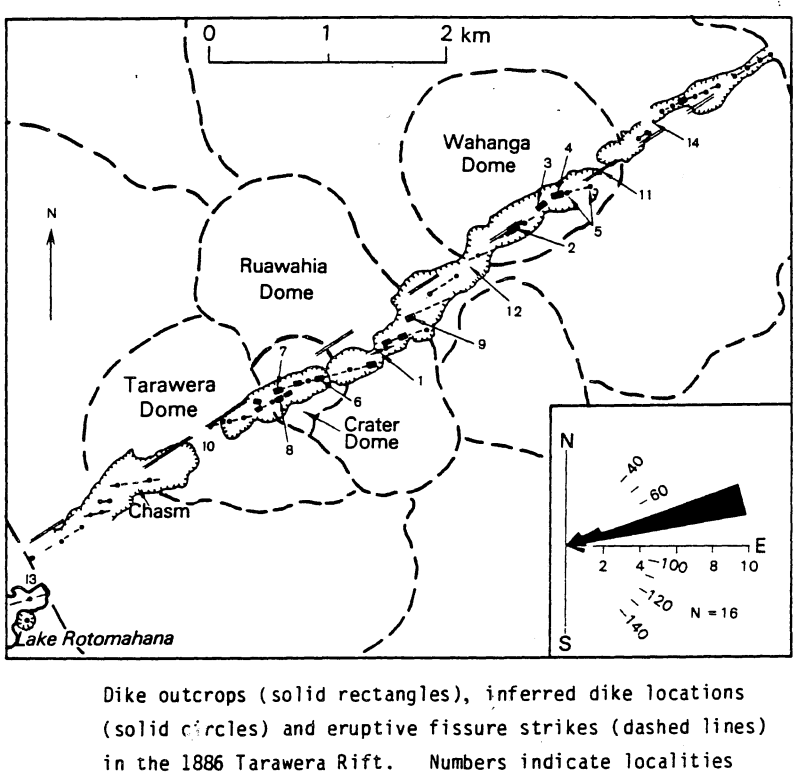
N.B. Take care crossing the air-strip at the summit, small planes may be landing.

Stop 3.3 Crater Rim, Mount Tarawera. (V16/182254)

At this position we are standing between Ruawahia and Wahanga Domes. In the rift one can observe dome mantling rhyolitic tephras of the 700 ka Kaharoa eruption, overlain by the basaltic deposits of the 1886 eruption. Note the lower deposits containing much wall rock and which pass up into the thick, often densely welded, variably oxidised zone of maximum accumulation and the upper units rich in ballistic blocks. Interpretation would suggest an early vent clearing explosive phase giving way to establishment of a series of fire fountaining eruption columns along the fissure system and waning with magma withdrawal with vent clearing explosions. Follow the track south west around the crater rim and ascend Ruawahia Dome to the trig point. From here the outline of the 700 y dome is quite clear. Descend the large scree to the floor of the crater and observe the 1886 basaltic dike in the fissure. Follow the track to the north east along the floor of the rift and



Map of Tarawera-Rotomahana-Waimangu area, with sites of pre-eruption (dark stipple) and modern lakes, the 1886 Rift craters across Tarawera Volcanic Complex, and dispersal patterns of Rotomahana ejecta. From Nairn (1979).



Dike outcrops (solid rectangles), inferred dike locations (solid circles) and eruptive fissure strikes (dashed lines) in the 1886 Tarawera Rift. Numbers indicate localities described in Nairn & Cole 1981. Rose diagram summarises orientation of actual dike outcrops in the Tarawera Rift.

Figure 3. (Top) Location map of Tauhara Volcanic Complex showing NE trending rift and limits of 1886 eruption products.

(Bottom) Detailed map of summit domes of Mount Tarawera.

ascend to the rim through the 1886 eruption sequence.

Return to the track and commence descent to the coach. On the return to the coach we shall examine a section through the Rotomahana Mud.

Stop 3.4 Disused quarry, foot of Mount Tarawera. (V16/173197)

This locality exposes an excellent sequence of silicic pyroclastic deposits associated with the ~ 700 yr dome forming events of the Tarawera Volcanic Complex (Nairn, 1990). Amongst the deposits exposed include airfall, thin pyroclastic flows (containing carbonised logs), surge and block and ash flow deposits. The sequence is topped by a thin layer of the 1886 Tarawera lapilli and Rotomahana Mud.

Route Guide, Day 4
Rotorua-Turangi
Ignimbrite geology and dacites

Day 4 Rotorua to Taupo and Tokaanu via Paeroa Fault Scarp, Whakamaru Ignimbrite, Wairakei Geothermal Field, Tauhara Dacite Dome Complex and Taupo 1850 yr eruption.

Route Guide

From Rotorua travel south on SH 5 to Waiotapu (~30 km). Loop first to the left and observe an excellent example of a bubbling mudpool, Stop 4.1. Return to route 5 and take turn off (right) to Waikite Valley. This road cuts across the Paeroa Fault scarp. Stop 4.2 Paeroa Fault scarp. Follow the road to Te Kopia road turning left into Te Kopia Road and drive along the foot of the fault scarp. Continue to the Puaiti Road turn off and turn right into Puaiti Road. Follow this road and stop at bridge over an arm of Lake Ohakuri. Stop 4.3 Valley Pond facies of Taupo Ignimbrite about 65 km from source. Drive over the bridge, turn left and cross another bridge and turn left onto Poutakataka Road. Take this road and turn left into Galatos Road, follow this road and turn left into Maleme Road. Follow this road to Ohakuri Road, turn left and drive to Lake Ohakuri Power House. Stop 4.4 Ohakuri Ignimbrite. From Ohakuri Dam follow Ohakuri Road west to intersection with SH 1 turning right (north) onto SH 1. Take this route north west, turning onto SH 30 follow the route along the north shore of Lake Whakamaru crossing at Whakamaru power house and continuing to Lake Maraetai. The road section at the north end of Lake Maraetai descends through a thick sequence of the Whakamaru Ignimbrite. Stop 4.5 Whakamaru Ignimbrite. Retrace route to Atiamuri and take SH 1 south to Puketarata Rhyolite dome and tuff ring. Stop 4.6 Puketarata Tuff ring pyroclastic deposits. Now take SH 1 south to intersection with State Highway 5. Turn right and travel the short distance to the Wairakei Geothermal Field. Stop 4.7 Wairakei geothermal Field. This is a lunch stop. Take SH 5 south towards Taupo, stopping at lookout over Taupo. Stop 4.8 Taupo view point, brief photographic stop. Follow this road to Huka Falls. Stop 4.9 Huka Falls. Photographic stop. Retrace route back to SH 5 and turn left taking route to Taupo. From Taupo take Centenial Drive east to the junction with Broadlands Road. Turn left into Broadlands Road and then take right into Mc Kenzie Road and on to Hipaua Road. Stop 4.10 Tephra section at road intersection shows Oruanui Ignimbrite (~ 22 ka) and Taupo post 20 ka eruptives. Stop 4.11 Tauhara Dacite Dome Complex. Retrace route along Broadlands road and take left turn into Crown Road. Follow Crown Road to intersection with SH 5 and take left turn. Follow SH 5 to type section at Hotel de Bretts. Stop 4.12 Hotel De Bretts type section through post 20 ka Taupo tephras. Take SH 5 west to intersection with SH 1 on outskirts of Taupo. Turn left onto SH 1 and follow route to road cut at Waitahanui. Stop 4.13 Waitahanui cut through Taupo Ignimbrite. Follow SH 1 to Hatepe Hill. Stop 4.14 Photographic stop, Valley Fill of Taupo Ignimbrite and southern Lake Taupo. Take SH 1 south to Hatepe and follow shoreline to Turangi. At Turangi, take SH 41 to Tokaanu.

FIELD GUIDE

Stop 4.1 Mud Pool Waiatapu Thermal Area. (U16/046124)

Mud pools are a common feature of water dominated geothermal systems and the Waiotapu example is a particularly good example of an acid sulphate system. This stop should be brief with time for a few photographs. Take care as the ground inside the fenced area is unstable.

Stop 4.2 Paeroa Fault Scarp. (U16/997147)

The Paeroa Fault Scarp is one of the more spectacular examples of NE (~0.40^0) normal faulting in TVZ. It is the locus of a number of small geothermal fields and three welded ignimbrites are exposed in the scarp where the total displacement is estimated to exceed 500 m.

Stop 4.3 Taupo Ignimbrite. (U17/868099)

This locality is more than 65 km from the source vent of the 1850 yr eruption of Lake Taupo. At this stop we can observe an exposure of the "valley pond" facies of the Taupo Ignimbrite. The deposit exposes several metres of unwelded pumice rich ignimbrite.

Stop 4.4 Ohakuri Ignimbrite. (U17/798058)

The Ohakuri Ignimbrite at Ohakuri Dam exposes the uppermost part of a fossil geothermal system. The ignimbrite is pumice rich but highly silicified, fractured and traversed by quartz veins. It has been the subject of a drilling programme associated with epithermal gold exploration.

Stop 4.5 Whakamaru Ignimbrite. (T16/492139)

Whakamaru Group ignimbrites, dated about 330 ka are the most voluminous ignimbrites of the Taupo Volcanic Zone with volumes exceeding 1000 km^3 of magma, Wilson et al, (1986). They crop out in areas east and west of Lake Taupo. In sections in the Waikato River gorge they are up to 220m in thickness with greater than 300 m being recorded in drillholes associated with geothermal exploration in the Wairakei area. Considerable debate surrounds the correlation of units making up the Whakamaru Group with ignimbrites to the west of Lake Taupo mapped as Maranui and Whakamaru Ignimbrites and those to the east as Te Whaiti and Rangitaiki Ignimbrites (Grindley, 1960; Martin,1961,1965; Healy et al, 1964; Briggs, 1973; 1976a,b). The source of the Whakamaru Group ignimbrites is also unresolved with some authors favouring Lake Taupo (eg Grindley, 1960 and Briggs, 1976 a,b) and others an area north of Lake Taupo (Wilson et al, 1986).

At Maraetai Dam a good section through the upper part of the Whakamaru Ignimbrite is exposed in a road cutting. The ignimbrite in this section shows relatively little variation in mineralogy with abundant phenocrysts of plagioclase and quartz and minor hypersthene, hornblende, biotite, sanidine and magnetite. The ignimbrite varies from intensely welded to non welded and different authors have identified a number of flow units, for example Ewart,(1965) recognised 3 units: bottom, middle and top while Briggs, (1973) recognised 6 subunits.

Chemical data are contained in Table 2, analysis 9. Since the detailed studies of Ewart in the 1960's, no detailed geochemical studies of the welded portions of these ignimbrites have been published.

Stop 4.6 Puketarata Rhyolite Dome and Tuff Ring. (U17/752903)

The rhyolite dome complex at Puketarata is one of a number of small dome-building eruptions in the Maroa Complex. Dated on tephrochronology at between 14 - 15 ka the rhyolite is biotite bearing with phenocrysts dominated by plagioclase (11-34%), quartz (3 - 6%), biotite (up to 1.6%), hornblende (up to 1.3%) and traces of hypersthene and magnetite (Ewart, 1968). Representative chemical analyses (from Brooker, 1988) are contained in Table 2, analysis 10.

The section visited forms a part of the outer slopes of the tuff-ring and exposes pyroclastic surge and air-fall deposits associated with phreatomagmatic activity. These deposits reflect the variable interaction of rhyolitic magma and groundwater. Wet surges are fine grained and variably sorted with subordinate well sorted lapilli fall beds. Pinch and swell structures are commonly observed within coarse to medium ash layers and are suggestive of emplacement by wet surges. Ballistic blocks with associated sag structures can be observed in some layers. Dry surges are generally coarser grained and better sorted than the wet surge layers.

At Puketarata approximately 0.062 km^3 of lava was erupted, (Brooker, 1988).

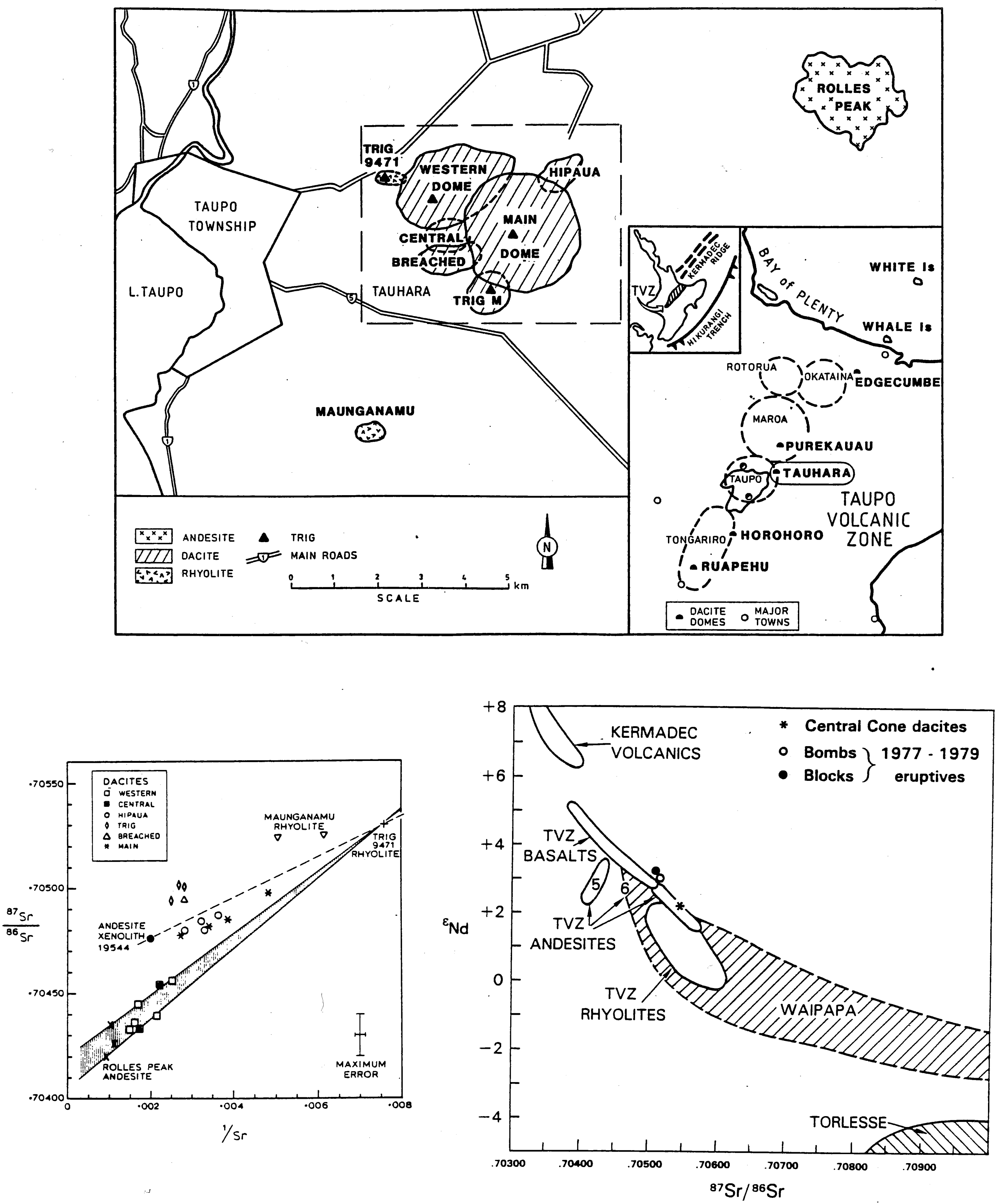


Figure 4. Location map (top) for Tauhara cumulo-dome complex. Quarry to be visited is located in Hipana Dome.

Lower left: Sr-isotopic vs $^1/Sr$ mixing diagram for dacites from Tauhara Complex (Graham and Worthington, 198).

Lower right: Compilation of available Sr- and Nd-isotopic data for TVZ volcanic rocks and basement greywackes (from Cole and Graham, 1989).

Stop 4.7 Wairakei Geothermal Field. (U17/790818)

The Wairakei Geothermal Field has been generating electricity from geothermal heat since 1958. The geology of the Wairakei system has been described by Grindley (1965) and the petrology by Steiner (1953, 1955). The geology of the area consists of a thick rhyolitic pumice breccia (Wairoa Formation) which varies in thickness from 450m to >900m. This horizon forms the aquifer for the geothermal system and it is capped by impermeable fine grained lacustrine sediments (60 - 150m thick) of the Huka Formation. The beds of the Huka Formation are in turn overlain by younger hydrothermally altered rhyolitic deposits (Wairoa Breccia) which outcrops at the surface in the geothermal area. The rhyolitic breccias of the Wairoa Formation are underlain by the Wairakei Ignimbrites (possible correlatives of the Whakamaru Group Ignimbrites).

Stop 4.8 Lake Taupo Overview. (U18/775766)

This is a brief panoramic photo stop. To the south is Lake Taupo and with views further south to the snow capped peaks of the andesite volcanoes of the Tongariro National Park. The island in Lake Taupo is Motutaiko Island, a rhyolite dome. To the east the dacite cumulo-dome complex of Tauhara (Lewis, 1968; Graham and Worthington, 1987) is clearly visible while the surfaces of the 20 ka Oruanui and 1800 bp Taupo ignimbrites are apparent. The skyline to the east is composed of the greywacke Kaimanawa Ranges.

Stop 4.9 Huka Falls. (U18/789791)

These spectacular falls developed where the Waikato River flows over the silicified upper members of the Huka Falls Formation, a sequence of water reworked rhyolitic deposits.

Stop 4.10 Oruanui Ignimbrite. (U18/868761)

This section exposes the upper part of the ~22.5 ka Oruanui Ignimbrite (Self, 1983) and overlying wind-reworked material and post 22 ka Taupo deposits. The Oruanui Ignimbrite and its associated airfall deposits have been known by a bewildering array of names such that it's stratigraphy is unnecessarily complicated. Froggatt and Lowe (1990) have reviewed the literature and advocate retention of the term Kawakawa Tephra Formation with Oruanui Ignimbrite for the ignimbrite and Aokautere Ash for all associated airfall ash deposits. The Oruanui Ignimbrite is typically unwelded, pumice poor with sparse phenocrysts of plagioclase, quartz, hypersthene, hornblende ± clinopyroxene.

The section is topped by the 1850 yr Taupo ignimbrite. Between the Taupo ignimbrite and the 22.5 ka deposits a sequence of airfall tephras can be noted. A number of charred logs can be observed in the deposits from which ^{14}C ages have been obtained. A chemical analysis is contained in Table 2, analysis 11.

Stop 4.11 Tauhara Cumulo- dome Complex. (U18/866756)

The dacite cumulo-dome complex of Tauhara comprises 6 mappable dacite domes (Lewis, 1968; Graham and Worthington, 1987) and Figure 4.

The domes are porphyritic dacites with phenocrysts of distinctive opacite rimmed hornblende, seived and complexly zoned plagioclase, orthopyroxene, clinopyroxene, Fe-Ti oxides and rare quartz. The latter are mantled by coronas of orthopyroxene. Based upon the petrographic evidence for disequilibrium in the phenocryst assemblages and the major element, trace element and Sr-isotopic data Graham and Worthington, (1987) favour an origin by magma mixing between andesitic and rhyolitic end members. Chemical analyses are contained in Table 3, analysis 4.

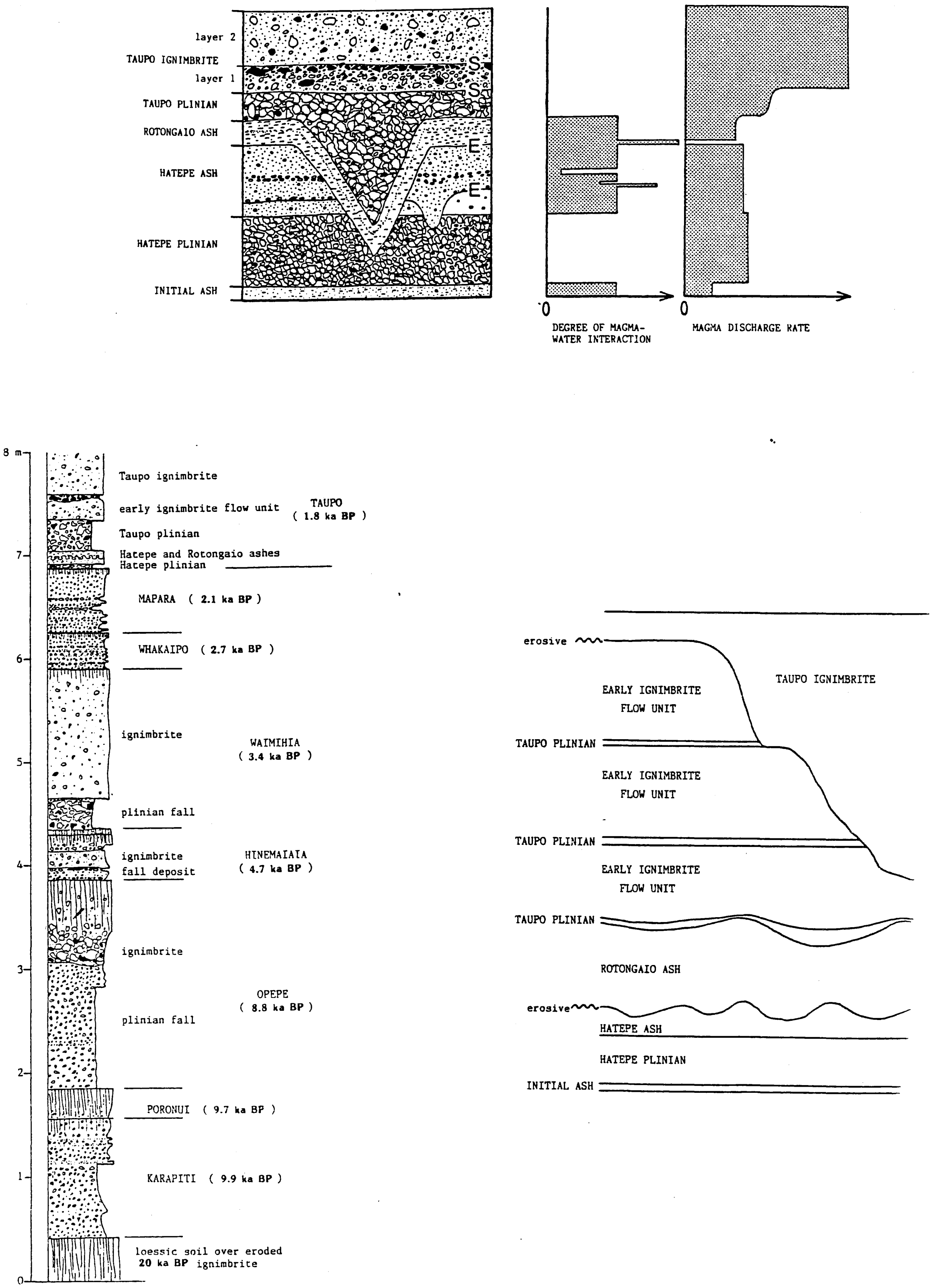


Figure 5. Top: Diagram to summarise the characteristics of the Taupo (1850 yr) eruption (from Houghton and Wilson, 1986). On the left the stratigraphic column details the various units of the eruption. E and S denote fluvial and pyroclastic flow erosion surfaces respectively. The graphs to the right depict water-magma interaction and magma discharge rate.

Left: A composite stratigraphic section of post-10 ka deposits and paleosols at Stop 4.12.

Right: A schematic section of the Taupo (1850 yr) sequence exposed at Stop 4.13.

Stop 4.12 Taupo post 20 ka eruption sequence at Hotel De Brett's. (U18/797728)

This section, which is partly annotated, is the type section of airfall and pyroclastic flow units of the Taupo Subgroup (Vucetich and Pullar, 1973) and Figure 5.

The section, with revised ages (Froggatt & Lowe, 1990, Table 1) is as follows:

Tephra Formation	**Age (ka BP)**
TAUPO PUMICE FM	
Taupo Ignimbrite	
Taupo Lapilli	1.8
Rotongaio Ash	
Hatepe Tephra	
MAPARA TEPHRA FM	2.1
WHAKAIPO TEPHRA FM	2.7
WAIMIHIA TEPHRA FM	3.3
HINEMAIAIA TEPHRA FM	5
MOTUTERE TEPHRA FM	5.4
OPEPE TEPHRA FM	8.9
PORONUI TEPHRA FM	9.7
KARAPITI TEPHRA FM	9.9
KAWAKAWA TEPHRA FM	22.5

Stop 4.13 Road cut through Taupo Tephra Formation at Waitahanui. (U18/773623)

The 1850 yr eruption from Lake Taupo was the last major ignimbrite eruption in New Zealand and involved around 50 km^3 of rhyolitic magma. The rhyolite is relatively sparsely porphyritic with phenocrysts of plagioclase, quartz, hypersthene, Fe-Ti oxides ± augite ± hornblende. Chemical analyses of individual pumice clasts from the plinian and ignimbrite deposits show limited compositional range and data are summarised in Table 2, analyses 12. Based upon isopach maps and lake bathymetry the source vent of the eruption is thought to lie in Lake Taupo in the vicinity of Horomatangi Reefs, which lie ~ 5km offshore between Waitahanui and Hatepe. The eruption has been studied in detail by Walker, (1980); Froggatt, (1982); Wilson, (1985); Wilson and Walker, (1985) and a short eruption allegory is available in the text book by Cass and Wright (1986).

A complete stratigraphic sequence of the Taupo Tephra Formation is not exposed owing to the erosive effects of the ignimbrite phases and the lateral facies variations resulting from ash dispersal. Based on the work of the above authors a typical sequence consists of 6 distinctive units, distinguishable by characteristics such as grain size and degree of sorting.

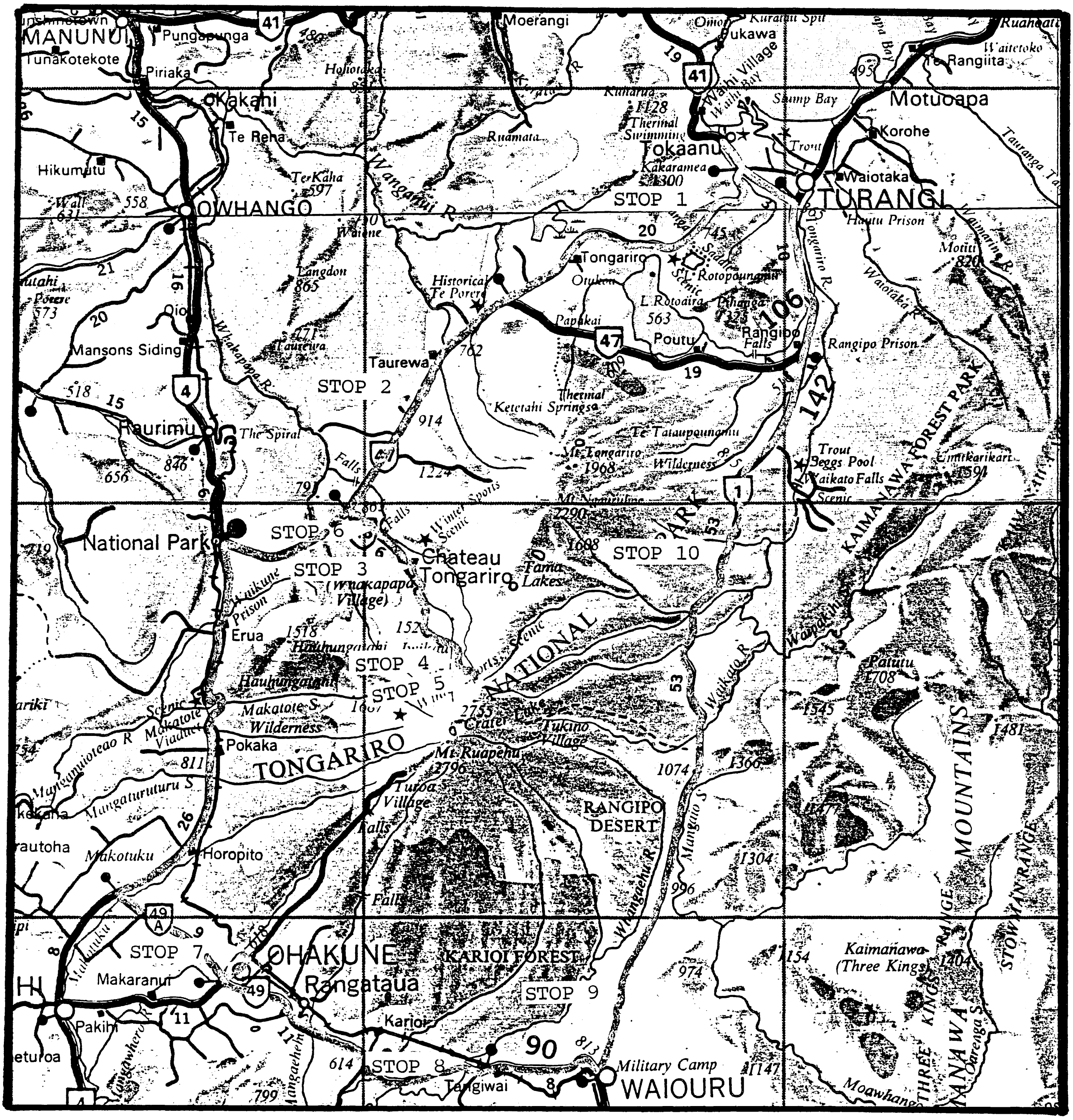
These units are as follows:

TAUPO IGNIMBRITE	Poorly sorted pumice rich ignimbrite. Three flow units at Waitahatanui.
TAUPO PLINIAN PUMICE	Well sorted airfall deposit.
ROTONGAIO ASH	Fine grained phreatomagmatic deposit.
---Erosion---	
HATEPE ASH	Phreatoplinian ash deposit.
HATEPE PLINIAN PUMICE	Well sorted airfall deposit.
INITIAL ASH	Fine grained initial phreatomagmatic ash.

The eruptive sequence, grain size characteristics and magma discharge rate are summarised diagramatically in Figure 5 (Houghton and Wilson, 1986). Figure 5 (from Houghton and Wilson, 1986) summarises the section at Waitahanui. This locality is the closest we shall approach to the source vent in the lake.

Stop 4.14 Hatepe Hill view point. Photographic stop. (U18/742564)

We stop here for a few minutes overlooking the Hinemaiaia River valley where valley pond facies of the Taupo Ignimbrite forms the flat, now incised floor of the valley.



Route Guide, Day 5
Andesite Volcanoes of Tongariro National Park

Day 5 Tongariro National Park. Ruapehu Strato Volcano and satellite vents.

Route Guide

From Tokaanu take SH 41 south to intersection with SH 47. Take SH 47 south between the extinct andesite cones of Pihanga and Kakaramea (~200 ka). Stop 5.1 Lake Taupo Lookout. From here continue south and over Te Ponanga Saddle to Lake Rotoaira and continue to a road cut in Tongariro andesite. Stop 5.2 early Tongariro olivine bearing andesite flow. From here continue along SH 47 to intersection with SH 48. Take SH 48 to Whakapapa village stopping at Tongariro National Park Headquarters. Stop 5.3 Headquarters of Tongariro National Park. Follow route up mountain stopping to observe the andesite lavas of the Whakapapa Formation. Stop 5.4 Whakapapa lava flows. Follow route to the"top of the Bruce" (weather permitting) and, Stop 5.5 view Mead's Wall dyke cutting Te Herenga Formation Flows and angular unconformity between pre and post glacial lava flows. Retrace route to Park Headquarters and follow SH 48 to near intersection with SH 47. Stop 5.6 Debris Avalanche Deposit in road cut. Rejoin SH 47 turning left to National Park turning left onto SH 4 to Ohakune. Stop 5.7 Ohakune Craters: an andesite cone and tuff-ring complex. Return to SH 49 and follow route to Waiouru. Stop 5.8 Whangaehu River Bridge, site of the Tangiwai disaster. Follow route to Waiouru and turn left onto SH-1 (the "Desert Road"). Follow SH-1 to Waihianoa Aqueduct. Stop 5.9 Photographic stop. Continue along SH 1 to the south bank of the Waihohonu Stream stopping en route for photographs if vistas of Ruapehu are appropriate. Stop 5.10 Taupo Ignimbrite overlying Tongariro subgroup tephras. Return to Tokaanu.

FIELD GUIDE

Stop 5.1 Lake Taupo Overview. (T19/495423)

From this vantage point an excellent panorama of the Taupo Volcanic Centre is available. To the north, at the far end of the lake is the dacite dome complex of Tauhara, adjacent to Taupo township. To the right of Tauhara, the white cliffs forming the lake shore are composed of Taupo Ignimbrite. To the left of Tauhara, rhyolite domes form the prominent features at the north end of the lake. The promontory extending into the lake north of the delta of the Tongariro River is the rhyolite dome of Motuapa. A small rhyolite dome (Maunganamu) is in the foreground.

Stop 5.2 Early Tongariro Andesite Lavas. (S19/297300)

This stop is outside the National Park, so samples may be collected. This cutting exposes the central part of a thick andesite lava flow similar to a sequence of flows which flowed north west and west from Tongariro. This flow is petrographically similar to a flow at Mahuia Rapids some distance to the south and dated at ~230,000 y. The lavas are distinctive in that they carry large olivine phenocrysts (Fo_{90-92}) which are enclosed within reaction coronas of orthopyroxene (hypersthene). Other phenocrysts include hypersthene (with coronas of bronzite), clinopyroxene and plagioclase both of which are strongly zoned compositionally. These lavas have been interpreted as hybrids (Graham and Hackett, 1987). Chemical analyses of typical lavas are shown in Table 4, analysis 8. These lavas are distinguished by high MgO, Cr and Ni and low Al_2O_3.

Stop 5.3 Tongariro National Park Headquarters. (S20/293196)

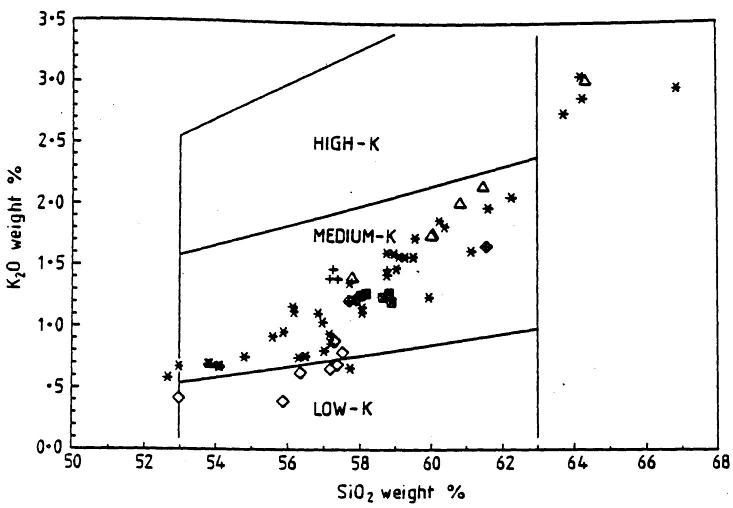
This is a brief comfort stop to allow a visit to the National Park Headquarters. The building contains a display room and sells souvenirs, posters, etc.

TABLE 4

Representative Chemical Analyses of Andesites from the Tongariro Volcanic Centre, Taupo Volcanic Zone

	1	2	3	4	5	6	7	8
SiO_2	55.56	61.33	57.74	59.10	57.91	56.29	56.79	57.01
TiO_2	0.77	0.78	0.68	0.75	0.66	0.75	0.53	0.69
Al_2O_3	17.40	16.75	20.34	15.33	15.49	16.60	14.50	14.29
Fe_2O_3*	8.44	6.45	6.07	6.82	7.84	9.19	8.86	7.84
MnO	0.12	0.07	0.08	0.07	0.17	0.15	0.19	0.15
MgO	5.00	3.21	2.09	5.74	6.12	5.18	7.07	8.64
CaO	8.11	5.87	7.96	6.54	8.22	8.32	9.05	7.26
Na_2O	2.93	3.49	3.60	2.85	2.90	3.11	2.32	2.75
K_2O	1.11	1.96	1.24	1.72	1.21	1.15	0.66	1.45
P_2O_5	0.12	0.17	0.11	0.14	0.10	0.16	0.07	0.11
LOI	1.09	0.66	0.55	0.86	0.56	-	0.73	0.83
Sc	26	19	-	22	25	28	31	21
V	216	162	167	176	207	220	226	181
Cr	132	51	36	240	231	100	192	507
Ni	49	26	27	81	73	29	39	237
Cu	54	37	59	29	60	41	102	96
Zn	74	69	63	63	73	89	74	71
Ga	19	20	18	16	17	19	18	16
Rb	34	81	39	73	40	38	16	49
Sr	251	253	344	222	334	247	390	277
Y	21	26	20	19	20	23	17	18
Zr	84	158	95	142	90	95	65	115
Nb	2	7	<2	5	3	-	3	5
Ba	313	418	317	338	294	214	144	355
La	-	19	-	11	-	-	-	15
Ce	20	36	-	20	-	-	-	29
Nd	-	-	-	-	-	-	-	-
Sm	-	-	-	-	-	-	-	-
Eu	-	-	-	-	-	-	-	-
Gd	-	-	-	-	-	-	-	-
Tb	-	-	-	-	-	-	-	-
Tm	-	-	-	-	-	-	-	-
Yb	-	-	-	-	-	-	-	-
Lu	-	-	-	-	-	-	-	-
Hf	-	-	-	-	-	-	-	-
Th	4	9	5	7	5	-	3	6
U	-	-	-	-	-	-	-	-
$^{87}Sr/^{86}Sr$	0.70529	0.70554	0.70524	0.70534	0.70502	0.70540	0.70436	0.70480
$^{143}Nd/^{144}Nd$	-	0.51271	-	0.51271	-	0.51273	0.51277	0.51275

1. Type I Ruapehu Lava, Mangawhero Formation, Mt Ruapehu, Graham & Hackett (1987).
2. Type I Ruapehu Lava, Mangawhero Formation, Mt Ruapehu, " " "
3. Type II Ruapehu Lava, Wahianoa Formation, Mt Ruapehu, " " "
4. Type III Ruapehu Lava, Mangawhero Formation, Mt Ruapehu, " " "
5. Type IV Ruapehu Lava, Mangawhero Formation, Mt Ruapehu " " "
6. Type I Ngauruhoe, 1954, flow, Graham & Hackett (1987).
7. Type V Ruapehu Lava, Ohakune Craters, Graham & Hackett (1987).
8. Type VI Ruapehu Lava, Pukeonake Scoria Cone, Tongariro National Park, Graham & Hackett (1987).



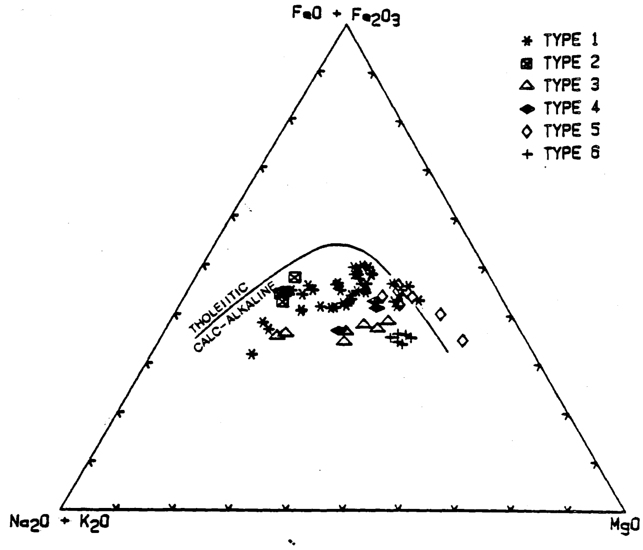


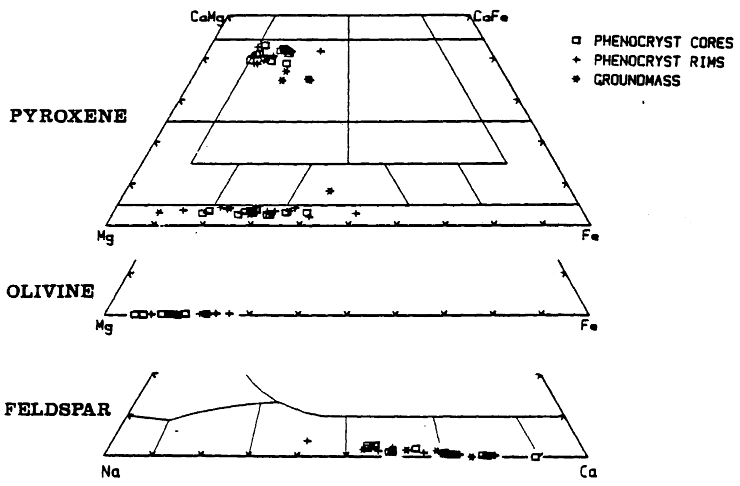
Figure 6. Top left: K_2O vs SiO_2 for lavas from Ruapehu and related vents (from Graham and Hackett, 1987).

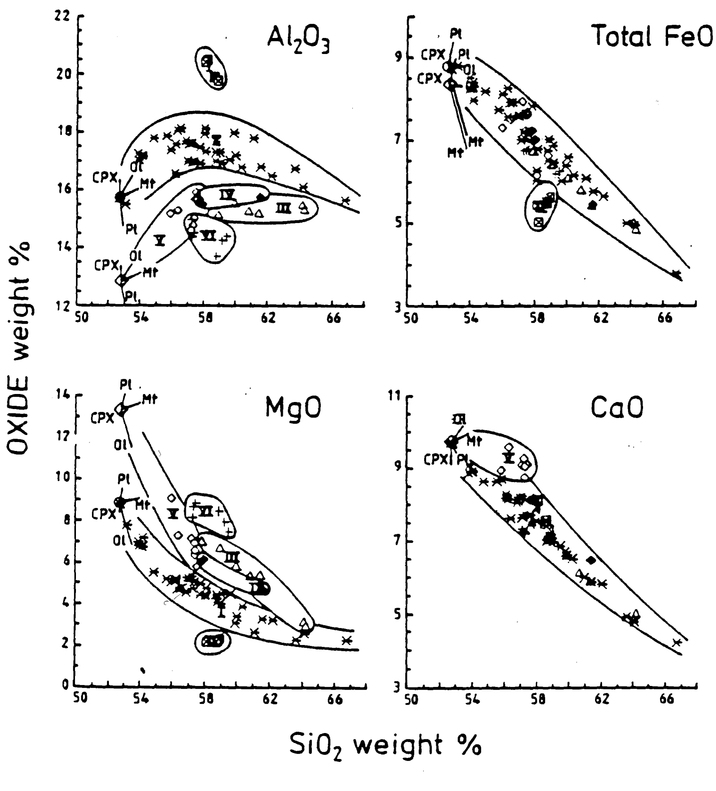
Top right: AFM diagram for lavas from Ruapehu and related vents (from Graham and Hackett, 1987).

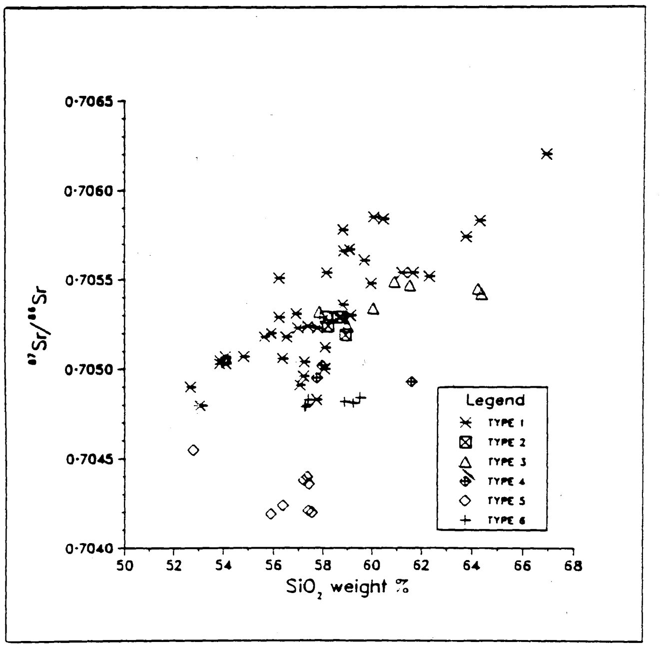
Centre: Electron microprobe data for pyroxenes, olivines and feldspars from Ruapehu lavas (from Graham and Hackett, 1987).

Bottom left: Harker-type diagrams for lavas from Ruapehu and related vents (from Graham and Hackett, 1987).

Bottom right: Sr-isotopic ratios vs SiO_2 for lavas from Ruapehu and related vents (from Graham and Hackett, 1987).







Stop 5.4 Andesite Lavas Ruapehu Volcano.

Ruapehu volcano is the largest of the andesite volcanic edifices in the Tongariro National Park. The summit (Tahurangi, 2797m) is permanently snowcapped and supports a number of permanent snow and ice fields. A crater lake fills the present day active crater in the plateau-like summit area and phreatic and phreatomagmatic explosions from this have been responsible for a number of minor eruptions and lahars over the last 50 years. A lahar from the crater lake was directly responsible for the Tangiwhai disaster on Christmas Eve 1953, when the Wellington - Auckland express train plunged into the swollen waters of the Whangaehu River after bridge supports had been swept away by a lahar. More than 150 lives were lost in the disaster.

Topping (1973) reported the detailed tephrostratigraphy of andesitic tephras from the Tongariro Volcanoes and Hackett (1985) reported the proximal stratigraphy of Ruapehu volcano in detail, recognising four main stratigraphic formations:

Formation	**Age (ka)***
Whakapapa	<15
Mangawhero	<50
Wahianoa	<150
Te Herenga	<500

* **NB** Ages are approximate

Andesites are the dominant lava type throughout Ruapehu but overall the lavas range form basalt to dacite. Graham and Hackett (1987) identified six lava types, based upon a combination of petrographic and geochemical parameters. The six types can be identified on oxide vs oxide variation diagrams (Figure) and they reflect the complexity of magmatic processes beneath an established calc alkaline volcano. Representative chemical analyses are contained in Table 4 and variation diagrams shown in Figure 6. These processes include source heterogeneity, mixing, hybridisation, fractional crystallisation and assimilation.

Type 1: Plagioclase-pyroxene phyric lavas which are the dominant lava type in all Tongariro Volcanic Centre volcanoes, occurring in all the Ruapehu formations. Phenocrysts range from 15 - 40% comprising plagioclase > pyroxene > olivine. The latter only occurs in the most basic lavas and orthopyroxene exceeds clinopyroxene in the more acidic lavas.

Type 2: Plagioclase phyric lavas which are probably accumulative with respect to plagioclase.

Type 3: Pyroxene -(olivine)- phyric lavas which represent accumulative lavas transitional from Type 1 but richer in pyroxene ± olivine.

Type 4: Pyroxene phyric lavas which are similar, petrographically, to Type 3 yet chemically distinctive.

Type 5: Olivine - pyroxene phyric lavas with plagioclase restricted to a groundmass phase.

Type 6: Hybrid lavas with phenocrysts showing disequilibrium textures and abrupt chemical zonation.

Stop 5.5 Meads Wall Dyke.

From this vantage point an excellent view of the angular unconformity between the younger (post-glacial) valley-filling Whakapapa Formation lava flows and the older Te Heranga Formation (pre-glacial) lavas can be appreciated. The Te Heranga lavas are in places hydrothermally altered and cut by shallow tonalitic intrusions. They form the jagged peaks of Pinnacle Ridge. Looking east from this vantage point in the direction of Ngauruhoe composite cone, the northern flanks of Pinnacle Ridge are draped with a distinctive welded air-fall andesite deposit whose source (~10 ka) Hackett (1985) inferred to be in the summit area, near Pinnacle Ridge.

Stop 5.6 Debris Avalanche Deposit, SH 48. (S19/264232)

The deposits exposed in this cut are representative of the numerous knolls and mounds between 3 and 8 m high on this segment of the Ruapehu Ring Plain. Over the years, these units have been variously interpreted as drumlins, lahars and, more recently, debris avalanche deposits. They are thought to represent deposits formed from a sector collapse episode on Ruapehu some 10 ka.

Stop 5.7 Ohakune Craters. Andesite Scoria Cone and Tuff Ring. (S20/176976)

Charcoal from distal tephras in the tuff ring of this deposit have been dated at 31.5 ka (Froggatt and Lowe, 1990). The deposits have been studied in detail by Houghton and Hackett (1984) who describe a tuff ring consisting of alternations of phreatomagmatic surge and airfall deposits and strombolian bomb beds. The tuff ring encloses a scoria cone of variably welded strombolian deposits.

The Ohakune rocks are andesitic in composition and distinguished by the presence of glomeroporphyritic aggregates of olivine - clinopyroxene ± orthopyroxene and the absence of plagioclase as a phenocryst phase. Chemical analyses, Table 4, analysis 7, reveal low SiO_2 and Al_2O_3 and high MgO and Cr compared to other andesites from Ruapehu. Sr-isotopic analyses are also amongst the lowest recorded from Ruapehu lavas and related vents (range 0.70420 to 0.70442, Cole et al, 1986; Graham and Hackett, 1987).

Stop 5.8 Tangiwai Rail Bridge, Whangaehu River. (T21/317300)

The Whangaehu River drains the crater lake at the summit of Mount Ruapehu. The natural waters have a very low pH and are continually murky and turbid. This site marks the location of New Zealand's last volcanic disaster when more than 150 passengers on the Auckland - Wellington overnight train were killed after a lahar for the crater lake of Ruapehu swept away the rail bridge minutes before the train was due to pass.

Stop 5.9 Wahianoa Aqueduct view point. Photographic stop. (T20/434985)

This view point affords an excellent panorama of the southeast flanks of Mount Ruapehu, the ring plain and the Rangipo Desert, a cool temperate low precipitation area in the rain shadow of Mt Ruapehu. The channel-way in the foreground is part of the workings of the Upper Tongariro Power Scheme which was completed in the 1970's by the Ministry of Works for the NZ Electricity Commission. Here, waters from the Wanganui catchment were diverted across the divide and into the headwaters of the Tongariro River, leading eventually to the Waikato River Hydro Dams. In April 1975 when tunnelling was almost complete, a lahar from Ruapehu's crater lake descended the Whangaehu River and partially filled the tunnel workings. Fortunately the a work-crew had just (minutes previously) come out of the tunnel for a tea-break and no lives were lost. This led to design changes such that the channel-way and tunnel are now sealed.

Stop 5.10 Waihohonu Stream. Taupo Ignimbrite overlying Tongariro Sub Group Tephras. (T20/462172)

At this locality we are some 50 km from source and ~ 600m above Lake Taupo. The road cut exposes a distal section (~2-3 m) of the ignimbrite. Note the sharp (erosive?) contact with the underlying airfall deposits from the Tongariro andesite volcanoes. The lower part of the ignimbrite is fine grained, crudely layered and pumice poor and a relatively sharp transition separates it from pumice rich ignimbrite which comprises the upper part of the section. Numerous carbonised logs occur in this deposit. Dark brown andesitic ash layers from post Taupo eruptions from Ruapehu, Tongariro and Ngauruhoe overlie the ignimbrite. The tephra layers beneath the ignimbrite are named the Mangatawai Tephra (Topping, 1974) and are thought to originate largely from eruptions which built Ngauruhoe cone.

NOTES

NOTES

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