EARTH SCIENCE JOURNAL Vol. 4, No. 1, 1970

THE SOILS OF THE SOUTHEASTERN SECTOR OF EGMONT NATIONAL PARK

P. J. TONKIN

Geology Department, Victoria University of Wellington*

Abstract

The soils of the southeastern slopes of Egmont National Park, Taranaki, are youthful in absolute age and also in soil development. They are classed as recent soils on a parent material basis : andesitic tephras, alluvium, and peat with interbedded tephra. Of these groups the former covers the greatest part of the surveyed area and was studied in the most detail.

The recent soils from andesitic tephra have a profile form dominated by buried soil horizons and little weathered tephra layers, the youngest of which was erupted 210 years ago. Characteristic features are the very weak weathering of minerals in the upper soil layers, the variable depth of melanisation, the extremely leached state of the soil profile and lastly the marked similarity of the soil chemical parameters despite appreciably different biotic regimes and a range in slope and altitude. It is concluded that the extremely high rainfall, in excess of 150 inches per annum, so controls soil processes that the variables of site and vegetation are not expressed in the measured soil parameters.

INTRODUCTION

Egmont National Park extends over 83,000 acres of the Taranaki peninsula, North Island, New Zealand (Figure 1). The park encloses within its boundaries a chain of andesitic volcanoes, aligned along a north-west axis. Mount Egmont and its parasitic cone of Fanthams Peak are the southern and most recent of these volcanoes. Within the park eruptive deposits from the volcanoes control the relief and the youngest superficial deposits determine the soil pattern. The soil pattern studied in the southeast sector is dominated by layered tephras which have fallen on a predetermined relief and the study of soils and tephras are complementary.

The suggestion that Mount Egmont erupted in recent times came from Mr A. W. Burrell who noticed pumice lapilli lodged in the forked branches of old trees on the eastern slopes of the mountain (Oliver, 1931). Recently Druce, (1966) established the sequence of events during the last eruptive phase some 300 years ago. Previously it was supposed that Fanthams Peak was the youngest eruptive centre, but closer examination of this vent and more accurate plotting of the isopachs of the most recent tephras show that this is not the case and all the recent eruptions have come from the Egmont crater.

TOPOGRAPHY

The eastern side of Mount Egmont which rises from 1,600 ft to 8,260 ft above sea level, is divided into three topographic units :

(a) The very steep lava and scoria slopes of the volcanic cones of Egmont and Fanthams Peak.

*Present address : Soil Science Department, Lincoln College, Canterbury.

(b) A gently to moderately sloping shoulder up to half a mile wide, at an elevation of 5,000 ft, extending from above North Egmont where it terminates in the shear Tahurangi Bluff, to south of Warwick Castle where it ceases at the edge of the Ngarara Bluff. This shoulder is formed of very thick lava flows, overlain by a thin veneer of scoria, ash, and avalanche debris. A smaller moderately sloping shoulder, between Ngarara Bluff and the Curtis Ridge (Stratford Plateau) lies 400 ft below the main shoulder. It is also formed of thick lava flows but is overlain by a much thicker mantle comprising at least 50 ft of poorly sorted bouldery and gravelly silty sands, which are in turn overlain by 13 ft of thinly banded ash and lapilli beds. The edges of these shoulders are marked either by a steep bluff or a marked steepening of slope.

(c) Below the shoulders the flanks of the volcanoes extend out as a broad, gently sloping, alluvial piedmont which is blanketed with ash and lapilli beds. This piedmont merges into the surrounding ash-mantled, easy rolling country.

Dissecting the mountain side is a closely spaced, radial pattern of entrenched streams and rivers. The streams are only slightly entrenched on the hard lava slopes, but across the shoulders they have cut vertical sided gorges to a depth of 300 ft. Gradually these streams and rivers become less entrenched until in the lower part of the piedmont their banks are only 10 to 50 ft high.

CLIMATE

Rainfall.

Monthly totals recorded at Dawson Falls Lodge (2,970 ft) and the Mountain House (2,775 ft), (Table 1) show that there is little variation between these two recording stations. The rainfall is fairly evenly distributed throughout the year with a slight increase in the winter months of May to August and in October. Records of rainfall for the years 1951 to 1965 indicate that heavy falls

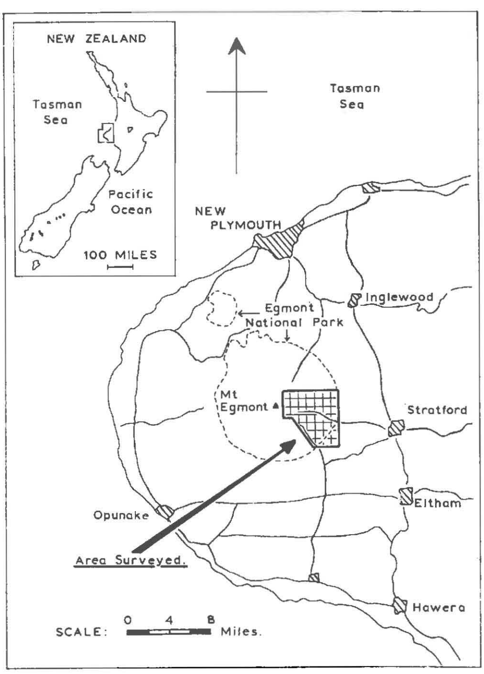

Figure 1. Locality Map.

Table 1. Rainfall and Climatic Data*

Monthly Rainfall Normals (inches)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Dawson Falls (14 years)	15.2	18.3	13.9	19.8	25.2	24.2	24.1	22.9	17.7	20.7	17.2	15.2	234.4
Mountain House (4 years)	15.2	18.4	14.0	19.9	25.3	24.3	24.2	23.0	17.7	20.7	17.2	15.2	235.1

Mean Temperature (°F), $\frac{1}{2}$(Max + Min)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mountain House (3 years)	54.7	57.3	54.1	48.1	43.6	39.8	38.1	40.1	41.8	45.5	48.0	52.2	46.9

Mean Daily Maximum Temperature (°F)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mountain House (3 years)	63.5	66.4	61.9	55.9	49.7	45.7	43.7	45.8	48.7	53.7	55.3	60.5	54.2

Mean Daily Minimum Temperature (°F)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mountain House (3 years)	45.9	48.4	46.4	40.2	37.5	34.0	32.6	34.5	35.6	37.1	40.7	43.9	39.7

* Supplied by the Director, New Zealand Meteorological Service.

(six to more than ten inches in 24 hours) may occur several times a year. At 3,000 ft the average annual rainfall is 235 inches on 220 raindays with 180 days per year on which there is 7/10 or more cloud cover.

Wind.

The percentage wind frequency recordings from New Plymouth indicate that the prevailing wind directions in Taranaki are from the west and south east. On Mount Egmont gale force winds are experienced several times a year, with accompanying heavy rain.

Snow.

A few light falls occur in the summer months between November and April but these melt rapidly. During the winter light falls are recorded down to 1,200 ft but the heaviest falls occur above 3,000 ft where the snow may lie on the ground for several months.

Temperature

Mean temperatures for the period 1965 to 1967, recorded at the Mountain House, are shown on Table 1.

Fog and ground frost

Several days of fog and ground frost are recorded at the Mountain House during most months of the year. The incidence of ground frost increases during the period May to October, when 10 to 20 frosts are recorded per month.

VEGETATION

The vegetation changes with altitude in the National Park and six major zones are recognised (Figure 2). The following is a brief description of each zone, as seen along the Stratford mountain road (Druce, 1964). The altitudes mentioned are only approximate, as the boundary of any one zone varies with aspect and topography. The zones tend to merge into each other with outgoing plants being gradually replaced by different species.

The notation used in the zone titles follows Druce (1959) : canopy layers are separated by a bar (/) and the species in the same layer by a hyphen (-). For a key to the plant names used in the text see Appendix 2.

Zone 1. rimu - rata / kamahi / mahoe forest. Altitude : 1,800 ft to 2,250 ft. Other species include : pate, broadleaf, miro, putaputaweta, black maire, raurekau, karamu, fuchsia, and supplejack.

Rata (many of which are dead or dying) and rimu, 90 ft high, form an emergent layer above an open canopy of kamahi, 60 ft high. Beneath this is a third layer of mahoe, pate, etc. at a height of 40 ft, with smaller shrubs and ferns growing below. Lianes such as supplejack are common. In places where the canopy is very open, grasses cover the forest floor.

Zone 2. kamahi forest. Altitude : 2,250 ft to 3,000 ft. Other species include : peppertree, broadleaf, rimu, wine berry, pate, putaputaweta, toro, Hall's totara, and tree ferns.

The kamahi forms an even canopy 60 ft high and a second layer is formed of peppertree at a height of 12 ft. The other species are scattered throughout the forest and occasionally form small groves.

Zone 3. Hall's totara - broadleaf - fuchsia forest. Altitude : 3,000 ft to 3,500 ft. Other species include : peppertree, mountain fivefinger, and kaikawaka.

This zone 3 forest gradually changes from its lower limit at 3,000 ft with an increase of Hall's totara and a decrease of kamahi. The canopy height is above 40 ft at first but decreases toward the upper limit of the zone, where Hall's totara and kaikawaka emerge from a close canopy of mountain fivefinger and other shrubs of the following zone. The kaikawaka are very scattered and the fuchsia are only locally abundant.

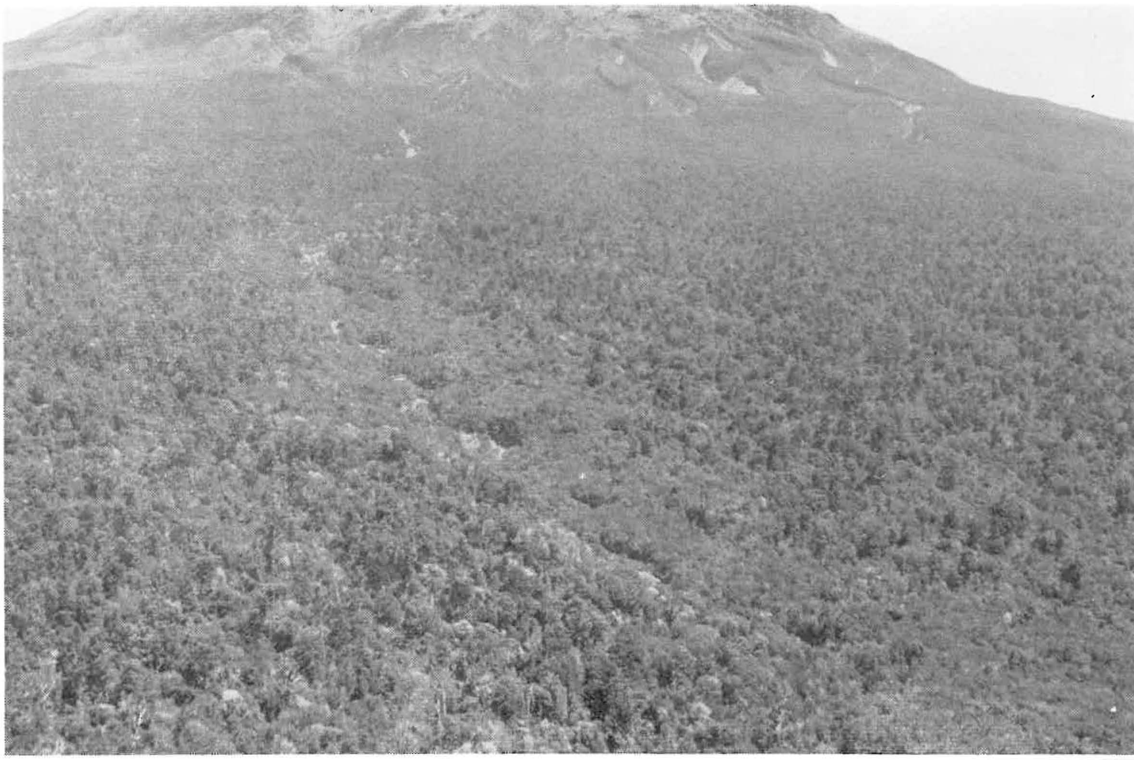

Figure 2. Eastern slopes of Mount Egmont showing : (a) the change in vegetation from forest to grassland with altitude and, (b) in the foreground the change from rimu - rata / kamahi forest on the Burrell soils, to kamahi forest on Hangatahua soils along the Manganui River (centre).
Photo : G. C. Kelly.

Zone 4. leatherwood scrub. Altitude : 3,500 ft to 4,500 ft. Other species include : koromiko, mountain fivefinger, inaka and several coprosma species.

These plants form a very even, thick, smooth looking canopy at a height of 8 ft, which decreases to a height of 2 ft near the upper limit of the zone.

Zone 5. tussock / herb field. Altitude : 4,500 to 5,250 ft. Species include : Egmont red tussock, mountain daisies, forstera, gaultheria, anisotome, greyish and orange mosses.

Apart from the red tussocks, most of the other plants are very small and grow close to the ground. Toward the upper limit of the zone the plant cover is irregular and instead of forming a continuous sward, the plants grow in scattered pockets in the lee of the protecting rocks.

Zone 6 rock and debris. Altitude : above 5,250 ft. Only scattered herbs, mosses and lichens are found growing on scree and lava slopes.

The effect of aspect on the vegetation can be seen in the way species extend on the northern faces of ridges above their general altitude limit. This is most noticeable above 3,000 ft. Other changes are noted as one moves around the mountain. For example along either side of the Manganui (Figure 2) and Kapuni rivers are almost pure stands of young kamihi forest, which traverse all zone boundaries up to the altitude of the leatherwood scrub. Between the Stratford mountain road and the Waingongo river at an altitude of 2,250 ft, there are a number of large peat bogs which have their own smaller vegetation zones surrounding them. The zones are in order from the outside : rimu - rata / kamahi forest, kamahi forest, manuka - flax scrub and manuka / sedge land in the centre-most part of the bog. Similar peat bogs are located between the Te Popo stream and the Manganui river.

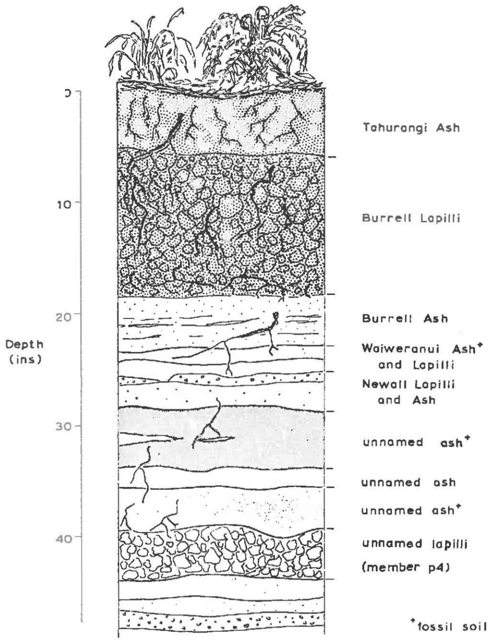

Figure 3. Tephra column of the Tahurangi fine sandy loam, in a section alongside the Stratford mountain road, opposite Jackson's Lookout.

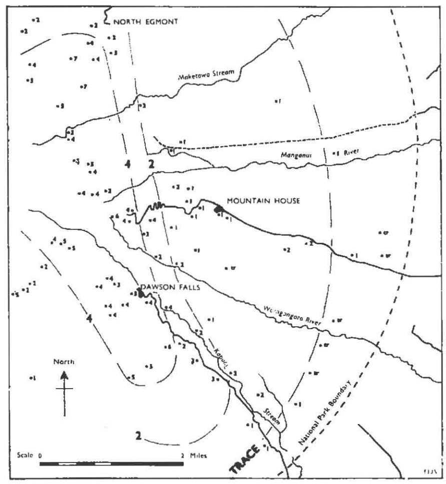

Figure 4. Isopach map showing the distribution of Tahurangi Ash (includes data from Druce, 1966). Thicknesses in inches.

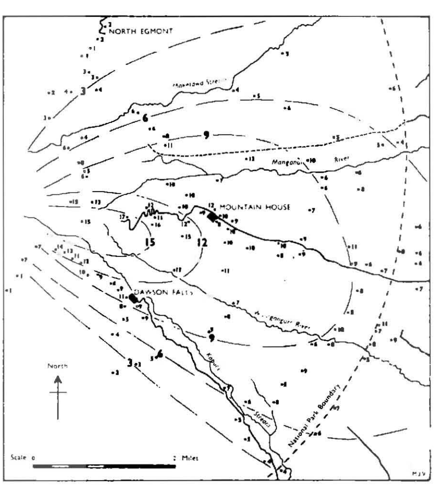

Figure 5. Isopach map showing the distribution of Burell Lapilli (modified from Druce, 1966). Thicknesses in inches.

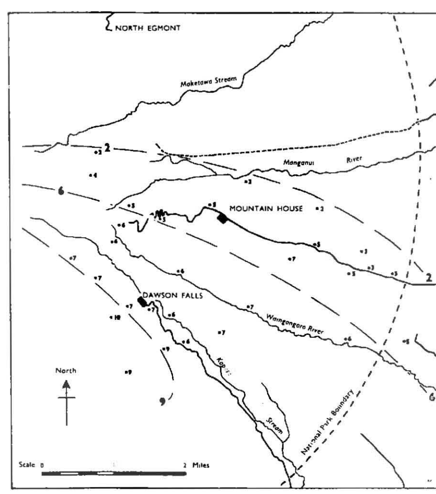

Figure 6. Isopach map showing the distribution of an unnamed lapilli (member p4 of Druce, 1966). Thicknesses in inches.

PARENT MATERIALS

With a few exceptions the parent materials of the soils are considered as layered systems in which well preserved tephra layers record past eruptive events and buried soil layers record intervening periods of soil formation. Druce (1966) has described and mapped the recent tephras on Mount Egmont, giving estimates of their ages from tree-ring counts. He grouped the tephras into the following formations :

Formation	*Member*	*Approximate Age*
Tahurangi Formation	Tahurangi Ash	A.D. 1755
Burrell Formation	Puniho Lapilli 1 Puniho Lapilli 2 Burrell Lapilli Burrell Ash	A.D. 1655
Newall Formation	Waiweranui Ash Waiweranui Lapilli Newall Lapilli Newall Ash	A.D. 1604

On the eastern side of Mount Egmont all of these members, with the exception of the Puniho members, form the tephra column. Beneath these beds are several unnamed ash beds and a pumice lapilli layer. This lapilli layer (member p4 of Druce, 1966) forms a distinctive marker bed and was mapped (Figure 6). Isopach maps show the distribution of the Tahurangi Ash (Figure 4) and the Burrell Lapilli (Figure 5). The other members progressively thin out and merge into each other so it has not been practicable to map them individually.

Table 2. Mineralogy of the Sand Fractions of the Tephra Layers.

Member	Sand (2mm - 0.02mm) Weight % of oven dry (105°C) Sample.	Glass	Andesine	Augite	Oxy-hornblende	Hornblende	Hypersthene	Biotite	Magnetite
Tahurangi ash (1)	67	A	C	S	S	R	R	R	R
Burrell lapilli (2A)	3	A	C	S	S	R	R	R	R
Burrell ash (2B)	59	A	C	S	S	R	-	R	R
Waiweranui ash (3A)	48	A	C	S	S	R	R	R	R
Waiweranui lapilli (3B)	71	A	C	S	S	R	R	R	R
Newall lapilli (3C)	53	A	C	S	S	R	R	R	R
Newall ash (3D)	28	A	C	S	S	R	R	R	R

A — very abundant 50% C — very common 10-29%
S — Scarce 1-4% R — rare 1%

The mineralogy of the sand fractions of the various tephra members is very similar (Table 2). Material larger than 60 mesh consisted mainly of rock fragments. Within a sample of the Burrell Lapilli are a pumiceous glass with a refractive index of 1.517, containing crystals of andesine, oxy-hornblende, diopsidic augite and minor amounts of magnetite. Minor amounts of pale grey, fine grained porphyritic augite-hornblende andesite and grey, fine grained porphyritic oxy-hornblende andesite are also present in this member.

A typical tephra column from the Stratford Plateau is shown in Figure 3.

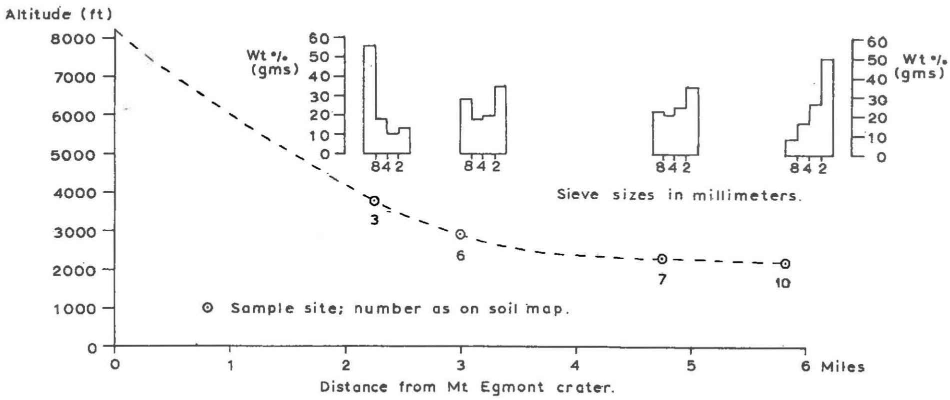

Figure 7. Change in the size fraction distribution, between the limits of greater than 8 mm and less than 2 mm, of the Burrell Lapilli along an east-west axis from its source of eruption.

SOIL CLASSIFICATION AND DESCRIPTIONS

The soils are discussed in the same order as they occur on the legend of the soil map (Figure 8).

(a) Recent soils from andesitic volcaniclastics
- Alpine soils
- Subalpine soils
  - Steepland skeletal soils
  - Tahurangi soils
- Upland temperate soils
  - Tahurangi soils
  - Burrell soils

(b) Recent soils from alluvium
- Hangatahua soils

(c) Soils from peat with interbedded tephra
- Organic soils

Detailed soil profile descriptions are to be found in Appendix 1. The Burrell and Hangatahua soils were originally described by Grange and Taylor (1933).

Recent soils from andesitic volcaniclastics

Recent soils from andesitic volcaniclastics are recognised within three environmental zones and are named accordingly; Alpine soils above 5,500 ft, Subalpine soils between 5,500 and 3,250 ft, and Upland temperate soils between 3,250 ft and the lower limit of the area surveyed at 1,500 ft. These zones provide convenient groupings and follow broadly the zoning of vegetation with the Alpine soils corresponding with sparse or no vegetation above the tussock / herb field, the Subalpine soils with the tussock / herb field, leatherwood scrub and Hall's totara - broadleaf - fuchsia forest, and the Upland temperate soils with the incoming of such lowland species as rimu in the kamahi forest and the rimu - rata / kamahi / mahoe forest.

Alpine soils

These soils were not examined in this survey.

Subalpine soils

Steepland skeletal soils occur on the steep to moderately steep slopes of the mountain above 4,500 ft and have a variable upper limit at approximately 5,500 ft. They have a shallow (less than five inches), humus stained, sandy topsoil and the subsoil is variable but generally consists of a porous mantle of broken

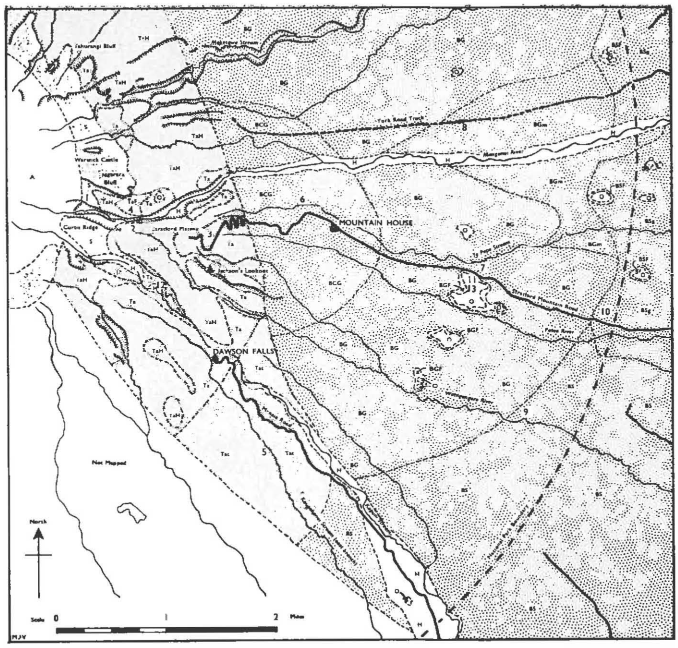

Figure 8. Soil map of the south-eastern sector of Egmont National Park.

LEGEND

Recent soils from andesitic volcaniclastics	
Alpine soils	A
Subalpine soils	
Steepland soils	S
Tahurangi hill soils	TaH
Tahurangi fine sandy loam	Ta
Tahurangi fine sandy loam with incipient iron pan	TaF
Upland temperate soils	
Tahurangi fine sandy loam, temperate phase	Tat
Burrell coarse gravel	BCG
Burrell gravel	BG
Burrell gravel, imperfectly drained phase	BGm
Burrell gravelly sand	BS
Burrell gravelly sand, poorly drained phase	BSg
Burrell gravel with incipient iron pan	BGF
Burrell gravelly sand with incipient iron pan	BSF
Recent soils from alluvium	
Hangatahua soils	H
Soils from peat with interbedded tephra	
Organic soils	O

rock and pumic lapilli overlying the pumice lapilli member p4 (Druce, pers. comm.) or lava and agglomerate. Throughout the soil and scattered over the surface are numerous andesite blocks. A constant feature of these soils is a layer of wind blown sand trapped in the moss mat that covers the surface.

Tahurangi soils occupy a belt across the flank of the mountain from 4,500 ft to 3,250 ft and south of the Manaia road they extend down to 2,200 ft. The boundary between the Tahurangi and the Burrell soils is taken to be the two-inch isopach of the Tahurangi ash. A generalised Tahurangi soil profile is : from six to 24 inches of melanised A horizon consisting of at least two inches of dark reddish brown, friable fine sandy loam (Tahurangi Ash) passing down into similarly coloured, very porous, loose pumice gravel (Burrell Lapilli). Abundant organic matter forms a distinctive coating on the sand and porous gravel fragments. The subsoil is comprised of layered dark brown and greyish brown fine sands and sandy loams. Some of these beds are firm and compact. The following mapping units are recognised :

Tahurangi fine sandy loam is a moderately well drained soil occurring on rolling slopes between 4,500 ft and 3,250 ft. A profile of this soil is shown in Figure 3.

Tahurangi hill soils mapped on moderately steep to steep slopes have many profiles similar to the Tahurangi fine sandy loam but include profiles modified by aeolian sand accretion and profiles modified by erosion of the Tahurangi Ash.

Tahurangi fine sandy loam with incipient iron pan has a slightly peaty melanised horizon, a very distinct zone of iron accumulation in the lower part of the pumice gravel (Burrell Lapilli) horizon and, a permanent water table within two feet of the surface. It occupies minor areas of impounded drainage on the Manganui ski field.

Upland temperate soils

Tahurangi fine sandy loam, temperate phase occurs on rolling and easy rolling slopes below 3,250 ft and except for the inferred environmental differences and the decreasing thickness of the tephras constituting the soil body, it is similar to the Tahurangi fine sandy loam.

Burrell soils occur on the lower slopes of the mountain below 3,250 ft. The three - inch isopach of the Burrell Lapilli corresponds with the lower limit of the Burrell soils. The Tahurangi Ash is generally unrecognisable in these soils and many of the other ashes in the soil body are thinner. A generalised Burrell soil profile is : nine inches of dark reddish brown, porous, organic stained, pumice gravel overlying layered dark brown and greyish brown fine sands and sandy loams. Drainage is impeded in many Burrell soils which have firm and compact subsoil layers. These soils cover a range from moderately to poorly drained and are subdivided into three units according to intensity of mottling and other gley characteristics. Within the Burrell soils the following units are recognised :

Burrell coarse gravel is a moderately well drained soil occurring on rolling slopes. The A horizon contains little Tahurangi Ash (less than two inches) and has more than 25% coarse gravel. The lower boundary of this mapping unit coincides with the 10-inch isopach of the Burrell Lapilli.

Burrell gravel occurs on rolling slopes and has similar properties apart from the content of medium gravel in its A horizon.

Burrell gravel, imperfectly drained phase, is underlain at shallow depth by the alluvial fans of the Manganui river and Te Popo stream. There is less than 2 ft of tephras between the Burrell Lapilli and the underlying alluvium. The subsoils are more strongly mottled and the water table is generally less than 3 ft from the surface. Mapped as an inclusion within this unit is a small area of Burrell gravelly sand, imperfectly drained phase, which differs only in the texture of its A horizon.

Burrell gravelly sand occurs on easy rolling slopes and has imperfect to moderate drainage properties according to local site factors. This soil occurs both within and beyond the boundaries of the National Park.

Burrell gravelly sand, poorly drained phase occurs on easy rolling slopes between the Manganui and Patea rivers. The soil body comprises less than 18 inches of Burrell Lapilli and other ashes over alluvium. This soil has a prominent Ag horizon at the base of the Burrell Lapilli, the subsoil is diffusely gleyed throughout and the water table is generally within 18 inches of the surface.

Two phases, the Burrell gravel and the Burrell gravelly sand, each with incipient iron pan occur around the fringes of the peat bogs on the lower eastern slopes of the mountain. These soils are distinguished by : a thin peaty H horizon, a distinct zone of iron accumulaton in the lower part of the pumice gravel (Burrell Lapilli), and a water table within 18 inches of the surface.

Recent soils from alluvium

Hangatahua soils occupy the gently sloping, moderately well drained, alluvial terraces along either side of the larger streams and rivers. They have been mapped as a complex along the Manganui and Kapuni rivers, and the soils range in texture from gravels and sands, to bouldery sandy loams. During periods of peak river discharge, detritus is still added to the surface of some of these soils, especially on the Kapuni 'fan' near the National Park boundary.

Soils from peat with interbedded tephras

Soils derived mainly from peat occupy a very small area within this survey and have not been designated with a type name. These organic soils occupy small peat bogs on the lower slopes of the piedmont, many of which are associated with the local emergence of springs. The peaty materials are very strongly to almost completely plup charged (D 6 to 8), in the terminology of Harris (1968). These soils contain tephra both dispersed and in layers and have a loamy peat texture.

VARIABILITY OF SOIL MAPPING UNITS

Variations in the morphology of the soils described will be briefly considered under the headings : texture, thickness of horizons, form of the organic profile, and soil drainage.

Texture

The texture of the Steepland skeletal soils and the Hangatahua soils varies greatly and is unpredictable. Textural variation in the Tahurangi and Burrell soils is more predictable (Figure 7) and, with the exception of minor erosion on the forest floor, the texture of the soils described is relatively consistent (Appendix 1).

Thickness of horizons

The A horizons of the Steepland skeletal soils and the Hangatahua soils are thin (from three to seven inches), and the subsurface layers vary in form and thickness. By comparison, the A horizon of the Tahurangi and Burrell soils extends to the lower contact of the Burrell Lapilli with older more compact ashes. The thickness of the A horizon varies considerably from place to place and can be estimated at any one site by superimposing the Tahurangi Ash and Burrell Lapilli isopach maps (Figures 4 and 5). The subsoil horizons are dominated by layering patterns of the tephra column, alluvium and fossil soils (see Figure 3). Generally the various tephra layers forming the subsoil are of similar texture and mineralogical composition. The soils with alluvium underlying the ash beds at shallow depth have been separated on the soil map (Figure 8).

Form of the organic profile

Three groups of organic profile are recognised : the organic profiles of the tussock / herb field and other grassland areas, the organic profiles of the scrub and forest zones, and the organic profiles associated with trees such as Hall's totara and rimu. Two further organic profiles are associated with conditions of high ground water : the thin peaty surface horizons of the Tahurangi and Burrell soils, both with incipient iron pans, and the organic soils.

The organic profile of the tussock / herb field is confined to an extremely thin (less than one-quarter of an inch) layer of fresh litter in which there is an abundance of granular and crumb mull-like-moder. Most of the organic matter in the mineral soil appears to be derived from the decay of dead roots and moss filaments. Included in this type of organic profile are the partly buried moss horizons of the Steepland skeletal soils.

The organic profiles of the scrub and forest zones are more variable and can be divided into three types :

Type (a) L ¼ to ½ in. fresh leaf and twig litter; laminated,
F ½ in. partly decomposed litter; laminated; plant structure visible, few fine roots,
H 1 to 3 in. medium granular moder and some raw humus (fragments of twigs and bark); friable; abundant fine roots.

Type (b) L ½ in. fresh leaf and twig litter; laminated,
F ½ in. partly decomposed litter; laminated; few fine roots, on humic fine sandy loam.

Type (c) L ¼ to ½ in. fresh leaf and twig litter; laminated,
H 2 to 3 in. medium granular moder and some raw humus; abundant roots, on melanised pumice gravel.

The relative abundance of these organic profiles of the scrub and forest zones has been difficult to assess but type (a) and (b) were most common on the Tahurangi soils and type (c) was most common on the Burrell soils.

The organic profiles associated with Hall's totara and rimu trees are similar to type (a) except the H horizon of fine to medium granular moder and raw humus is very much thicker, varying from five to in excess of twelve inches. The top of the underlying mineral soil profile is rich in fine crumb and granular mull-like-moder and there are scattered bleached sand grains. These thicker organic profiles merge into other forest types at a distance of from four to eight feet from the trees under which they occur. A large part of the litter around the boles of rimu trees appears to be bark.

Soil drainage

Mapping the drainage classes recognised for the Burrell soils has posed some difficulties and strong micro-relief control of drainage prevents small areas of imperfectly drained soils being shown. On the lower slopes of Mount Egmont the dense vegetation cover limits observations to selected traverses and the drainage status may not always be correctly shown.

SOIL CHEMISTRY

The results of analyses of five soil profiles and four litter layers are given in Tables 3 and 4. The analytical methods used follow Metson (1956) and Metson and Blakemore (1964). Individual bases were determined by flaming ammonium acetate leachates in an atomic adsorption spectrophotmeter and the total exchangeable bases were obtained by addition. In all cases analyses were determined on material less than 2 mm in diameter. This presented a problem with the soil samples containing pumice gravel (Burrell Lapilli) in which the proportion less than 2 mm in diameter varied between 13 and 33% of the total weight of the sample. Thus to achieve as representative a sample as possible the pumice gravel was lightly ground until it passed through a 2 mm sieve. In the litter analyses difficulty was experienced in the alkalinity of the ash determinations with the precipitation of $A1(OH)_3$ affecting the end points of the titrations. The same problem has been encountered in the analysis of other peaty litters from volcanic ash soils (L. C. Blakemore, pers. comm.).

Table 3. Soil Analyses

Horizon	Depth (ins)	pH	%C	%N	C/N	CEC. in me%	TEB. in me%	%BS	Ca^{++} in me%	Mg^{++} in me%	K^{+} in me%	Na^{+} in me%
Tahurangi hill soil. Site 2.												
A 1.1	0 – 2½	5.4	6.2	0.36	17	18.2	2.08	11.4	0.74	0.74	0.60	0.00
A 1.2	2½– 7½	5.5	5.9	0.29	20	18.5	1.49	8.1	0.67	0.43	0.34	0.05
A 1.3	7½–10½	5.8	4.8	0.23	21	17.5	0.47	2.7	0.14	0.19	0.14	0.00
A 1.4	10½–13½	5.6	4.6	0.18	26	13.5	0.92	6.8	0.51	0.21	0.17	0.03
Tahurangi fine sandy loam. Site 3.												
F	1½– 0	5.7	18.8	0.87	22	47.2	24.5	51.9	20.1	1.95	1.53	0.90
A 1.1	0 – 3	4.9	14.4	0.73	20	36.7	4.96	13.6	0.94	1.85	1.14	1.03
A 1.2	3 – 4	5.0	7.9	0.39	20	22.3	0.95	4.3	0.12	0.43	0.40	0.00
A 1.3	4 – 5½	5.2	7.9	0.35	23	26.1	1.25	4.8	0.09	0.33	0.73	0.10
A 1.4	5½–19½	5.3	7.3	0.32	23	27.9	1.12	4.0	0.02	0.49	0.42	0.19
A 1.5	19½–21½	5.5	5.4	0.23	24	18.8	0.80	4.3	0.15	0.28	0.35	0.02
A 1.6	21½–22	5.5	5.2	0.21	25	14.8	0.42	2.8	0.01	0.11	0.30	0.00
Dr1	22 –26	5.6	0.4	0.04	10	6.6	0.23	3.5	0.00	0.01	0.22	0.00
Burrell coarse gravel. Site 6.												
H	2½– 0	4.3	21.4	1.25	17	83.1	19.6	23.6	10.2	7.71	0.77	0.97
A 1.1	0 – 2	5.0	6.2	0.42	15	17.3	4.21	24.2	1.92	2.14	0.15	0.00
A 1.2	2 –10	5.4	5.7	0.34	17	29.2	2.03	7.0	1.03	0.66	0.20	0.14
A 1.3	10 –10½	5.3	6.5	0.31	21	31.7	1.03	3.3	0.45	0.33	0.11	0.14
Dr1	10½–12	5.4	3.9	0.21	19	–	–	–	–	–	–	–
1uA	12 –18	5.4	5.8	0.36	16	–	–	–	–	–	–	–
Burrell gravel. Site 7.												
H	3 – 0	4.0	52.6	2.17	24	186.1	31.2	16.7	15.2	9.21	1.74	5.03
A 1.1	0 – 2½	4.8	5.1	0.26	20	14.4	1.35	9.4	0.00	0.66	0.26	0.43
A 1.2	2½– 6½	4.9	4.7	0.22	21	19.5	1.12	5.7	0.17	0.57	0.14	0.24
A 1.3	6½–12	5.4	4.9	0.21	23	21.9	0.54	2.5	0.00	0.26	0.16	0.12
Dr1	12 –16	5.5	4.5	0.26	17	–	–	–	–	–	–	–
Dr2	16 –21	5.4	4.5	0.26	17	–	–	–	–	–	–	–
Burrell gravelly sand, poorly drained phase. Site 10.												
H	2 – 0	5.2	36.9	1.90	19	120.4	36.5	30.1	25.5	7.93	1.27	1.82
A 1	0 – 4½	5.4	7.6	0.51	15	18.2	1.36	7.5	0.58	0.42	0.18	0.18
A 3g	4½– 7½	5.5	3.9	0.24	16	14.0	0.34	2.4	0.05	0.13	0.09	0.07
Dr2g	7½–14½	5.5	3.9	0.21	19	21.2	0.20	0.9	0.00	0.09	0.07	0.04
Dr3G	14½–20½	5.4	7.4	0.41	18	–	–	–	–	–	–	–

Table 4. Litter Analyses.

Soil Type	Horizon	Depth (ins)	pH	%C	%N	C/N	Loss on Ignition	Alkalinity of the ash
Tahurangi fine sandy loam	F	1½-0	5.7	18.8	0.87	22	32.1	25.4
Burrell coarse gravel	H	2½-0	4.3	21.4	1.25	17	71.0	21.6
Burrell gravel	H	3 -0	4.0	52.6	2.17	24	66.6	29.9
Burrell gravelly sand, poorly drained phase	H	2 -0	5.2	36.9	1.90	19	66.3	27.1

The clay fractions were not determined by standard procedures. The "field test for allophane" (Fieldes and Perrott, 1966) was negative for the Tahurangi Ash and the Burrell Lapilli part of the soil body but strongly positive for the underlying ash layers.

The soil analyses (Table 3) indicate that the Tahurangi and Burrell soils have similar chemical properties. These soils are moderately to strongly acid with very high carbon to nitrogen ratios and very low percentage base saturations.

GENERAL DISCUSSION

From the work of Druce (1966) it is possible to estimate the relative ages of the soils comprising identified tephra layers or with an absence of covering tephra. The Hangatahua soils have no tephra covering and must post-date the eruption of the Tahurangi Ash approximately 210 years ago. The Tahurangi and Burrell soils range in age from 210 to in excess of 460 years, the latter being the estimated age of the prominent fossil soil developed on the Newall Ash (Druce, 1966). In view of the youth of these soils it is not surprising that they are relatively unweathered.

The sand fractions examined (Table 2) consisted of fresh minerals, showing little sign of surface pitting or corrosion along cleavages. Allophanic materials are apparently absent in the Tahurangi Ash which is only 100 years younger than the Burrell Ash. Both the Burrell Ash and the Tahurangi Ash comprise fine detrital material and may have contained clay sized materials originating from hydrothermal weathering within the volcanic vent. Any differences in the content of allophane or other clay colloids within the soil layers may be geologic rather than pedologic.

Melanisation of the Tahurangi and Burrell soils extends to the base of the pumice gravel (Burrell Lapilli) and in extreme cases A horizons are 25 inches thick. The greatest proliferation of plant roots is in the lower part of the litter and also in the upper part and to a lesser extent the basal part of the A horizon. In some profiles most of the organic matter has accumulated at these three sites. The accumulation of organic matter in the pumice gravel toward the base of the A horizon gives rise to the 'built in B horizon' effect, referred to in the description of the Tahurangi fine sandy loam (Appendix 1). However chemical analyses for the representative soils (Table 3) shown percentage carbon and carbon/nitrogen values which remain relatively constant throughout the A horizon. Such a uniform distribution is unrelated to the root pattern and leads to the conclusion that the organic matter, under the influence of the very high rainfall, is being washed down through the A horizon. If this suggestion is correct, it presents an alternative mode of formation of the 'humic layer' beneath the Burrell Lapilli, in the Tahurangi fine sandy loam, which Druce (1966) has interpreted as a buried litter. This 'humic layer' is here considered to represent melanisation downwards by illuviation into the top layer of the Burrell Ash, which is a little more friable than the lower part of the same bed. However the 'buried litter hypothesis' cannot be discounted, as emanations of gases accompanying volcanic eruptions are known to cause complete defoliation of plants (Dickson, 1965) which would presumably produce very thick litters.

The soils analyses (Tables 3 and 4) illustrate the importance of the litter horizons as part of the soil in a forest system. In the litters the proportion of readily available nutrients to total nutrients is high whereas in mineral soils the proportion is low but the potential supply is considerable. The perecentage base saturations of the mineral horizons from the Tahurangi and Burrell soils are very low and indicate that these soils are impoverished. Miller (1963) illustrates in his studies on hard beech *(Nothofagus truncata)*, that the soil is only one phase in the cycle of nutrients in a forest system. In the Tahurangi and Burrell soils nutrient reserves include the potential supply from unweathered minerals and glasses in the soil body, in the decomposing litter on the forest floor and in time the recycling of those nutrients stored in the vegetation. There are also continuous additions of salts to the system via the atmosphere, indirect evidence of which comes from salt damage to the vegetation (Druce, 1964).

The pattern of iron accumulation observed in the Tahurangi and Burrell soils indicates that the dominant process is lateral movement through porous tephra layers rather than illuviation down the soil profile. The most conspicuous example of this is in the soils with incipient iron pans. In these soils gel-like hydrated ferric oxides are actively accumulating in the lower part of the porous

Burrell Lapilli. In the Tahurangi soil, with incipient iron pan, iron presumably in solution and suspension, moves laterally on the steeper slopes, through the Burrell Lapilli. At the break in slope, which lies just above flat lying small swampy depressions, the iron compounds are deposited in this bed. Burrell soils, with incipient iron pans, are associated with small peat bogs, marking the emergence of springs on the lower slopes of the piedmont. As indicated on the soil map (Figure 8), these soils form a marginal zone around the bogs indicating that ferrous solutions move out from the springs in all directions and are oxidised and precipitated in these soils.

Because of the high, evenly distributed rainfall the soils on Mount Egmont are always moist. From observational evidence it appeared that there is considerable lateral movement of water, especially on slopes over five degrees. The upper porous horizons of the Tahurangi and Burrell soils drain more freely than the underlying compact ash beds. It is only on the gently sloping lower piedmont that the impervious subsoil layers give rise to perched water tables, as in the Burrell gravelly sand, poorly drained phase. There is also evidence that these compact subsurface horizons prevent water deeper in the subsoil from rising to the surface by acting as a pressure capping. In some Burrell gravelly sand profiles examined, a compact layer was encountered at a depth of 2 ft, and when punctured a small fountain of water several inches high emerged, rapidly filling the hole to within a foot of the surface.

The soils sampled for chemical analyses (Table 3) span the vegetation zones, from rimu - rata / kamahi / mahoe forest (zone 1) to the tussock / herb field (zone 5). The details of the vegetation contributing to the litter at each of these sample sites is recorded with the soil profile descriptions (Appendix 1). The analytical data shows some variation between the litter horizons but there is a marked similarity of the mineral horizons of all these soils irrespective of the vegetation cover. From the information presented no positive conclusions on the influence of plant composition on the chemical properties of the soils can be drawn. With respect to the litter horizons of the soils (Table 4), the loss on ignition of the H horizons and the alkalinity of the ash determinations are reasonably consistent. The differences in pH, % Carbon and % Nitrogen may only reflect the relative state of decomposition and not the identity of the plants contributing to the litters. The only exception to these generalisations is the F horizon of the Tahurangi fine sandy loam. Wright and Miller (1952) obtained comparable determinations to those given for the three H horizons (Table 4), from a litter under rimu - rata / kamahi forest in Breaksea Sound, Fiordland.

In summary, it would appear that the high rainfall is the factor most strongly reflected in the Tahurangi and Burrell soils, causing : high leaching losses, a humus shift in the porous A horizon, and because of the stratified nature of the soil body, a significant lateral movement of water containing dissolved materials such as iron hydroxides. With increasing age the expected trends in soil profile development are a continued build up of organic matter in the A horizon associated with a slow decomposition rate and further development of thin iron pans at the interfaces of the layered subsoil horizons.

Soil Classification

The soils are classified as recent because the upper soil horizons, although containing organic materials, retain the lithology of the tephra layers. Where appreciably weathered fossil soil and ash layers occur at shallow depth as on the lower slopes of the piedmont the soils are classified with less certainty. The latter soils resemble in gross morphology the yellow - brown loams from andesitic ash. The classification of the recent soils from andesitic volcaniclastics, in terms of the New Zealand Genetic Soil Classification (Taylor and Pohlen, 1962) is given in Table 5).

Table 5. Soil Classification

Recent soils from andesitic volcaniclastics	New Zealand Genetic Soil Classification (Taylor and Pohlen, 1962)
Steepland skeletal soils	very strongly enleached, hygrous, weakly accumulative, eldeclini-volic soils from wind-blown sand, andesitic tephra and colluvium.
Tahurangi fine sandy loam	very strongly enleached, hygrous, elderego-subalvic soil from andesitic tephra.
Tahurangi hill soils	very strongly enleached, hygrous, eldeclino-subalvic soils from andesitic tephra.
Tahurangi fine sandy loam, with incipient iron pan	very strongly enleached, hygrous, iron accumulative, elderego-subalvic soil from andesitic tephra.
Tahurangi fine sandy loam, temperate phase; Burrell coarse gravel; Burrell gravel; Burrell gravel, imperfectly drained phase; Burrell gravelly sand	very strongly enleached, hygrous, elrego-subalvic soils from andesitic tephra.
Burrell gravelly sand, poorly drained phase	very strongly enleached, weakly gleyed, hygrous, elrego-subalvic soil from andesitic tephra.
Burrell gravel, with incipient iron pan; Burrell gravelly sand, with incipient iron pan	very strongly enleached, hygrous, iron accumulative elegro-subalvic soil from andesitic tephra.

ACKNOWLEDGMENTS

I am indebted to: Messrs C. G. Vucetich, A. P. Druce, and Dr N. H. Taylor for advice during this study, and to Mr C. G. Vucetich and Dr J. D. McCraw for commenting on the manuscript. Mr M. J. Vennard prepared the diagrams and soil map, and the Egmont National Park Board provided accommodation on Mount Egmont.

REFERENCES

Dickson, J. H., 1965: The Effects of the Eruption of 1961 on the Vegetation of Tristan Da Cunha Pt. IV. *Trans. R. Soc. Lond.* B 249 (759): 403-24.

Druce, A. P., 1959: An Empirical Method of Describing Stands of Vegetation. *Tuatara.* 8 (1): 1-12.

————, 1964: "The Vegetation", in *Egmont National Park Handbook.* pp. 41-55. Egmont National Park Board, New Plymouth.

————, 1966: Tree-ring Dating of Recent Volcanic Ash and Lapilli, Mt Egmont. *N.Z. Jl Bot.* 4 (1): 3-41.

Harris, W. F., 1968: Peat Classification by Pedological Methods, applied to the Peats of Western Wellington, New Zealand. *Bull. N.Z. Dep. scient. ind. Res.* 189: 138 pp.

Fieldes, M.; Perrott, K. W., 1966: The Nature of Allophane in Soils Pt. 3. *N.Z. Jl Sci.* 9 (3): 623-9.

Grange, L. I.; Taylor, N. H., 1933: Field-work on Soils of Western Taranaki. *Rep. Dep. scient. ind. Res. N.Z.* 1932-33: pp. 33-5.

Metson, A. J., 1956: Methods for Chemical Analysis of Soil Survey Samples. *Bull. Soil. Bur. N.Z.* 12: 208 pp.

————; Blakemore, L. C., 1964: Determination of Cation-exchange Capacity of Soils by Determinations of Adsorbed Ammonium Ion. *Rep. Soil. Bur.* 6/1964: 12 pp.

Miller, R. B., 1963: Plant Nutrients in Hard Breech. Pt. 3. *N.Z. Jl Sci.* 6 (3): 388-413.

Oliver, W. R. B., 1931: An Ancient Maori Oven on Mount Egmont. *J. Polynes. Soc.* 40: 73-80.

Taylor, N. H.; Pohlen, I. J., 1962: Soil Survey Method. *Bull. Soil. Bur. N.Z.* 25: 242 pp.

Wright, A. C. S.; Miller, R. B., 1952: Soils of South-west Fiordland. *Bull. Soil Bur. N.Z.* 7: 30 pp.

APPENDIX 1

Soil Profile Descriptions

The terminology used follows Taylor and Pohlen (1962) and Harris (1968). The location of each soil profile described is indicated on the soil map (Figure 8) by a site number.

Steepland skeletal soil

Map symbol (S), site number (1). Location; on the upper slopes of the Manganui ski field, just below the Ngarara Bluff. Slope; 40 degrees. Aspect; east. Altitude; 5,200 ft. Vegetation; grey and orange mosses - gaultheria.

A 1.1 2 in. moss stems with medium sand throughout; turfy; distinct boundary,
A 1.2 5 in. dark greyish brown (10YR 4/2) fine sand with partly decomposed plant material; loose; single grained structure; many fine roots; indistinct boundary,
Dr 1 on dark greyish brown (10YR 4/2) coarse gravel and sand; loose but gravels interlocking; few fine roots.

Tahurangi hill soil

Map symbol (TaH), site number (2). Location; Curtis ridge. Slope; 25 degrees. Aspect; south. Altitude; 4,475 ft. Vegetation; leatherwood - inaka - Egmont red tussock / forstera - mountain daisies - mosses.

1 in. matted moss stems with fine sand,
F ¼ in. partly decayed moss stems; indistinct boundary,
A 1.1 2½ in. dark reddish brown (5YR 3/2) fine sandy loam; friable; weakly developed fine crumb structure; matted with fine roots; indistinct boundary,
A 1.2 5 in. dark brown (7.5YR 3/2) sandy loam; friable; weakly developed fine granular and crumb structure, peds fragile; abundant fine and medium roots; indistinct boundary
A 1.3 3 in. dark brown (10YR 3/3) sandy loam; friable; slightly greasy; weakly developed fine granular structure, peds fragile; many fine roots; distinct boundary,
A 1.4 3 in. dark brown (7.5YR 3/2) loamy fine to medium pumice gravel; loose, slightly interlocking in place; single grained structure; fragments stained and thinly coated with organic matter; many fine roots; distinct boundary,
Dr 1 12 in. blotchy grey (5Y 5/1) coarse pumice gravel and small stones; loose, slightly interlocking in place; single grained structure; many fine roots; distinct boundary,
Dr 2 ½ in. grey (10YR 5/1) loamy medium sand; firm; greasy; massive; no roots; distinct boundary,
Dr 3 fe ¼ in. yellowish red (5YR 4/8) loamy sand; firm; slightly greasy; massive, weakly cemented with iron oxides; no roots; distinct boundary,
Dr 4 5½ in. dark grey (10YR 4/1) loamy sand; friable; greasy; single grained structure; few faint reddish brown mottles; no roots; distinct boundary,
2uA on. dark reddish brown sandy loam; strongly mottled.

Tahurangi fine sandy loam

Map symbol (Ta), site number (3). Location; drainage cutting 1 chain east of shelter on the Stratford Plateau. Slope; 3 degrees. Aspect; north-east. Altitude; 3,780 ft. Vegetation; leatherwood - koromiko - inaka - coprosma.

L ½ in. fresh litter, mainly leatherwood leaves and twigs,
F 1½ in. black (5YR 2/1) partly decomposed plant litter with some fine crumb moder; fluffy when dry; many fine roots; indistinct boundary,
A 1.1 3 in. dark reddish brown (5YR 3/2) humic fine sandy loam; slightly turfy; friable; moderately developed fine granular and crumb structure, peds fragile; many medium and fine roots; indistinct boundary,
A 1.2 1 in. dark reddish brown (5YR 3/2) sandy loam and fine gravel; friable; moderately developed fine to medium granular structure, peds fragile; many medium and fine roots; indistinct boundary,
A 1.3 (1uA) 1½ in. dark reddish brown (5YR 3/3) coarse pumice gravel and small stones; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; few fine roots; distinct boundary,
A 1.4 14 in. dark reddish brown (5YR 3/3) coarse pumice gravel and small stones; loose, slightly interlocking in place; fragments coated and stained with organic matter; few fine roots; diffuse boundary; in exposed sections this horizon has much of the organic matter washed out of it and takes on a paler colour,

A 1.5 2 in. dark reddish brown (5YR 3/2) medium pumice gravel; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; many fine roots; distinct boundary; (in exposed sections this horizon retains organic matter showing that it has the characters of a built in B horizon, produced by the root mat that occurs at the base of this horizon),

A 1.6 ½ in. dark reddish brown (5YR 3/2) sandy loam; friable, greasy; massive; few fine roots; distinct boundary,

Dr 1 4 in. greyish brown (2.5Y 5/2) fine sandy loam; very firm; massive; many faint elongated yellowish red mottles; few fine roots; distinct boundary,

2uA 1 in. dark brown (7.5YR 3/2) sandy loam; friable greasy; massive; few distinct yellowish red mottles; few fine roots; distinct boundary,

Dr 3 1 in. greyish brown (2.5Y 5/2) sandy loam with fine gravel; friable, greasy; massive; few fine distinct yellowish red mottles; few fine roots; distinct boundary,

Dr 4 1 in. greyish brown (2.5Y 5/2) sandy loam; friable, greasy; massive; few fine distinct yellowish red mottles; few fine roots; distinct boundary.

3uA 7 in. very dark brown (10YR 2/2) fine sandy loam; friable, slightly sticky, greasy; massive; many distinct tubular and platy dark reddish brown (2.5YR 3/4) mottles; no roots; distinct boundary.

Tahurangi fine sandy loam with incipient iron pan

Map symbol (TaF), site number (4). Location; alongside ski tow, immediately below the Ngarara Bluff. Slope; 10 degrees. Aspect; east. Altitude; 4,350 ft. Vegetation; Egmont red tussock - anaka - koromiko - leatherwood / gaultheria - various small grasses.

H 2 in. dark reddish brown (5YR 3/2) fine granular and crumb moder; turfy, slightly peaty; matted with abundant fine roots; indistinct boundary,

A 1.1 2½ in. dark reddish brown (5YR 3/2) humic fine sandy loam; turfy, friable, greasy; weakly developed fine granular and crumb structure, peds fragile; abundant fine and medium roots; indistinct boundary,

A 1.2 1½ in. dark brown (7.5YR 4/2) sandy loam; friable, slightly greasy; weakly developed granular structure, peds fragile; many fine and medium roots; indistinct boundary,

A 1.3 (1uA) 2 in. dark reddish brown (5YR 3/2) loamy medium to coarse pumice gravel; loose, slightly interlocking in place; single grained structure, most of the fragments are coated with organic matter; few medium and fine roots; distinct boundary,

A 1.4 8 in. greyish brown (2.5Y 5/2) and dark reddish brown (5YR 3/2) coarse pumice gravel and small stones; loose, slightly interlocking in place; single grained structure; fragments coated with organic matter especially toward the base of the horizon; many fine roots; distinct boundary,

(B) (fe) 5 in. red (2.5YR 4/6) coarse pumice gravel and small stones; very weakly cemented; single grained structure; scattered reddish brown mottles in the upper part of the horizon, several thin anastomosing iron pans at the base; few fine roots; distinct boundary,

Dr 1 2 in. grey (10YR 5/1) sandy loam; firm, slightly greasy; massive; many medium distinct red mottles; distinct boundary,

Dr 2 1½ in. dark brown (7.5YR 3/2) sandy loam; firm, greasy; massive; many fine faint yellowish red mottles; few fine roots; distinct boundary,

Dr 3 2 in. dark grey (10YR 4/1) coarse sand; friable; massive; many fine distinct reddish brown mottles along old root traces; few fine roots; distinct boundary.

2uA 6 in. very dark brown (10YR 2/2) fine sandy loam; friable; greasy; massive; very few fine roots; distinct boundary.

Tahurangi fine sandy loam, temperate phase

Map symbol (Tat), site number (5). Location; 200 yards south of the east branch of the Kaupokonui Stream, and alongside the Mangawhero track. Slope; 5 degrees. Aspect; east. Altitude; 2,525 ft. Vegetation; rimu / kamahi / raurekau - peppertree / tree ferns.

L ¼ in. fresh litter, mainly kamahi, rimu and raurekau leaves and twigs,

F ½ in. partly decomposed litter; laminated; very few fine roots; indistinct boundary;

A 1.1 1 in. dark reddish brown (5YR 2/2) humic sandy loam; very friable; moderately developed fine granular structure, peds fragile; abundant medium roots; distinct boundary,

A 1.2 5 in. dark reddish brown (5YR 3/2) coarse sandy loam; friable, slightly greasy; moderately developed fine and medium granular structure, peds fragile; many medium roots; indistinct boundary, A 1.3 (1uA) 4½ in. dark reddish brown (5YR 3/2) medium gravel and coarse sand; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter especially in the lower part of the horizon; many medium roots; distinct boundary,

2uA 4½ in. dark reddish brown (5YR 3/2) sandy loam, firm, greasy; massive, few medium roots; distinct boundary,

Dr 2 5 in. dark brown (7.5YR 3/2) coarse pumice gravel and coarse sand; fragile, compact in place; single grained structure, fragments coated with iron oxides and organic matter; no roots; irregular and distinct boundary,

Dr 3 fe 3 in. dark yellowish brown (10YR 3/4) mottled with dark reddish brown (5YR 3/4) coarse pumice gravel and coarse sand; fragile, compact in place; single grained structure, weakly cemented with iron oxides; no roots; indistinct boundary,

Dr 5 3½ in. dark yellowish brown (10YR 3/4) coarse sandy loam; firm, greasy; massive; abundant medium distinct yellowish brown mottles; no roots; distinct boundary,

Dr 6 on dark brown (10YR 3/3) loamy gravel and sand.

Burrell coarse gravel

Map symbol (BCG), site number (6). Location; 15 chains north of the Te Popo stream on the Curtis falls track. Slope; 5 degrees. Aspect; east. Altitude; 2,875 ft. Vegetation; kamahi - Hall's totara / wineberry - peppertree / astelia - blechnum.

L ½ in. fresh litter, mostly kamahi leaves and twigs,

F ½ in. dark reddish brown (5YR 2/2) partly decomposed leaves, mostly kamahi; laminated; few medium roots; distinct boundary,

H 2½ in. very dusky red (2.5YR 2/2) medium granular moder with a little fine sand; very friable, fluffy when dry; abundant fine and medium roots many of which are nodulated; indistinct boundary,

A 1.1 2 in. dark reddish brown (5YR 3/2) coarse pumice gravel and sand with a few small stones and some fine granular moder; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; few fine and medium roots; distinct boundary,

A 1.2 8 in. dusky red (2.5YR 3/2) coarse pumice gravel with small stones; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; few fine and medium roots; distinct boundary,

A 1.3 ½ in. dark reddish brown (5YR 3/3) sandy loam; friable, greasy; massive; few fine roots; distinct boundary,

Dr 1 1½ in. dark greyish brown (10YR 4/2) fine sand; firm, compact; massive; few fine faint elongated yellowish red mottles; few fine roots; distinct boundary,

1uA 6 in. dark brown (7.5YR 3/2) fine sandy loam; firm, greasy; massive; many medium distinct tubular dark reddish brown (2.5YR 3/4) mottles along old root traces; few medium roots; diffuse boundary,

Dr 3 7½ in. dark brown (10YR 3/3) fine sandy loam; firm, greasy; massive; many large distinct dark reddish brown mottles; few medium roots; distinct boundary,

Dr 4 on dark brown (7.5YR 3/2) coarse sandy loam; firm, greasy; massive; many dark reddish brown mottles; no roots.

Burrell gravel

Map symbol (BG), site number (7). Location; to the east of a gravel pit between the Te Popo Stream and the Stratford mountain road. Slope; 5 degrees. Aspect; east. Altitude; 2,260 ft. Vegetation; rimu / kamahi / toro - raurekau - tree fern / asplenium - astelia.

L ½ in. fresh leaves and twigs; mainly rimu, kamahi and toro leaves,

H 3 in. very dusky red (2.5YR 2/2) fine to medium granular moder; friable; matted with abundant roots; distinct boundary,

A 1.1 2½ in. very dark grey (5YR 3/1) coarse pumice sand with fine gravel and some fine granular moder; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter although some of the sand grains are clean; many fine roots; indistinct boundary.

A 1.2 4 in. very dusky red (2.5YR 2/2) fine to medium pumice gravel with scattered small stones; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; many fine roots; indistinct boundary,

A 1.3 5½ in. dark reddish brown (2.5YR 2/4) fine to medium pumice gravel and coarse sand; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; few fine roots, distinct boundary,

Dr 1 4 in. dark greyish brown (10YR 4/2) fine sandy loam; friable, slightly greasy; massive; few fine elongated yellowish red mottles along old root traces; few fine roots; indistinct boundary,

luA 5 in. dark greyish brown (10YR 4/2) sandy loam with some fine gravel; friable, greasy; massive; many medium distinct tubular dark reddish brown (2.5YR 3/4) mottles along old root traces; few fine roots; distinct boundary,
Dr 3g 6 in. greyish brown (2.5YR 5/2) coarse sand; firm; massive tending to single grained structure; many large yellowish red mottles; no roots; indistinct boundary,
Dr 4g on loamy gravel and sand.

Burrell gravel, imperfectly drained phase

Map symbol (BGm), site number (8). Location; 1½ miles west of the National Park gates on the York road track. Slope; 4 degrees. Aspect; north-east. Altitude; 2,150 ft. Vegetation; kamahi / raurekau - mahoe - tree fern - astelia.

L 1 in. fresh litter, mainly kamahi, raurekau and tree fern leaves and twigs,
H 1 in. black (5YR 2/1) fine granular moder with some fine sand; friable; many fine and medium roots; distinct boundary,
A 1.1 6 in. very dusky red (2.5YR 2/2) medium pumice gravel and coarse sand; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; few large and many fine roots; indistinct boundary,
A 1.2 4½ in. dark reddish brown (2.5YR 2/4) medium pumice gravel and coarse sand; loose, slightly interlocking in place; single grained structure, fragments coated with organic matter; many fine and medium roots; distinct boundary,
Dr 1 4½ in. very dark greyish brown (10YR 3/2) fine sandy loam; friable, greasy; massive; few fine faint yellowish brown mottles; few fine and medium roots; distinct boundary.
Dr 2 7½ in. dark greyish brown (10YR 4/2) fine sandy loam with coarse sand; friable, greasy; massive; many fine faint yellowish brown mottles; few fine distinct boundary.
Dr 3 on grey (10YR 5/1) fine gravel and coarse sand with stones.

Burrell gravelly sand

Map symbol (BS), site number (9). Location; on the northern side of the Waingongoro River and half a mile from the National Park boundary. Slope; 3 degrees. Aspect; east. Altitude; 2,000 ft. Vegetation; rimu / mahoe - pate / raurekau - tree fern / asplenium - blechnum.

L ½ in. fresh litter, mainly rimu, mahoe and pate leaves and twigs,
F 1½ in. partly decomposed litter, loose; laminated; indistinct boundary,
H 2 in. dark reddish brown (5YR 2/2) fine granular and crumb moder; friable; matted with fine roots; diffuse boundary,
A 1.1 1 in. dark reddish brown (5YR 2/2) loamy sand with fine pumice gravel and some fine granular and crumb moder; friable; single grained structure; many fine roots; indistinct boundary,
A 1.2 8½ in. dark reddish brown (5YR 3/2) fine pumice gravel and coarse sand; loose; single grained structure, fragments are coated with organic matter; few dusky red (2.5YR 3/2) mottles in the lower part of the horizon; many medium roots; indistinct boundary,
Dr 1 8 in. very dark brown (10YR 2/2) sandy loam; firm, greasy; massive; few medium and fine roots; distinct boundary,
Dr 2 fe ¼ in. dusky red (10YR 3/3) coarse sandy loam; fragile; massive; very weakly cemented with iron oxides; no roots; distinct boundary,
Dr 3 5½ in. dark yellowish brown (10YR 4/4) coarse loamy sand; friable, greasy; tending to single grained structure; no roots; indistinct boundary,
Dr 4 6 in. dark yellowish brown (10YR 4/4) loamy fine pumice gravel; firm, greasy; single grained structure; weakly cemented with organic matter and iron oxides; no roots; indistinct boundary,
Dr 5 on dark greyish brown (10YR 4/2) fine sandy loam.

This soil cleared of forest and now under pasture has the following profile :

A 1.1 2 in. very dark greyish brown (10YR 3/2) loamy fine gravelly sand; turfy, friable; single grained with some weakly developed fine crumb structure; abundant fine roots; diffuse boundary,
A 1.2 6½ in. dark greyish brown (10YR 3/2) loamy fine gravelly sand; loose; single grained with some weakly developed fine granular and crumb structure; many fine roots; indistinct boundary;
A 1.3 2½ in. dark yellowish brown (10YR 4/4) fine gravelly sand; loose; single grained structure, fragments thinly coated with brown organic matter; many fine roots; distinct boundary,
on dark yellowish brown fine sandy loam, etc.

Burrell gravelly sand, poorly drained phase

Map symbol (BSg), site number (10). Location; 50 chains west of the gates of the National Park on the Stratford mountain road. Slope; 2 degrees. Aspect; east. Altitude; 1,870 ft. Vegetation; rimu / kamahi - mahoe / raurekau - tree fern / miro - astelia - asplenium - blechnum.

L ½ in. fresh litter, mainly rimu, kamahi and mahoe leaves and twigs,

H 2 in. very dusky red (2.5YR 2/2) fine granular moder; friable; matted with abundant fine roots; distinct boundary,

A 1 4½ in. dark reddish brown (5YR 3/2) coarse sand and fine pumice gravel with some fine granular moder; loose; single grained structure, fragments coated with organic matter; many fine roots; distinct boundary,

A 3g 3 in. dark brown (7.5YR 4/2) coarse sand and fine pumice gravel; loose; single grained structure, fragments stained with organic matter; few fine roots; distinct boundary,

Dr 1g 1½ in. dark greyish brown (2.5Y 4/2) fine sandy loam; friable, greasy; massive; few fine roots; distinct boundary; (this is an intermittent horizon),

Dr 2g 7 in. dark brown (7.5YR 4/2) sandy loam with some coarse sand and fine gravel; slightly sticky and slightly plastic, greasy; massive; many faint reddish brown tubular mottles; few fine roots; diffuse boundary,
water table.

Dr 3G 6 in. dark brown (10YR 3/3) loamy fine gravel and coarse sand; friable, greasy; single grained; slight reddish brown staining throughout the horizon; no roots; distinct boundary,

Dr 4G on grey fine sand and pumice gravel; weakly cemented with thin iron pans.

Burrell gravel with incipient iron pan

Map symbol (BGF), site number (11). Location; north edge of the large bog immediately to the south of the Stratford mountain road. Slope; 5 degrees. Aspect; east. Altitude; 2,250 ft. Vegetation; kamahi - toro / raurekau / peppertree / astelia - blechnum.

L ½ in. fresh litter, mainly kamahi and toro leaves and twigs,

F ½ in. very dusky red (2.5YR 2/2) partly decomposed leaves; laminated; indistinct boundary,

H 2 in. very dusky red (2.5YR 2/2) loamy peat; turfy, spongy; fine granular structure; moderately decomposed (H5); many fine and medium roots; diffuse boundary,

A 1.1 1½ in. dark reddish brown (5YR 2/2) peaty loamy sand; friable; single grained structure; few fine and large roots; many fine and medium roots; diffuse boundary.

A 1.2 3 in. dark reddish brown (5YR 3/2) loamy fine pumice gravel and coarse sand; loose; single grained structure, fragments coated with organic matter; few fine roots, distinct and irregular boundary,

(B) fe 7 in. dark reddish brown (2.5YR 3/4) fine pumice gravel and coarse sand; loose; single grained structure, fragments stained and coated with iron oxides in a gel form and many small to medium flecks of brownish yellow (10YR 6/8) soft, creamy iron material (limonite ?); no roots; distinct boundary,

Dr 1g 4 in. very dark greyish brown (10YR 3/2) sandy loam; slightly peaty, greasy; massive; many pieces of wood; diffuse boundary,

Dr 2G on very dark greyish brown (10YR 3/2) sandy loam with a little fine gravel; greasy; massive; no roots.

Hangatahua gravelly sand

Map symbol (H), site number (12). Location; north bank of the Kapuni Stream, ¾ mile upstream of Dawson Falls. Slope; 5 degrees. Aspect; south-east. Altitude; 3,500 ft. Vegetation; leatherwood - mountain fivefinger - inaka - broadleaf - coprosma / coriaria - astelia.

L ¼ in. fresh litter, mainly inaka and leatherwood leaves and twigs,

F 1 in. dark reddish brown (5YR 3/2) partly decomposed litter with some sand; friable, fluffy; weakly developed fine crumb structure; matted with roots; indistinct boundary,

A 1.1 2 in. dark reddish brown (5YR 2/2) humic sandy loam; friable; moderately developed medium granular and crumb structure, peds fragile; abundant medium and fine roots; diffuse boundary,

A 1.2 5 in. dark reddish brown (5YR 3/2) coarse sand and gravel with numerous very large stones and boulders; loose; single grained structure; many medium and fine roots; distinct boundary,

Dr 1 6 in. very dark greyish brown (10YR 3/2) coarse gravel and sand with numerous large boulders; loose; single grained structure; few medium roots; diffuse boundary,

Dr 2 on dark grey (10YR 4/1) coarse gravel with very large boulders.

Organic soil

Map symbol (O), site number (13). Location; 200 yards from the north-western edge of the large bog immediately to the south of the Stratford mountain road. Slope; 5 degrees. Aspect; east. Altitude; 2,250 ft. Vegetation; manuka / flax - astelia / juncus - blechnum - mosses.

5½ in. black (5YR 2/1) loamy peat; turfy; very strongly decomposed (D6) with a small amount of root and woody material; distinct boundary, water table.
5 in. dark reddish brown (5YR 2/2) loamy peat; semi-fluid; completely decomposed (D8) with very little root material; distinct boundary,
9 in. dark reddish brown (5YR 3/2) fine pumice gravel and coarse sand; loose, slightly interlocking in place; single grained structure, fragments heavily coated with organic matter; buried manuka sticks poke up into this horizon; distinct boundary,
2 in. very dark greyish brown (10YR 3/2) fine sandy loam; friable, greasy; massive; indistinct boundary,
1 in. dark reddish brown (5YR 2/2) peat; mushy; completely decomposed (D8); indistinct boundary,
3 in. dark brown peaty sand with fine gravel; indistinct boundary,
on dark reddish brown peat; mushy, completely decomposed (D8).

The depth of peat with interlayered tephras is estimated to be in excess of 12 ft at this site.

APPENDIX 2

Key to common plant names mentioned in the text.

anisotome	*Anisotome aromatica*
black maire	*Gymnelaea cunninghamii*
broadleaf	*Griselinia littoralis*
coprosma	*Coprosma pseudocuneata* var. *pseudocuneata*
Egmont red tussock	*Chinochloa rubra* var.
fivefinger	*Pseudopanax arboreum*
forstera	*Forstera bidwillii* var. *densifolia*
flax	*Phormium tenax*
fuschia	*Fuschia excorticata*
gaultheria	*Gaultheria* sp.
Hall's totara	*Podocarpus hallii*
inaka	*Dracophyllum longifilium* var.
kaikawaka	*Libocedrus bidwillii*
kamahi	*Weinmannia racemosa*
koromiko	*Hebe stricta* var. *egmontiana*
leatherwood	*Senecio elaeagnifolius* var. *elaeagnifolius*
mahoe	*Melicytus ramiflorus*
manuka	*Leptospernum scoparium*
miro	*Podocarpus ferrugineus*
moss, dull orange	*Rhacomitrium ptychophyllum*
moss, greyish white	*Rhacomitrium lanuginosum* var. *pruinosum*
mountain daisies	*Celmisia glandulosa* var. *latifolia* *Celmisia gracilenta* var.
mountain fivefinger	*Pseudopanax colensoi*
pate	*Schefflera digitata*
peppertree	*Pseudowintera colorata*
putaputaweta	*Carpodetus serratus*
rata	*Metrosideros robusta*
raurekau	*Coprosma australis*
rimu	*Dacrydium cupressimum*
toro	*Myrsine salicina*