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SOILS OF ELTHAM COUNTY
AND THE
TEPHROCHRONOLOGY
OF
CENTRAL TARANAKI

A thesis presented in partial fulfilment
of the requirements for the degree of
Doctor of Philosophy in Soil Science
at Massey University

by

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Frontispiece.

View across the south of Eltham County, to the north-west, with Mt. Egmont in the background, from Tirimoana Road, at N129/917395. The landscape shown here comprises an uplifted marine bench (Kaiatea Terrace) overlain by laharic breccia (Eltham Lahars) and thick volcanic ash. Soils are mapped as Stratford hill-Stratford association.

ABSTRACT

The soils of Eltham County west of the Patea River, are described and their distribution shown on a map at a scale of 1:50,000. The soil-forming factors are discussed with particular emphasis on the soil parent materials, which range from volcanic ash in the west, to peat and sedimentary rock, mainly siltstone and sandstone, in the east. An account is given of the genesis and historical development of the Ngaere and Eltham Swamps and a classification made of the Eltham peat.

A detailed account is given of the stratigraphy of the late Quaternary tephras in central Taranaki. Eight new tephra units (p2, p1, E5, E4, E3, E2, E1 and Mahoe) are described, with type sections and reference localities designated. Isopach maps of their distribution are presented and an attempt is made to correlate these tephras with those further north. Details are given of the westernmost occurrences of Aokautere Ash and the implications of these for the Late Quaternary in Taranaki are examined.

Petrographic studies, X-ray fluorescence and chemical analysis of titanomagnetites by inductively-coupled argon plasma emission spectroscopy (I.C.P.) are also applied to effect positive identification and correlation of the tephras. The composition of the lithic Manganui tephra is established as basaltic.

The morphology and physical properties of the soils are described as are the soil mapping units employed in this survey. Characteristics of the component members of the mapping units are given in an extended legend. Fifteen soil taxonomic units have been recognised and named in the soil survey. Descriptions designed primarily for correlation and reference purposes are provided for each of the taxonomic units. The soils are also rated in terms of their limitations for pastoral cropping, horticultural, forestry and urban uses and in terms of their value for food production. The position of the boundary between Stratford and Egmont soils is established and a basis for distinguishing the two soils is proposed. By examining two steepland subcatchments in detail an insight is provided into the wide range of variability found in the steepland soils in the east of Eltham County. An indication of the presence of volcanic ash or its absence due to erosion is gained by applying the phosphate retention and allophane test. This also provides an understanding of the pattern of parental material variability.

Finally, selected laboratory analyses have been chosen to help characterise the chemical and physical properties of five yellow-brown loams, a gley, an intergrade between yellow-brown loams and recent soils and an organic soil from Eltham County. Detailed analytical data from ten New Zealand Soil Bureau reference sites in Taranaki are included for comparative purposes.

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CHAPTER 1

CHAPTER 1

INTRODUCTION

PREVIOUS WORK

The first soil survey of the Taranaki region was published in 1933 as a reconnaissance soil map (Grange and Taylor, 1933). The survey was initiated because it was thought that differences in pasture responses to potash and lime were due to differences in soil types on which various experiments were sited. The scale of the map was 1:253,440 but the eastern and north-western parts of Eltham County were omitted.

A more comprehensive but unpublished report of Taranaki soils prepared by Grange and Taylor, became available as a D.S.I.R. internal report dated 1934. Four soil series were identified within the area now comprising Eltham County. These were the Eltham, Glenn, Stratford and Egmont series. The series were sub-divided into soil types; the more wide-spread ones were the Stratford sandy loam, Stratford sand, Egmont black loam and Egmont brown loam. Stratford sandy loam occurred where the Stratford Shower was 0.22m or less in thickness, while the Egmont Shower was approximately 0.6-0.9m where it formed the Egmont soil. According to Grange and Taylor four principal soil series were derived from the Stratford Shower, the Patua, Norfolk, Inglewood and Stratford series.

In a paper published in 1933, Grimmett and Brogan recognised the wide variety of soil textures in Taranaki and noted how they became progressively finer away from Mt. Egmont.

In 1951, an unpublished soil map of Taranaki was prepared (Gibbs, 1951), in which the previously unmapped area of Eltham County to the west of Eltham Borough was mapped as Awatuna loam, Glenn loam, Stratford sand and Stratford sandy loam. To the east, Eltham peaty loam, Stratford hill soils, Egmont hill soils and Stratford sandy loam were mapped.

In the general survey of the soils of the North Island at 1:253,440 scale (N.Z. Soil Bureau, 1954), additional mapping units were introduced for the area occupied by Eltham County. The main purpose behind the mapping was to obtain an overall impression of North Island soils, their fertilizer needs and an estimation of their production potential. It was a co-operative wartime project and was consequently limited by many factors prevailing at that particular time. An extended legend was compiled with agricultural production information tentatively correlated with the soil units. Publication of the coloured soil maps began in 1945 and was completed in 1948. Finally in 1954 Soil Bureau Bulletin (n.s.)5 was issued.

The area west of Eltham Borough was mapped in Patua, Inglewood, Kahui, Awatuna, Glenn and Stratford soil sets. East of Eltham Borough, the Eltham peat was included in Piako soil set. Stratford hill soils and Egmont hill soils were included in Stratford and Egmont sets and New Plymouth, Whangamomona and Moumahaki soil sets were all introduced.

These early surveys were invaluable because they provided a basic insight into the soils of Taranaki, with certain information acting as long-term sources of reference. The facilities that were available for soil surveying at the time must be taken into account. In the soil surveys of the 1930's there were no aerial photographs, handbooks or colour books and the standards were general agreements amongst pedologists. The individual descriptions of structure and consistence varied a great deal. In order to avoid ambiguity the published profile descriptions tended to be simple depth, colour and texture differences between horizons. It was not until after the Soil Conference in 1954, that a certain element of uniformity was achieved with comprehensive descriptions, and standard terminology adopted.

In 1970, Tonkin published an account of the south-eastern slopes of Egmont National Park, to the east of the Eltham County sector of the Park. Previously the soils had been mapped as Burrell and Patua sets (N.Z. Soil Bureau, 1954). The boundary between the Taurangi and the Burrell soils was established at the 50mm isopach of the Taurangi Ash. The relative ages of the soils were estimated by applying the tephrostratigraphy of Druce (1966). Soil chemical analyses were carried out and the soils were classified in terms of the N.Z. Genetic Soil Classification (Taylor and Pohlen, 1962).

By the 1970's there were more established soil correlation procedures. Soil unit sheets were in use for which pedological criteria, such as soil colour, depth of soil horizon and consistence were all fixed, so that a stricter definition of soil mapping and classification units was obtained. Three of the counties adjacent to Eltham County have been mapped in this detail:- Waimate West, Stratford and Egmont.

Waimate West County was mapped at a scale of 1:63,360 and published as part of the Land Inventory Survey (Campbell and Wilde, 1970). The New Zealand Land Inventory project was stimulated by the 1964 Agricultural Development Conference and aimed to provide basic information about the land, its resources, uses and potential in a standardised, readily available form. It was undertaken as a County series and Waimate West was chosen as a "trial" for the project since it is one of the smallest counties in New Zealand, occupying an area of approximately 21497 ha. Strongly mottled sub-soil phases were introduced when mapping the Egmont brown loam and Egmont black loam. In addition a moderately deep phase of the Egmont brown loam was recognised. The Hangatahua series was mapped as two soil types: Hangatahua sandy loam and Hangatahua silt loam, and a Warea-Awatuna complex^{was} recognised.

In 1971 a soil survey of Stratford County was conducted, at a scale of 1:63,360, by Aitken et al., (1978). An extended legend accompanied the soil maps and summarised the main soil properties and soil limitations for pastoral, forestry and cropping uses. It was the first time soils of the steep land and hill country had been mapped in any great detail. Rowan, Lowgarth, Uia, Kohuratahi, Tirangi and Tahora series were all introduced as new soil series. Field criteria were established to distinguish the Egmont and Stratford Showers and Rowan and Lowgarth soils were recognised as forming on an unnamed ash, above the Stratford ash. This lithic-rich ash is now informally referred to as the Manganui tephra.

The information on soil series obtained by the Waimate West and Stratford County Surveys provided a basis for the investigation of magnesium content of soils and pastures and the incidence of grass tetany or hypomagnesaemia in Taranaki. The results of work by Turner et al., (1978) have suggested a link between some soil series and hypomagnesaemia.

An increase in the knowledge of the geology and tephrochronology of

Taranaki in the 1970's stimulated an interest in the soils of the region and led to the completion of the soil survey of Egmont County, at 1:50,000 scale by Palmer et al., (1981). In that survey fourteen new soil series were introduced. Existing series were more narrowly defined and the distinction between them made explicit. The distinction between geographically associated soils was explained in detail and the range of profile features within taxonomic units given. In most cases, in the past, soils had been defined only on the basis of a modal or central concept, which meant a great deal of intuition and experience was required to place the large number of pedons with intermediate characteristics, on one or other side of the boundary. Emphasis throughout, the survey tended to be on stratigraphic relationships and the actual nature of the parent material, with depth of volcanic ash and morphology being stressed, as opposed to the elevation and rainfall aspects as in past surveys. Laboratory analyses were carried out by Soil Bureau and the soil series were classified, according to the New Zealand Genetic Soil Classification (Taylor and Pohlen, 1962), Soil Taxonomy (Soil Survey Staff, 1975) and the Andisol Proposal of 1978 (Smith, 1978). ? this

Time factors have influenced the mapping of soils in Taranaki and concepts have been altered and abandoned according to the state of current knowledge. New parent materials have been identified and age relationships between soils have been established, according to the distribution of tephra and lahar deposits.

Table 1.1 correlates the soil series now recognised in Eltham County with soil sets of the "General survey of the soils of North Island, New Zealand" (N.Z. Soil Bureau, 1954) and units of the four other soil surveys, in Taranaki. These various soil surveys reflect the concepts of soil classification prevailing at the time of their compilation. For example, the Hangatahua series has undergone several changes in concept having been regarded in turn as a recent soil, a yellow-brown loam and now an intergrade between yellow-brown loams and recent soils.

Table 1.1 Correlation of soil series in this survey with soil sets of "General survey of the soils of North Island, New Zealand" (N.Z. Soil Bureau, 1954) and units of other soil surveys in Taranaki

This Survey	Reconnaissance soil map of Western Taranaki (DSIR Annual Report, 1933)	General survey of the soils of the North Island (N.Z. Soil Bureau, 1954)	Waimate West County (N.Z. Land Inventory Survey, 1970)	Stratford County (N.Z. Soil Survey Report 42, 1978)	Egmont County (N.Z. Soil Survey Report 64, 1981)
Rowan series	-	Patua sandy loam and loam (70)	-	Rowan gravelly sandy loam, Rowan coarse sandy loam	Rowan series
Makaka series	-	Inglewood coarse sandy loam (69)	-	Inglewood coarse sandy loam	-
Mangawhero series	-	Awatuna loam (100a)	Awatuna sandy loam	-	Awatuna series
Riverlea series	-	Stratford sand (68)	-	-	-
Kahui series	-	Egmont brown loam (66)	Egmont brown loam	-	Kahui series
Tipoka series	-	Glenn silt loam (100)	Glenn silt loam	-	Tipoka series
Awatuna series	-	Glenn silt loam (100)	Awatuna sandy loam	-	Awatuna series
Lowgarth series	Inglewood series	Inglewood coarse sandy loam (69)	-	Lowgarth sandy loam	-
Stratford series	Stratford series	Stratford sandy loam (66b) Stratford sand (68)	-	Stratford coarse sandy loam, Stratford fine sandy loam	-
Stratford series, fine topsoil variant	Egmont series	New Plymouth black loam (67a)	Egmont brown loam	Stratford fine sandy loam; also New Plymouth brown loam	-
Hangatahua series	Hangatahua series	Esk (1b)	Hangatahua silt loam, Hangatahua sandy loam	Hangatahua sandy loam	Hangatahua series
Okato series	Glenn series	Esk (1b)	Glenn silt loam	Rahotu sandy loam	Okato series
Eltham series	Eltham series	Piako peaty loam and loamy peat (108)	-	Eltham peaty loam	-
Ngaere series	Stratford series	Stratford sandy loam (66b)	-	-	-
Whangamomona series	-	Whangamomona complex (116a), Whangamomona silt loam (116)	-	Whangamomona steepland soils Moumahaki steepland soils	-
Tahurangi series	-	Mountain soils	-	Tahurangi fine sandy loam, Tahurangi hill soils	Tahurangi series
Unnamed subalpine soils	-	Mountain soils	-	Unnamed subalpine soils	Unnamed subalpine soils
Unnamed alpine soils	-	Mountain soils	-	Unnamed alpine soils	Unnamed alpine soils

GENERAL DESCRIPTION OF AREA

Eltham County was originally a portion of Hawera County but was established as a separate county in 1904. It is bounded by Egmont County in the west, Waimate West and Hawera Counties in the south, Stratford County in the north and Patea County in the east (Figure 1.1). The total area, including that part within Egmont National Park, is 536 km² (53,600 ha).

Eltham County extends from Awatuna, in the west, to the catchment boundary of Moeawatea Stream, in the east. In the north-west, the County boundary extends to the summit of Mt. Egmont, 2518m elevation to include a wedge-shaped segment of Egmont National Park. Many rivers and streams flow through the County in a southerly direction from Mt. Egmont (Figure 1.2). The major township is Eltham Borough, sited in the centre of the County, with the smaller township of Kaponga to the west. In the 1981 census the population of Eltham County was 2,492, compared with 2,410 in Eltham Borough and 398 in Kaponga.

Eltham was the last major settlement in Taranaki to be cut out of the forest on the railway link between New Plymouth and Hawera. This railway link was completed in 1882 and in 1884 Eltham Village settlement was established. The Mangamingi district, in the east, (Figure 1.1) was opened up and settled in 1891, while the settlement of Rawhitiroa, immediately east of Eltham, followed later in 1898.

In the 1880's a Chinaman named Chew Chong recognised the value of the edible Jew's-ear fungus (Auricularia polytricha) found in the district and developed an export industry for the product. The sale of this product, locally referred to as "Taranaki wool", meant ready cash for Taranaki dairy farmers, as this supplemented their income. In 1885 Chew Chong sent two kegs of Eltham butter to England. Although he lost money on the venture, it has been claimed that this trial shipment marked the beginning of New Zealand's flourishing dairy-export industry. In 1887, he opened the "Jubilee Dairy Factory" in Eltham and was responsible for the establishment of creameries at Hunter Road, Te Roti, Mangatoki and Rawhitiroa, all in Eltham County. Chew Chong introduced the concept of sharemilking into Taranaki and became a dominating influence in the local dairy industry during the late 1880's and early 1890's. Dairy factories were subsequently erected at Lowgarth, Matapu,

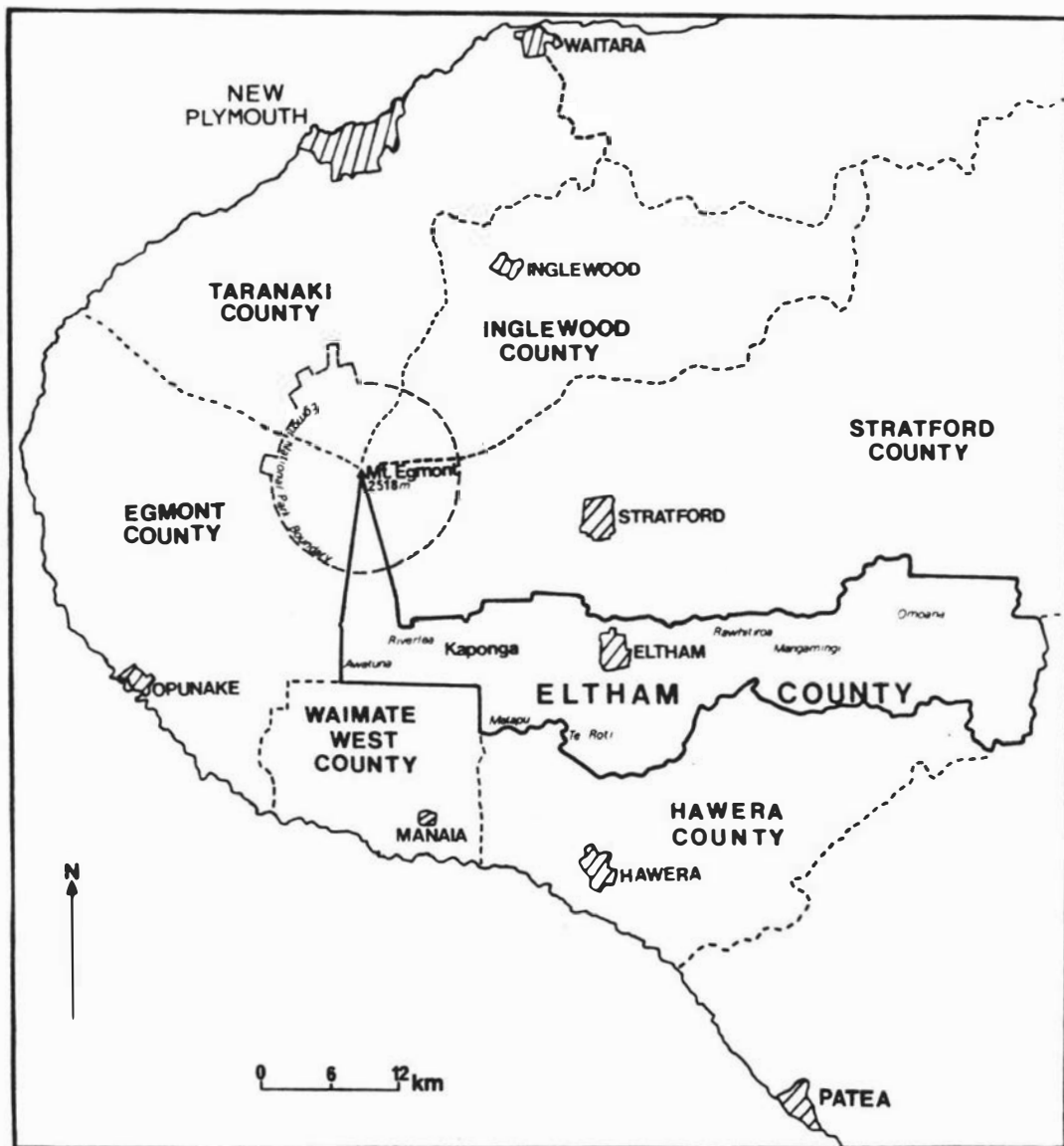


Figure 1.1 Location of Eltham County

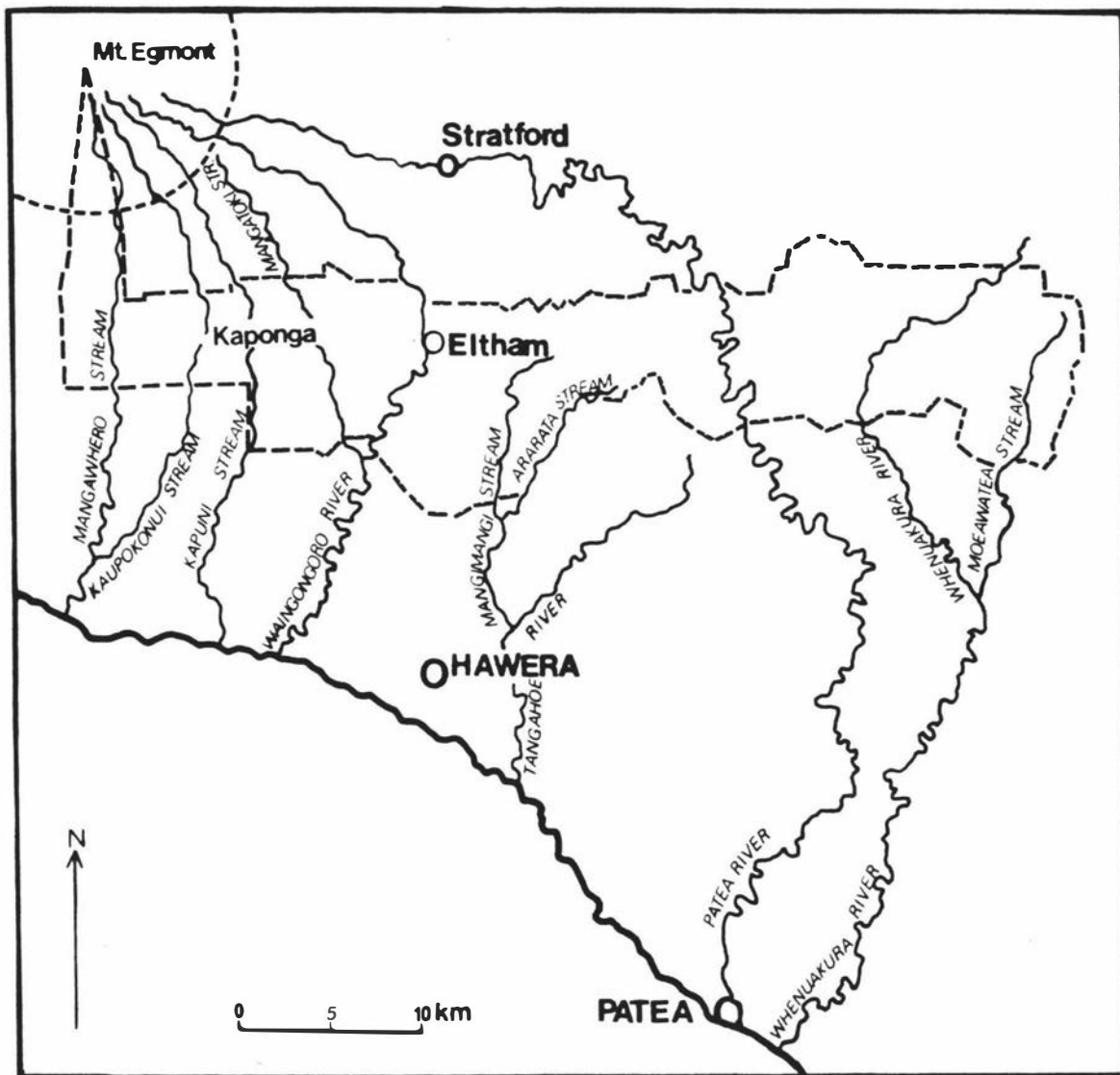


Figure 1.2 Principal streams and rivers in Eltham County

Riverlea, Awatuna, Tirimoana and Mountain Road. However, amalgamation has reduced the present number of factories in the County to two, now based at Kaponga and Eltham. Further amalgamation has now occurred with the major Kiwi Co-operative, south of Hawera.

Land use within the County is mainly dairy farming, with minor sheep and beef cattle farming. There are several industries in Eltham that include the New Zealand Co-op. Rennett Company, which exports a wide variety of cheeses and Huttons Ltd., which exports mainly beef.

CHAPTER 2

CHAPTER 2

SOIL FORMING ENVIRONMENT OF ELTHAM COUNTY

This chapter discusses the five traditional soil-forming factors; physiography, vegetation, climate, parent material and time. The last two factors are discussed together in an account of the history of the parent materials. In addition the process of drainage and iron movement is dealt with and there is an account of the genesis and historical development of the Ngaere and Eltham Swamps.

1. PHYSIOGRAPHY

Eltham County can be divided up into several distinct physiographic units. A fundamental two-fold division of units is recognised. First, the western part of the County comprises a segment of Mt. Egmont and its associated volcanic ring plain. Second, an extensive area of dissected hill and stepland country lies in the east of the County and is separated from the ring plain by a zone of swamps.

The Egmont ring plain has been built up gradually over the last 35,000 years (Neall, 1979) through the accumulation of lahar, alluvium and volcanic ash deposits. A lahar is "a large mudflow or debris flow mostly composed of volcanoclastic detritus, often including large blocks, on or surrounding the flanks of a volcano", (Neall, 1976). The ring plain in Eltham County is largely laharc in origin and can be divided into two sections, an upland and a lowland terrain.

The upland laharc terrain ranges from 220-1,100m elevation and includes an afforested area of Egmont National Park. Between 220-460m elevation are numerous lahar mounds, which may be concentrated together, as for example above the junction of Auroa and Opunake roads. The mounds are considered to have formed by accumulation and subsequent immobilisation of coarser material in lahar flows that travel down-slope. The mounds commonly produce an easy rolling or rolling landscape. Two cumuldomes, the Northern and Southern Beehives (Neall, 1971) are located at 952 and 846m

elevation respectively. They probably represent two local points where magma rose along vertical fractures, arranged radially around the base of Mt. Egmont (Neall, 1971). Above 600m elevation the Ouri and Otakeho streams have formed deeply incised gorges. Lava flows, less than 3,500 years B.P., are evident above the forest zone and originated from the parasitic cone of Fanthams Peak, at 1,962m elevation.

The lowland laharic terrain ranges between 90-340m elevation. It is characterised by flat to gently undulating landscape, with only occasional lahar mounds. In the vicinity of Eltham Borough remnants of Eltham Lahars have been highly dissected to form a distinctive hilly landscape.

The streams flowing from Mt. Egmont form a characteristic radial pattern. The Otakeho, Mangawhero, Kaupokonui, Kapuni, Inaha, Waingongoro and Patea streams all flow generally in a southerly direction through Eltham County to the sea (Figure 1.2). The streams flow in steep gorges on the mountain and in well incised channels, as they traverse the ring plain. River terraces and levées border these streams in their lower reaches.

The swamps between the volcanic ring plain in the west and the hill country to the east, lie between 210 and 220m elevation. Typically flat, the swamps are bordered to the east by steep hills, rising to over 300m.

The steepland country in the eastern part of the County, is strongly dissected with narrow steep-sided valleys, entrenched streams and sharp ridges, reaching elevations of 490m. The drainage pattern is typically dendritic with meandering stream channels. Stream gradients are not as steep as on the volcanic ring plain (Plate 2.1).

In the south-east, between 120-180m elevation, there are remnants of two Quaternary marine terraces, the Brunswick Terrace and the Ngarino Terrace. The Ngarino Terrace is younger and lies obliquely below the Brunswick Terrace. The landscape is flat and rolling, where it is dissected by the Mangapoua and Mangimangi streams and their tributaries.

2. VEGETATION

The extensive vegetation clearance conducted first by the Maori and later by the European settlers, removed all but a few isolated remnants of the native vegetation below about 400m elevation. Above this altitude forest is preserved within Egmont National Park. Vestiges of original



Plate 2.1

View of Mangamingi district, looking north-west, near N119/029497, above Mangamingi Stream.

The Stratford Formation occurs in the foreground and highly dissected Kaiatea terrain in the background.

Mt. Egmont is visible in the distance (to the left).



Plate 2.2

View of Mangamingi district, near N119/034491.

The Stratford Formation forms the foreground and the Mangamingi Stream flows beyond to the right.

Kaiatea marine bench is evident in the left of the photo, approximately 20 m. below. Volcanic coverbeds forming the upper 2 m. of the surface in the background.

Mt. Egmont is visible in the distance.

native forest are also still present in the steep-land country of eastern Eltham County. An area of bush (215ha) surrounding Lake Rotokare (18ha) has been reserved as a domain and public walkway. Apart from two large Dacrycarpus dacrydioides (kahikatea), the vegetation in the reserve is mainly Beilschmiedia tawa (tawa) and Melicactus ramiflorus (mahoe). Typha orientalis (raupo) and Phormium tenax (flax) skirt the lake fringes.

The original lowland forest in the west of Eltham County was podocarp-hardwood forest, containing Dacrydium cupressinum (rimu), Beilschmiedia tawa (tawa) and Metrosideros robusta (rata). Weinmannia racemosa (kamahi), replaces the tawa with increasing elevation, accompanying the increase in rainfall and leaching.

European fires were used to clear areas of heavy bush for farming, grass seed then usually being sown in the ashes. Uncontrolled bush fires were a problem at first and in 1908 the Awatuna and Auroa district experienced a serious fire. However, as the forest area diminished so did the risk of fire. Introduced pasture grasses established in the late 1800's included Lolium perenne (perennial ryegrass), Dactylis glomerata (cocksfoot), Phleum pratense (timothy) and Festuca ovina (hardy sheep's fescue) and Trifolium spp. (clovers). It is noteworthy that grass seeds, especially cocksfoot, were the first export directly produced from the land in Taranaki. There was little fertilizer applied in the early days and with the subsequent fertility decline accompanying the change in the eco-system, came weed infestation, with, for example, Rubus spp. (blackberry), Ulex europaeus (gorse), Senecio jacobaea (ragwort) and Plantago spp. (plantain). Eltham was one of the first areas in New Zealand to tackle the problem of noxious weed eradication by providing a hormone-spraying service for farmers.

With the advent of fertilizer topdressing, use of certified seed, and controlled grazing the first class pastures of today, consisting of ryegrass and white clover, evolved. In the poorly drained areas Juncus spp. (rush), Ranunculus spp. (buttercups) and Rumex obtusifolius (broad-leafed dock), predominate. Berberis glaucocarpa (barberry) is an integral feature of the landscape and provides shelter for stock. It was first introduced as an inexpensive means of providing subdivision.

The Ngaere and Eltham Swamps, east of Eltham Borough, contain a well preserved record of vegetation changes, in the Taranaki region, during late Quaternary time. This record has been obtained by peat coring of the swamps and sampling for palynological identification.

Preliminary unpublished results (M. McGlone and V.E. Neall, pers. comm.) indicate that 13,000 years ago the region contained no forest and was dominantly grassland. With the post-glacial climatic warming, fossil pollen present in cores from the swamps records forest invasion of Taranaki about 12,000 years B.P. and cyclical changes in forest composition since. The dominant trees on the swamps at the time of European arrival were Dacrycarpus dacrydioides (kahikatea), Laurelia novae-zelandiae (pukatea), Dacrydium cupressinum (rimu), Beilschmiedia tawa (tawa), Metrosideros robusta (rata) and Podocarpus ferrugineus (miro). Some areas were in dead standing bush, due to firing, while others were in Leptospermum scoparium (manuka). Areas of bog with Carex secta (niggerheads), and Phormium tenax (flax), together with Typha orientalis (raupo) were also present. As the bush on the swamp was felled, large stands of Solanum aviculare (poroporo) proliferated. Most of the Ngaere and Eltham Swamps have been "stumped", drained and developed into dairy pasture but in some areas they remain in an undeveloped state. However, stands of live bush are not extensive because, as the swamp consolidates, it leaves the roots of the standing bush increasingly exposed.

In the west of the County an altitudinal sequence of vegetation zones occurs within Egmont National Park. The various vegetation zones tend to merge into each other without dramatic change. The lowland forest zone, from 442-750m elevation has Beilschmiedia tawa, Weinmannia racemosa and Melicytus ramiflorus predominating, with Dacrydium cupressinum and Metrosideros robusta emergent over the canopy. Above 750m Dacrydium and Metrosideros decrease in frequency with Weinmannia comprising two-thirds of the cover. The upland forest zone extends between approximately 900 and 1,100m where Podocarpus hallii (Hall's totara), Libocedrus bidwilli (kaikawaka), Fuchsia excortica (fuchsia) and Griselinia littoralis (broadleaf) predominate.

With further elevation the forest is replaced gradually by sub-alpine scrub consisting of Senecio elaeagnifolius (leatherwood), Hebe spp. (koromiko), and Pseudopanax arboreus (mountain five-finger). Chionochloa rubra (red tussock) occurs above 350m elevation. The area occupied by herbs increases with increasing elevation, so that by 1,500m it has replaced the tussock. Above about 1,650m the mossy herbfield becomes discontinuous and the mosses, flowering plants and lichens decline with further elevation.

A conspicuous feature of the forest is the absence of Nothofagus spp. (beech) in Egmont National Park.

The hill and stepland country in the east of Eltham County, west ^{of} the Patea River, was once all clothed in podocarp-hardwood-beech forest. Beilschmiedia tawa, Dacrydium cupressinum, Dacrycarpus dacrydioides, Weinmannia racemosa, Podocarpus ferrugineus and Nothofagus spp. predominated. Penetration of the area began in the 1890's and was renewed after World War I. However, the practice of burning vast areas of forest and sowing pasture grasses was not a success. Ignorance of the fact that the natural soil fertility cycle was inherently associated with the presence of the native trees meant that heavy leaching losses occurred after clearance. A preference for sheep meant a diminished control of second growth and this encouraged ferns and secondary re-growth of bush to crowd out pasture grasses. There followed a period of deterioration and by 1940 much of this area was characterised by abandoned farms and erosion, with large areas reverted to secondary growth.

However, the introduction of aerial topdressing in the 1950's brought about an improvement in pastoral farming. Areas of vegetation that had reverted to Paesia scaberula (hard fern) and scrub, have been subsequently cleared again. Today pasture is the main vegetation cover of the area and the species vary according to fertilizer usage and management. The species Sporobolus capensis (ratstail), Agrostis tenuis (browntop) and Danthonia spp. (danthonia) tend to prevail, with weeds such as Senecio jacobaea (ragwort), Juncus spp. (rush) and Cirsium spp. (thistle) common.

3. CLIMATE

Situated on the western side of New Zealand, Eltham County is exposed to dominant weather systems migrating from the west over the Tasman Sea.

There are three rainfall recording stations in the County located at Rowan (375m), Riverlea (259m) and Eltham (183m). A rainfall recording station at Omoana (213m), in the stepland area, was closed in 1977. No field climatological stations are based in the County, the nearest being at Stratford Demonstration Farm (311m), 1km east of Stratford, and Manaia Demonstration Farm (98m), 10km south of the southern boundary of the County. ^{(formerly Demonstration Farm (MAF) East of Manaia)}

Precipitation

The distribution of mean annual rainfall in Taranaki is shown in Figure 2.1. This data shows high rainfall zones are more extensive to the north of Mt. Egmont, resulting in a steep isohyet gradient to the south. The precipitation is relatively evenly distributed throughout the year, with a winter maximum and summer minimum. The seasonal distribution of rainfall normally allows the water needs of growing pasture to be met during most of the year but the store of available soil moisture can be reduced during the late spring and summer. Although the rainfall is generally reliable, a few long periods without rain have occurred. For example, at Riverlea, January monthly totals of 2mm and 8mm have been recorded for the years 1928 and 1978, respectively (Table 2.1).

Mt. Egmont has a distinct orographic effect on the regional distribution of precipitation in Taranaki. Annual precipitation increases with elevation. Mean annual precipitation varies from 1,600mm at 183m to 2,000mm at 400m elevation and rises yet more steeply with elevation beyond that. It has been suggested by Kidson (1930) and supported more recently by Mark and Rowley (1976) that beyond an elevation of about 1,000 to 1,500m a decline in the rainfall amount, as distinct from overall precipitation (including snow and ice), occurs. Consequently the rainfall near the summit of Mt. Egmont could be as low as 3000mm (Thomson, 1981). In the steep-land area of eastern Eltham County a slight increase in precipitation with increase in elevation can also be observed (Table 2.2).

The number of rain days with greater than 1mm rainfall is generally between 100 and 150 per annum (Thomlinson, 1976), although up to 200 days occur on the higher slopes of Mt. Egmont (Coulter, 1976). Heavy rainfalls can occur in comparatively short periods, for example during frontal passages. The greatest falls of rain, in 2-3 day periods, are usually the result of prolonged falls of moderate intensity (J.D. Hessel, pers. comm.).

During the winter light snow falls are recorded down to 360m and there is a winter snowline on Mt. Egmont between 1,500m and 1,800m elevation. The winter and spring snow tends to lie for long periods, especially in gullies, but during the summer months the snow is usually absent from the upper slopes of the mountain. A permanent ice cover occupies the crater.

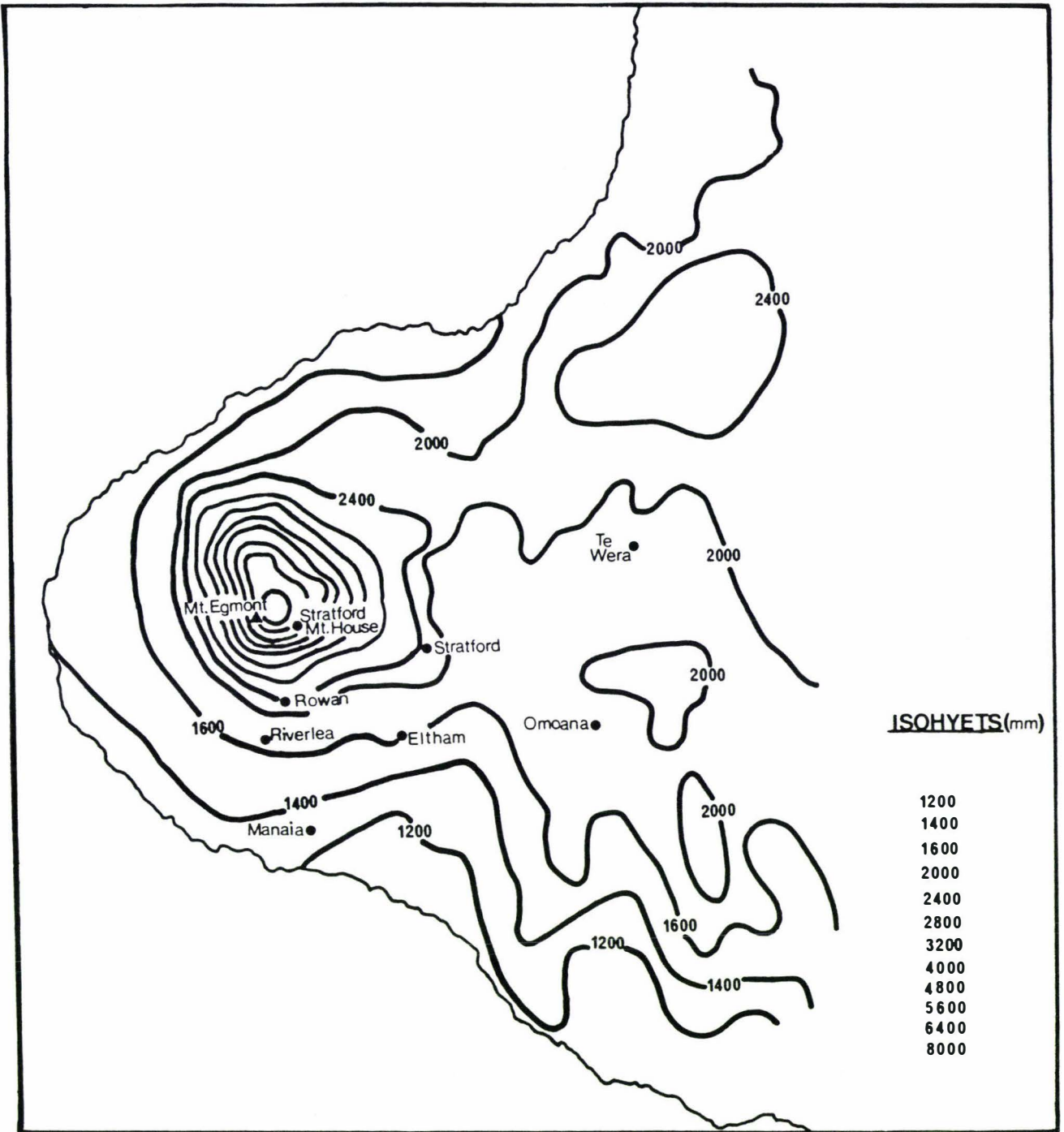


Figure 2.1 Mean annual rainfall isohyets, Taranaki region
(Official New Zealand, Meteorological Office
data 1941-1970)

Table 2.1

MONTHLY AND ANNUAL RAINFALL FIGURES
FOR RIVERIEA BETWEEN 1913-1980 (in mm.)

Supplied by N.Z. Meteorological Service

MONTH	NUMBER OF OBSERVATIONS	MEAN	STANDARD DEVIATION	HIGHEST	LOWEST
JANUARY	63	106	56	251	2
FEBRUARY	63	109	70	379	4
MARCH	63	98	53	245	8
APRIL	63	135	56	310	35
MAY	62	169	73	433	63
JUNE	63	181	74	372	35
JULY	63	174	70	399	69
AUGUST	63	157	56	292	28
SEPTEMBER	63	132	54	270	20
OCTOBER	63	147	67	299	19
NOVEMBER	63	130	62	316	38
DECEMBER	63	119	59	250	14
ANNUAL	-	1657	226	2127	1205

Table 2.2

N.Z. METEOROLOGICAL SERVICE RAINFALL NORMALS FOR ELTHAM AND OMOANA 1941-1970 (in mm.)

from N.Z. Meteorological Service Misc. Pub. 145

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YEAR
ELTHAM (198m)	100	100	100	120	160	180	170	160	130	150	120	120	1610
OMOANA (213m)	119	124	124	140	188	201	203	185	160	175	147	145	1911

The average number of days with hail, thunder, ground frost and air frost, for Stratford Demonstration Farm and Stratford Mountain House is shown in Tables 2.3 and 2.4. The frequency of frosts increases with increase in elevation. The incidence of ground frost increases during the period May to October, when 10 to 20 frosts are recorded per month. The frequency of hail, thunder and snow below 400m is low.

Temperature

Temperature data is available from Stratford Demonstration Farm for 21 years of observations (1960-1980), Table 2.3. This indicates a comparative absence of extreme values. The mean annual air temperatures tend to be between 10⁰ and 15⁰C, although at higher elevations above 400m they fall below 10⁰C (Thomlinson, 1976). The mean annual air temperature at Stratford Demonstration Farm is 11.6⁰C and the difference between mean summer and mean winter air temperatures is 7.7⁰C. In terms of Soil Taxonomy the soil temperature regime over most of Eltham County is mesic since the mean annual soil temperature lies between 8-15⁰C and the difference between the mean summer and mean winter soil temperature is more than 5⁰C.

The mean monthly air humidity at 9.00 a.m. averages between 80% and 90% throughout the year, with a maximum in winter and a minimum in summer (N.Z. Meteorological Service, 1983), although the figures will be generally higher on the upper slopes of Mt. Egmont.

Wind

The prevailing winds, in exposed places, are from the west but orographic modification is locally important. Mt. Egmont thus modifies the wind pattern to the east, as well as sheltering the southern part of the County from northerly winds. Exposure to strong winds increases with increase in elevation, on Mt. Egmont, with gale force winds being experienced several times a year. The average wind speed at the summit of Mt. Egmont is about 40km per hour, while the average wind speed for a low-level inland site, such as Stratford, is 11km per hour (Coulter, 1976).

Sunshine

The data from Stratford Demonstration Farm shows an average annual sunshine total of 1,972 hours, which is 47% of the total sunshine possible.

Table 2.3. N.Z. METEOROLOGICAL SERVICE SUMMARIES OF CLIMATOLOGICAL OBSERVATIONS TO 1980 FOR STRATFORD DEMONSTRATION FARM

E94133	STRATFORD DEM FARM	GRID REFS.	NZMS 1, NZMS 260.	1:63360 1:50000	N119872582 Q20224068	LAT. 39 20S	LONG. 174 18E	HT. 311 M.							
		PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
RAINFALL. MILLIMETRES															
HIGHEST MONTHLY/ANNUAL TOTAL		1960-1980	294	337	290	285	337	378	533	498	440	426	405	259	2691
90 PERCENTILE VALUE		1960-1980	262	209	230	238	293	343	332	312	339	298	290	240	2408
MEAN		1960-1980	144	124	140	148	204	205	217	205	188	166	168	144	2053
10 PERCENTILE VALUE		1960-1980	51	26	41	61	119	92	86	121	101	71	93	56	1693
LOWEST MONTHLY/ANNUAL TOTAL		1960-1980	21	2	21	49	102	66	55	101	76	14	67	46	1644
AVERAGE RAIN DAYS, 1.0MM OR MORE		1960-1980	10	7	10	11	13	14	16	16	14	13	12	11	147
MAXIMUM 1-DAY RAINFALL		1960-1980	81	25.4	81	105	112	140	102	126	122	64	110	109	254
MAXIMUM 2-DAY RAINFALL		1960-1980	142	317	106	121	193	156	150	229	146	104	166	118	317
TEMPERATURE OF THE AIR. DEGREES CELSIUS															
HIGHEST RECORDED		1960-1980	28.2	28.1	26.6	24.0	19.5	18.3	16.6	17.4	19.1	21.6	24.1	27.8	28.2
AVERAGE MONTHLY/ANNUAL MAXIMUM		1960-1980	25.1	25.1	24.0	20.4	17.3	15.4	14.4	15.1	17.0	19.0	20.9	23.3	26.2
AVERAGE DAILY MAXIMUM		1960-1980	20.7	20.9	19.6	16.8	13.9	11.6	10.9	11.7	13.4	15.2	16.9	19.0	15.9
MEAN		1960-1980	15.8	16.0	15.0	12.5	10.0	8.0	7.1	7.9	9.4	10.9	12.4	14.4	11.6
AVERAGE DAILY RANGE		1960-1980	9.8	9.9	9.2	8.5	7.8	7.2	7.6	7.6	8.0	8.7	8.9	9.6	8.6
AVERAGE DAILY MINIMUM		1960-1980	10.9	11.0	10.4	8.3	6.1	4.4	3.3	4.1	5.4	6.5	8.0	9.4	7.3
AVERAGE MONTHLY/ANNUAL MINIMUM		1960-1980	5.9	5.5	4.1	2.2	0.1	-1.0	-2.3	-1.4	-0.1	0.6	2.3	3.6	-2.8
LOWEST RECORDED		1960-1980	4.0	2.2	1.0	-0.3	-1.8	-3.5	-6.8	-3.4	-2.7	-1.6	-0.6	0.4	-6.8
TEMPERATURE OF THE GROUND, DEGREES CELSIUS															
LOWEST GRASS MINIMUM RECORDED		1960-1980	-5.0	-4.6	-7.0	-10.1	-10.6	-11.1	-9.8	-12.9	-12.5	-8.8	-6.7	-3.9	-12.9
AVERAGE GRASS MINIMUM		1960-1980	7.2	6.9	6.1	3.9	1.6	-0.2	-0.5	1.0	1.5	2.6	4.2	6.0	3.4
AVERAGE AT 10 CM DEPTH		1960-1980	17.3	17.1	15.4	12.6	9.4	7.2	6.1	7.0	8.9	11.5	13.7	16.1	11.9
AVERAGE AT 30 CM DEPTH		1960-1980	18.0	17.9	16.6	14.1	11.2	9.0	7.7	8.3	9.9	12.2	14.3	16.5	13.0
AVERAGE AT 1 M. DEPTH		1960-1980	15.5	16.2	16.2	15.3	13.6	11.8	10.1	9.6	10.1	11.2	12.6	14.1	13.0
FROST															
AVERAGE DAYS OF GROUND FROST		1960-1980	0.5	1.1	2.0	5.1	10.6	12.3	16.1	14.0	10.6	9.5	3.7	1.8	86.3
AVERAGE DAYS OF AIR FROST		1960-1980				0.1	1.1	2.7	4.5	2.5	1.0	0.5			12.4
RELATIVE HUMIDITY (%)															
AVERAGE AT 9 A.M.		1960-1980	82	83	84	85	87	88	88	87	83	81	80	80	84
VAPOUR PRESSURE. MILLIBARS															
AVERAGE AT 9 A.M.		1960-1980	15.6	15.6	15.0	13.0	11.0	9.5	8.9	9.5	10.4	11.5	12.3	14.1	12.2
SUNSHINE, TOTAL HOURS															
HIGHEST		1963-1980	292	262	233	197	175	140	192	177	189	223	258	281	2103
MEAN		1963-1980	233	207	176	151	129	106	118	121	138	184	193	216	1972
% OF POSSIBLE		1963-1980	53	56	48	48	44	40	41	39	41	47	47	48	47
LOWEST		1963-1980	164	152	112	95	101	63	74	83	106	143	136	170	1732
WIND															
MEAN DAILY WINDRUN. KILOMETRES		1962-1980	266	250	230	247	243	233	231	266	285	292	297	282	260
SPECIAL PHENOMENA. AVERAGE DAYS OF															
SNOW		1960-1980					0.1	0.2	0.1	0.1					0.5
HAIL		1960-1980			0.1	0.1	0.6	0.5	0.8	0.8	1.0	0.7	0.4	0.2	5.2
THUNDER		1955-1980	1.2	0.2	0.7	0.3	0.9	0.3	0.5	0.6	0.5	0.4	0.8	0.7	7.1
GALF		1960-1980	0.3		0.1	0.3	0.3		0.4	0.6	0.5	0.6	0.5	0.3	3.9
FOG		1960-1980	0.8	1.7	1.4	1.5	0.8	1.0	1.7	0.8	0.7	1.0	1.0	13.8	

Table 2.4. N.Z. METEOROLOGICAL SERVICE SUMMARIES OF CLIMATOLOGICAL OBSERVATIONS TO 1980 FOR STRATFORD MOUNTAIN HOUSE

E94313 STRATFORD MTN HOUSE	GRID REFS. NZMS 1, NZMS 260.	1:63360 N19701614		LAT. 39 18S		LONG. 174 07E		HT. 846 M.							
		1:50000 P20068101													
	PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	
RAINFALL. MILLIMETRES															
HIGHEST MONTHLY/ANNUAL TOTAL	1963-1980	871	898	787	921	973	1107	1573	1633	1360	933	1256	699	7234	
90 PERCENTILE VALUE	1963-1980	772	860	767	889	969	1046	1359	1418	1147	923	1068	674	7220	
MEAN	1963-1980	364	348	387	502	664	641	670	728	626	503	508	429	6370	
10 PERCENTILE VALUE	1963-1980	66	38	68	184	344	328	212	484	280	141	204	206	5150	
LOWEST MONTHLY/ANNUAL TOTAL	1963-1980	32	3	62	139	331	322	192	463	250	59	193	204	5112	
AVERAGE RAIN DAYS, 1.0MM OR MORE															
AVERAGE RAIN DAYS, 1.0MM OR MORE	1963-1980	12	10	14	16	17	19	20	21	19	17	16	14	195	
MAXIMUM 1-DAY RAINFALL	1963-1980	270	408	222	286	378	300	340	427	388	276	380	248	427	
MAXIMUM 2-DAY RAINFALL	1963-1980	368	796	327	492	749	439	376	794	451	391	564	311	796	
TEMPERATURE OF THE AIR. DEGREES CELSIUS															
HIGHEST RECORDED	1965-1980	25.6	27.0	23.4	20.5	16.7	13.7	13.2	14.9	20.3	21.7	23.9	26.1	27.0	
AVERAGE MONTHLY/ANNUAL MAXIMUM	1965-1980	23.4	23.4	21.4	17.7	14.8	12.0	10.6	12.2	14.6	17.5	20.0	21.8	24.7	
AVERAGE DAILY MAXIMUM	1965-1980	18.2	18.2	16.6	13.2	10.0	7.8	6.8	7.7	9.5	11.9	14.1	16.2	12.5	
MEAN	1965-1980	13.1	13.2	12.2	9.4	6.7	4.7	3.8	4.6	6.0	7.6	9.6	11.4	8.5	
AVERAGE DAILY RANGE	1965-1980	10.3	10.1	8.8	7.6	6.6	6.2	6.0	6.3	7.0	8.6	9.0	9.6	8.0	
AVERAGE DAILY MINIMUM	1965-1980	7.9	8.1	7.8	5.6	3.4	1.6	0.8	1.4	2.5	3.3	5.1	6.6	4.5	
AVERAGE MONTHLY/ANNUAL MINIMUM	1965-1980	2.8	2.9	2.3	0.4	-1.4	-2.7	-3.0	-3.1	-2.2	-1.5	-0.2	1.2	-3.9	
LOWEST RECORDED	1965-1980	1.0	-0.6	-0.6	-1.6	-3.1	-4.3	-4.6	-4.7	-5.0	-3.0	-1.8	-1.2	-5.0	
TEMPERATURE OF THE GROUND. DEGREES CELSIUS															
LOWEST GRASS MINIMUM RECORDED	1965-1980	-2.8	-4.4	-5.0	-7.5	-7.7	-8.9	-9.5	-10.0	-6.5	-9.6	-5.4	-4.6	-10.0	
AVERAGE GRASS MINIMUM	1965-1980	5.3	5.4	5.0	2.8	0.7	-0.7	-1.2	-0.4	0.4	0.7	2.7	4.1	2.1	
FROST															
AVERAGE DAYS OF GROUND FROST	1965-1980	1.0	0.9	2.5	6.3	11.9	14.4	16.7	13.6	11.4	12.1	5.1	2.7	98.6	
AVERAGE DAYS OF AIR FROST	1965-1980		0.1	0.1	0.6	4.1	9.8	13.2	10.1	5.6	3.9	1.1	0.2	48.8	
RELATIVE HUMIDITY (%)															
AVERAGE AT 9 A.M.	1965-1980	83	85	89	92	93	95	94	94	90	82	83	82	83	
VAPOUR PRESSURE. MILLIBARS															
AVERAGE AT 9 A.M.	1971-1980	12.7	12.7	12.5	10.9	9.0	8.0	7.4	7.9	8.5	9.3	10.1	11.1	10.0	
SPECIAL PHENOMENA. AVERAGE DAYS OF															
SNOW	1965-1980			0.1	0.4	1.4	2.8	3.9	3.6	3.0	1.9	0.7	0.2	18.0	
HAIL	1965-1980	0.4	0.1	0.5	0.7	1.8	1.8	2.3	1.6	1.8	1.8	0.9	1.0	14.7	
THUNDER	1955-1980	0.7	0.1	0.5	0.5	0.9	0.6	1.0	0.7	0.8	0.6	0.5	0.9	7.8	
GALE	1965-1980	0.4	0.2	0.3	0.8	0.6		0.4	0.6	0.1	0.2	0.3	0.3	4.2	
FOG	1965-1980	2.2	3.2	3.0	4.6	3.3	3.1	3.8	4.7	4.5	3.9	2.9	2.9	42.1	

This is an average to high figure when compared with the rest of New Zealand. There is a gradual decrease in sunshine hours with increase in elevation due to the accumulation of cloud around the higher slopes of Mt. Egmont.

4. SOIL PARENT MATERIALS

i. REGIONAL QUATERNARY HISTORY

The evolution of the landscape and associated soil pattern can be largely attributed to continual volcanism and laharic deposits, on the one hand, and on the other to Quaternary uplift of thick, moderately consolidated, sedimentary strata and their subsequent dissection by streams and rivers.

Volcanic activity in the chain of Quaternary andesitic volcanoes in Taranaki began in the north, at Kaitake, about 575,000 years B.P. It moved progressively south to the Pouakai centre, active between 216,000 and 250,000 years B.P. and then Mt. Egmont, which first became active about 50,000 - 70,000 years B.P. and last erupted in 1755 A.D. (Stipp, 1968; Neall, 1979). The gently dipping surface formed from lahars and other volcanoclastic deposits that surround each centre was termed the volcanic ring plain by Morgan and Gibson (1927). The Egmont ring plain is best preserved and forms a roughly circular outline from Cape Egmont in the west to Stratford in the east, with its surface contours exhibiting a near perfect catenary curve in cross-section. The ring plains associated with Kaitake and Pouakai have been largely destroyed but the northern quadrants and eastern remnants of each ring plain are preserved in Eltham County.

According to Grant-Taylor (1964a, b) the periods of ring plain formation coincided with periods of Pleistocene glaciation, since no evidence of warm climate floras has been found in the laharic deposits. Pollen assemblages from the Opunake and Stratford Lahars (Egmont source), Maitahi Lahars (Pouakai source) and Eltham Lahars (Kaitake source) have all indicated cold climates. It was assumed by Grant-Taylor that marine terraces were formed in the warm climate interglacial periods, as high sea levels cut extensive platforms across the moderately consolidated Tertiary sediments. In short, marine terrace formation alternated with volcanic aggradation during glacial periods. However, a glacial climate origin cannot always be assumed for lahar formation, since Neall (1972,1979)

has shown that in the past 10,000 years there have been several major lahars derived from Mt. Egmont.

The stratigraphic relationships between the lahar units and the marine terraces recognised by Grant-Taylor (1964a, b) were adapted by Hay (1967) for the Geological Map of New Zealand, 1:250,000, Sheet 7, Taranaki. The lahars have never all been formally established and some doubt exists as to whether the New Plymouth, Inglewood and Lepperton lahars are distinct stratigraphic units.

The long term geomorphic evolution of the South Taranaki terrace sequence has recently been quantified by Pillans (1981). The stratigraphic relationships and ages determined in his study, together with unpublished K/Ar dates (1968) and published C^{14} dates (Grant-Taylor, 1964a, b; Neall, 1979) have enabled a better correlation between the lahars and the South Taranaki marine terraces (Table 2.5). A complicating factor to age relationships is that one lahar may overwhelm a number of old marine benches. Thus it is incorrect to interpret that each lahar deposit on each marine bench is of differing age. This is particularly the case in the south of Eltham County.

ii. QUATERNARY HISTORY OF ELTHAM COUNTY

The Kaiatea terraces (Fleming, 1953), (Table 2.5), have been subdivided from oldest to youngest, respectively, into Kaiatea I, II and III (Grant-Taylor, 1964a, b). Pillan's (1981) work designated new type localities for the three Kaiatea terraces and showed that there are at least two older pre-Kaiatea terraces. In the east of Eltham County eroded remnants of Kaiatea terraces are preserved and are here referred to as highly dissected Kaiatea terrain (Figure 2.2). This terrain comprises rare Kaiatea Terrace remnants overlying Pliocene Tangahoe Formation, comprising massive sandy mudstone with scattered concretions and the Matemateonga Formation, a massive sandstone, commonly containing shell-beds and conglomerate bands, interbedded with mudstone and siltstone in the lower part (Plate 2.2).

The Omahina Tephra is an important stratigraphic marker in the area and has been fission track dated at c. 370,000 years B.P. (Pillans, 1981). Pillan's work showed that the Tephra overlies wave-cut surfaces of Kaiatea III and older terraces. This indicates that the cutting of these surfaces predates the existence of the Omahina Tephra. The Tephra has

Table 2.5

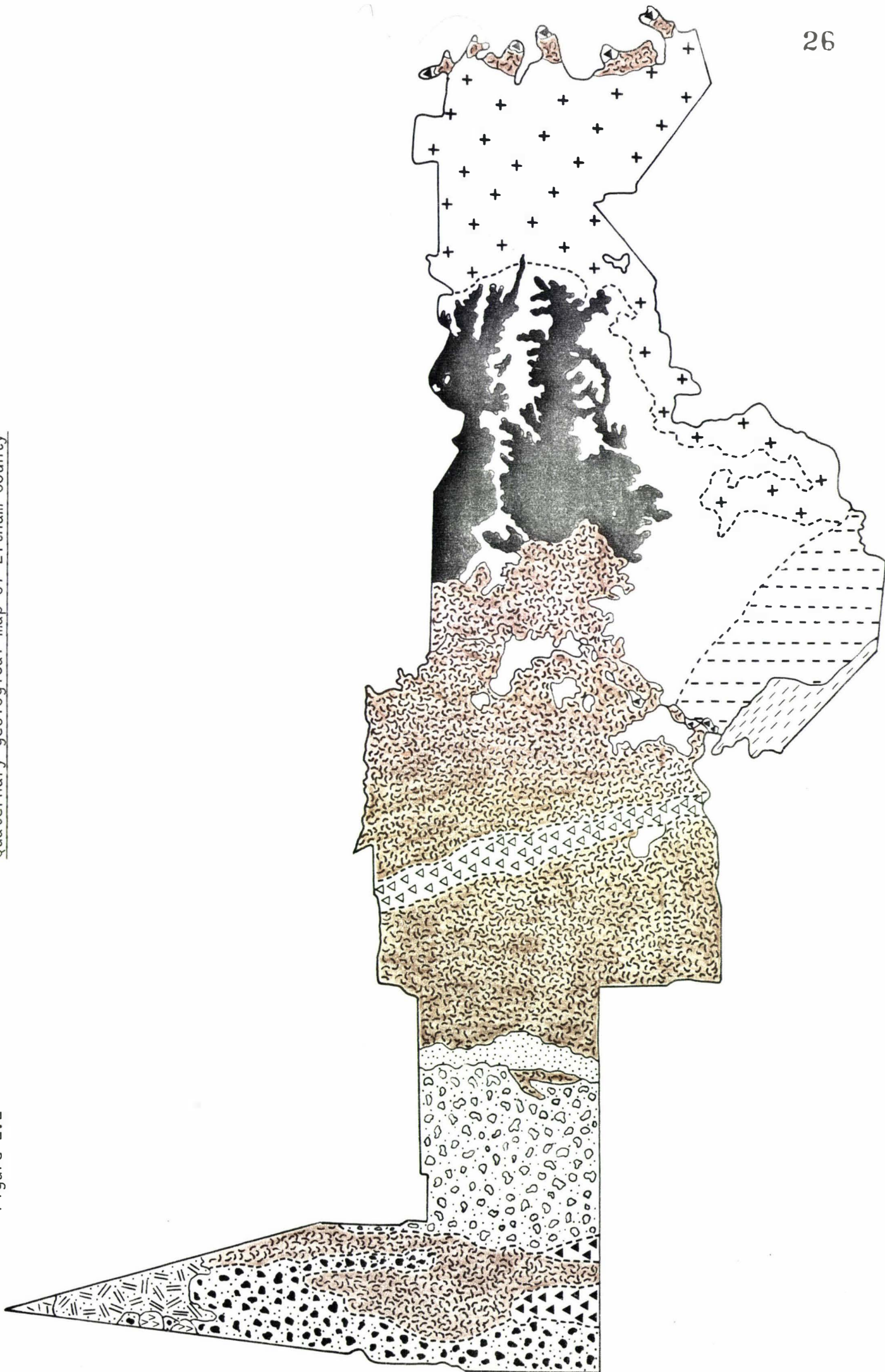
RELATIONSHIPS BETWEEN SOUTH TARANAKI MARINE TERRACES AND
VOLCANIC ACTIVITY IN WESTERN TARANAKI AS ADOPTED IN THIS SURVEY

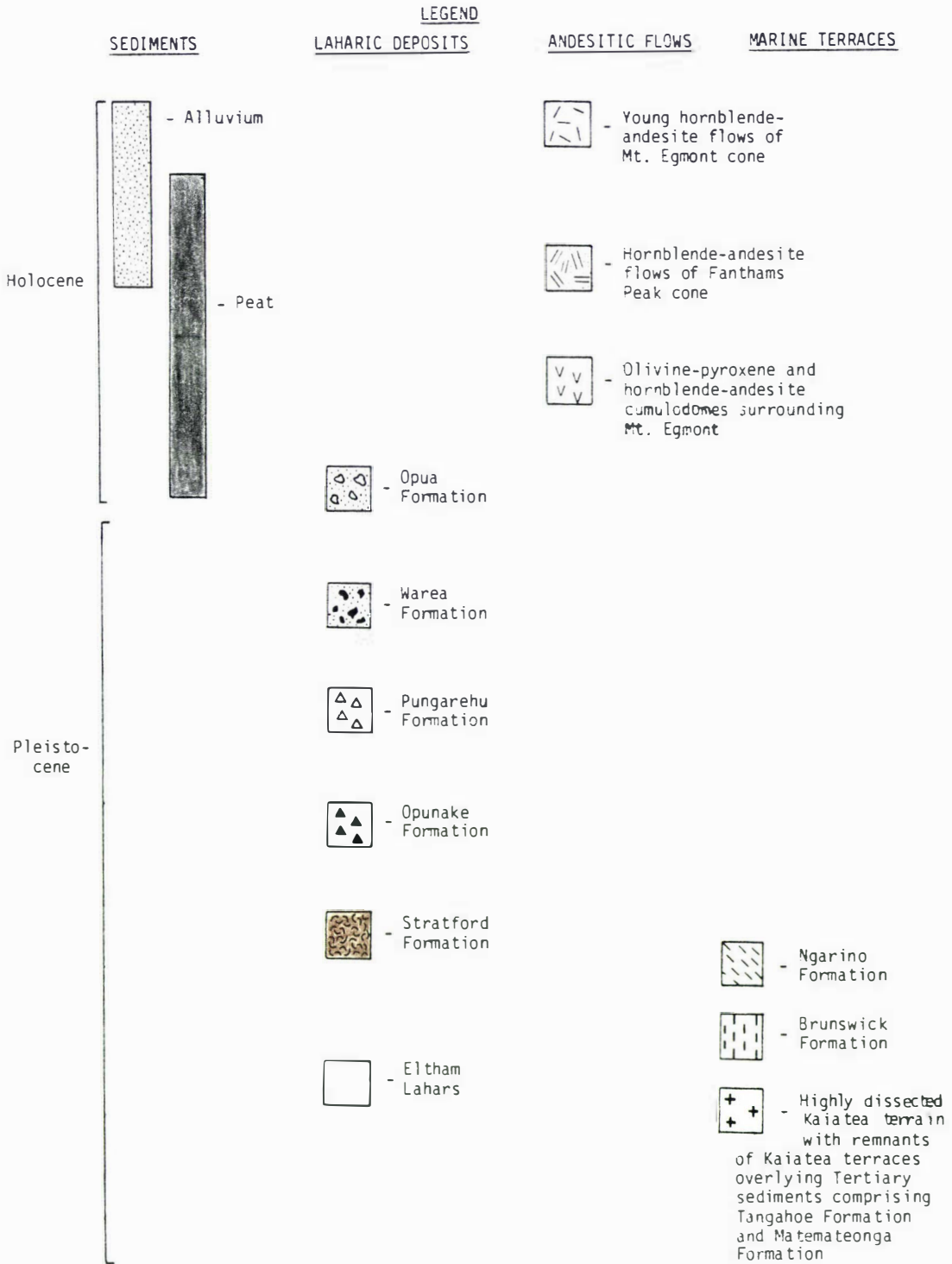
(Adapted from Pillans, 1981)

LAHAR AND SOURCE	SOUTH TARANAKI MARINE TERRACE AND AGE ESTIMATE	INPUT OF BLACK SAND TO SOUTH TARANAKI MARINE TERRACES	VOLCANIC ACTIVITY IN WESTERN TERANAKI	K/Ar AGES WESTERN TARANAKI LAVAS (Stipp,1968; Neall,1979)
Opunake	60ka unnamed	high		21 ± 3ka
Stratford	80ka unnamed	high		
	Inaha 105ka	high		
	Rapanui 120ka	moderate	EGMONT	
	Ngarino 210ka	high		224 ± 7ka 216 ± 7ka 227 ± 7ka 246 ± 4ka 249 ± 3ka
Maitahi	Brunswick 310ka	high	POUAKAI	
	Upper Brunswick 340ka	moderate		
Eltham	Kaiatea III 400ka	low		
	Kaiatea II 440ka	low		
	Kaiatea I 520ka	low-moderate		
	Two Pre-Kaiatea Terraces 600ka 680ka		KAITAKE	575 ± 14ka

Quaternary geological map of Eltham County

Figure 2.2





been found (i) on Tirimoana Road, where it occurs above old volcanic breccias and (ii) on Rotokare Road, in the south-eastern hill country of Eltham County.

At Tirimoana Road, the Omahina Tephra overlies a lahar deposit correlated with the Eltham Lahars (Grant-Taylor, 1964; Hay, 1967). If this correlation is confirmed by future stratigraphic research then the Eltham Lahars must be considered older than the Omahina Tephra, i.e. older than 370,000 years B.P. and thus older than all K/Ar dates known from the Pouakai centre. Hence, the Eltham Lahars presumably originated from the Kaitake centre.

In the vicinity of Eltham Borough, there remains an extensive area of dissected Eltham Lahars, with eroded remnants nearby that represents the Eltham Lahar constructional surface mantled with thick accumulations of tephra and now deeply dissected by fluvial erosion (Plate 2.3).

To the south is a small marine terrace remnant, named the Upper Brunswick Terrace, at a higher elevation than the principal Brunswick Terrace named by Fleming (1946, 1953) and redefined by Pillans (1981). The cover bed stratigraphy of these two terraces differs from that of the Kaiatea Terraces in that the Omahina Tephra is absent from within the Brunswick cover beds. In Eltham County remnants of the Brunswick Terrace occur in the vicinity of Te Roti. The Ngarino Terrace (Dickson *et al.*, 1974) is cut obliquely below the Brunswick Terrace, with a distinct fossil sea cliff separating the two marine terraces.

The Stratford Formation (Grant-Taylor and Kear, 1970) (Stratford Lahars, Grant-Taylor, 1964; Hay, 1967), which is of Otiran age and greater than 50,000 years B.P., originated from the Egmont centre. It is an extensive surface, between Eltham Borough and Kaponga, mantled with moderately thick (4-5m) andesitic tephra deposits, although parts have been buried by the Pungarehu Formation, around 23,000 years B.P. The "Mangawhero Ridge", which lies between Auroa and Mangawhero roads, in the north-west of the County, is probably a remnant of the Stratford surface. It owes its existence to a "proto-Fanthams Peak cone" on the south side of Mt. Egmont, deflecting Egmont-source lahars to either side.

Small areas of Opunake Formation (Grant-Taylor and Kear, 1970) (Opunake Lahars, Grant-Taylor, 1964; Hay, 1967) of late Otiran age and dated c. 30,000-38,000 years B.P. (Grant-Taylor and Kear, 1970), are



Plate 2.3

Looking north-west between Mountain Road and Boylan Road, near N119/868400.

Eltham Lahars occur in the foreground and are mapped as Stratford hill soils.



Stratford terrace

Opunake terrace

Plate 2.4

View of Mangamingi district, looking west from N119/043484.

Patea River in the foreground with Opunake terrace and Stratford terrace above. Stratford soils, fine topsoil variant mapped on the terraces. Whangamomona stepland soils occur on the highly dissected Kaiatea terrain in the background.

found in the Kapuni, Waingongoro and Patea catchments (Plate 2.4). The depth of andesitic tephtras covering this formation varies from 1-2m.

The Pungarehu Formation (Neall, 1979), occurs in the west of the County having been previously mapped as part of the Opunake Lahars by Hay (1967). It has been dated (NZ 1623B) at $22,700 \pm 600$ years B.P. The source area appears to have been slightly west of the present Mt. Egmont summit. The deposit is typically unsorted breccia and conglomerate, with no bedding present (Plate 2.5). It can be seen just below 7m depth in road cuttings, along the Opunake and Eltham roads, in Eltham County. It is progressively buried to the north and west by the younger Warea and Opua Formations. The uppermost units of the Opunake Formation may be a lateral facies equivalent of the Pungarehu Formation.

The Aokautere Ash (c. 20,000 years B.P.) has been found at a depth of 7m, in the west of Eltham County. The thickness of tephtric and associated materials that have accumulated above the Aokautere Ash has been established by Geddes et al., (1980). The relative thickness of late Quaternary andesitic tephtra in Eltham County is much greater compared with the area to the west of Mt. Egmont, in Egmont County.

The Warea Formation, originating from Mt. Egmont, was deposited between c. 12,000 and 15,000 years B.P., in three lobes. The southern lobe occurs in the extreme west of the County and its distribution was restricted physiographically by the presence of the Mangawhero Ridge. The lithology is similar to the Pungarehu Formation, containing angular clasts, in a coarse breccia. However, towards its lateral margins in Eltham County, the Warea Formation becomes reduced to an "ashy" conglomerate. Adjacent to the boundary with Egmont County closely spaced lahar mounds occur (Plate 2.6). The cover of andesitic tephtra can be less than 1m on the mounds (Plate 2.7), whereas elsewhere the depth of tephtras varies up to 2m maximum.

In the west of Eltham County, in the area between Rowan Road, Riverlea and Kaponga, there occur deposits of a young lahar equivalent in age to the Opua Formation, which has been dated (NZ 1781C) at $7,320 \pm 110$ years B.P. This area was mapped previously as the south-east lobe of the Warea Formation. The lithology consists of boulders, stones and gravels, mixed with volcanic ash and grey sands (Plate 2.8). Post-Opua Formation soil parent materials are dealt with under the section on Tephrochronology.



Plate 2.5 Pungarehu Formation, near Lower Stuart Road, N119/843447.

Note the unsorted nature of the laharic debris.



Plate 2.6

Mt. Egmont. Lahar mounds of the Warea Formation. East of Upper Auroa Road, below the Egmont National Park Boundary (460 m), near N118/636514.

Soils mapped as Rowan hill-Mangawhero association.

Juncus spp. in the foreground.



Plate 2.7

Warea Lahar exposed on Upper Auroa Road, at N118/634513.

The poorly sorted, non-bedded nature of the laharc breccia is evident. The covering of volcanic ash is less than 1 m thick.

The soil is mapped as Rowan hill soil.



Plate 2.8

Opua Lahar exposed on Eltham Road, near Riverlea,
at N119/677463.

Note the stones and gravels, mixed with volcanic ash and
grey sands.

5. DRAINAGE AND IRON MOVEMENT

The mobilisation, movement and precipitation of iron is a significant soil-forming process in the genesis of soils in Eltham County.

Iron is mobilised under primarily two different conditions:-

1. where reduction of iron occurs under the influence of a high water-table, for example the Mangawhero series.
2. where there is excessive movement of water under perhumid (high rainfall) conditions, in an otherwise freely draining soil, for example in the Rowan series.

Perched water-tables may be found above lithified or cemented lahar deposits. Lahar deposits are typically unsorted and consist of andesite boulders, stones and gravel, within a matrix of sand, silt and clay. Lithification is common in the lahar deposits and there are two possible explanations for this phenomenon. The first involves cementation of constituent particles by the precipitation of weathering products, which are either leached from the soil above or derived from ground waters. The second explanation revolves around the possibility of the deposits being derived from hot laharic material, which was lithified immediately after deposition due to a welding process. The cemented lahars of the Warea and Opuia Formations, in the west of Eltham County, cause soil drainage to be impeded so that gleying is a feature of many laharic soils. The Mangawhero (Plate 2.9) and Awatuna series are poorly drained soils, which have the morphology of gley soils up to and sometimes within A horizons. Weakly gleyed soils, for example the Makaka and Tipoka series are also recognised, in which the A horizon and one or more B horizons are well drained with mottling confined to the lower-most horizons.

Where porous pumiceous lapilli are concentrated in bands between beds of finer ash, as in the Mangawhero series, the lapilli bands act as aquifers for the lateral and downward percolation of water.

According to Soil Taxonomy the aquic moisture regime implies a reducing regime that is virtually free of dissolved oxygen because the soil is saturated by ground water or by water of the capillary fringe from which the dissolved oxygen has been removed by the respiration of micro-organisms, roots and soil fauna.

Soil Taxonomy refers specifically to mottles with chromas of two or less as a criterion for poorly drained conditions. However, the criterion

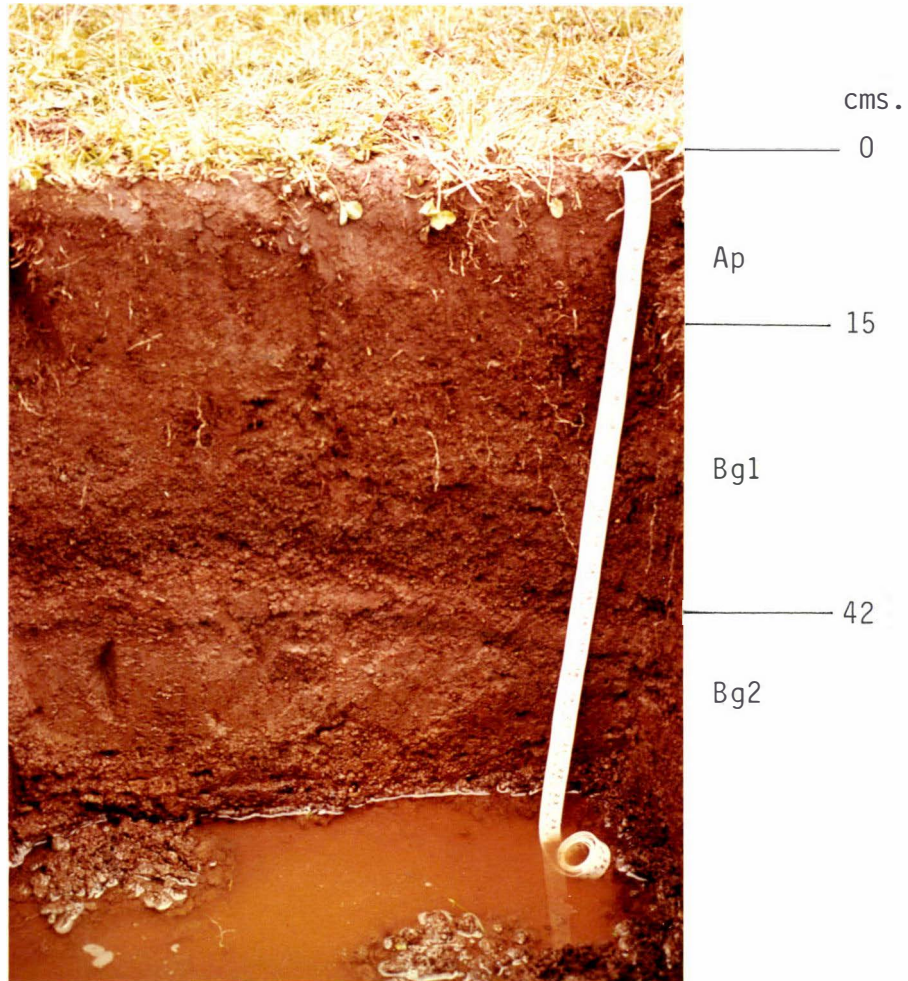


Plate 2.9 Mangawhero soil, near Riverlea,
at N119/683465.
Iron pan at 0.66 m. Manganui tephra
occurs between 15-42 cms.

is difficult to apply to soils developed from dark coloured volcanic parent materials, as is the case with yellow-brown loams.

Mottling can be confined to irregular surface staining of pumiceous and lithic lapilli or of soil aggregates. Spot mottling is common and where the ground is wet for a large proportion of the time, the spots are hard and may grade into concretions. A tendency for this gradation from mottles to concretions to occur with increasing depth was noted in the Mangawhero soils. In addition there is an increasing abundance of both mottles and concretions with depth, especially at the textural boundary between volcanic ash and laharic debris. Tephras may be found cemented by iron to form a brittle vesicular pan. These iron pans have a discontinuous distribution and are found mainly in the west of Eltham County. They are distinct from placic horizons, as described in Soil Taxonomy, which are often referred to as thin iron pans. Placic horizons have wavy or convolute forms, as in Rowan soils, and range from 2mm to 10mm in thickness.

6. GENESIS AND HISTORICAL DEVELOPMENT OF THE NGAERE AND ELTHAM SWAMPS

General description and historical development

The Ngaere and Eltham Swamps, east of Eltham Borough, are located between the Egmont volcanic ring plain in the west and dissected hill country to the east. The surface of both swamps is typically flat (Figure 2.3).

An old survey map, dated 1887, obtained from the Department of Lands and Survey, New Plymouth, shows clearly the outline of bush, as distinct from the two lagoon-like areas of open swamp. The open swamp in the north, Ngaere Swamp, is marked as being 2,400 acres in area and the Eltham Swamp, to the south, as 2,100 acres. These estimates were conservative, as later estimates (Every, 1974) were 3,500 acres for Ngaere Swamp and 3,000 acres for Eltham Swamp.

The Ngaere Swamp and the Eltham Swamp occur at two different levels, 220m (720') and 210m (685') respectively. The Eltham Swamp is drained by the Mangawhero Stream, a tributary of the Waingongoro River to the west and by the Mangimangi Stream to the south. The Ngaere Swamp (Plate 2.10) is drained to the north by the Ngaere Stream, a tributary of the Patea River.

In the early 1890's the Government bought the land comprising the Swamps from the Maoris and partially drained it with a circuit drain dug round the edge of both Swamps. An area of 5,076 acres was available for settlement in 1895 (Figure 2.4). The cutting of subsidiary drains and stumping of the open swampland without standing timber was the prerogative of the individual farmer. The control of the area was under the auspices of the Hawera County Council. However, the response was poor, because the drainage attempt had not been a success and the conditions of the Swamps reverted back almost to their original state. It was decided that local control was necessary, if the Swamps were to be drained effectively. Consequently, in 1901, the Eltham Drainage Board was formed.

During the next 40 years the Board carried out further drainage work, using manual labour. The work involved constructing, widening and deepening drains and outfalls along the main drain reserve. A stumping machine was brought into use in 1931 and some areas were stumped six times, then cropped and sown in pasture. In 1931, the total rateable area of the

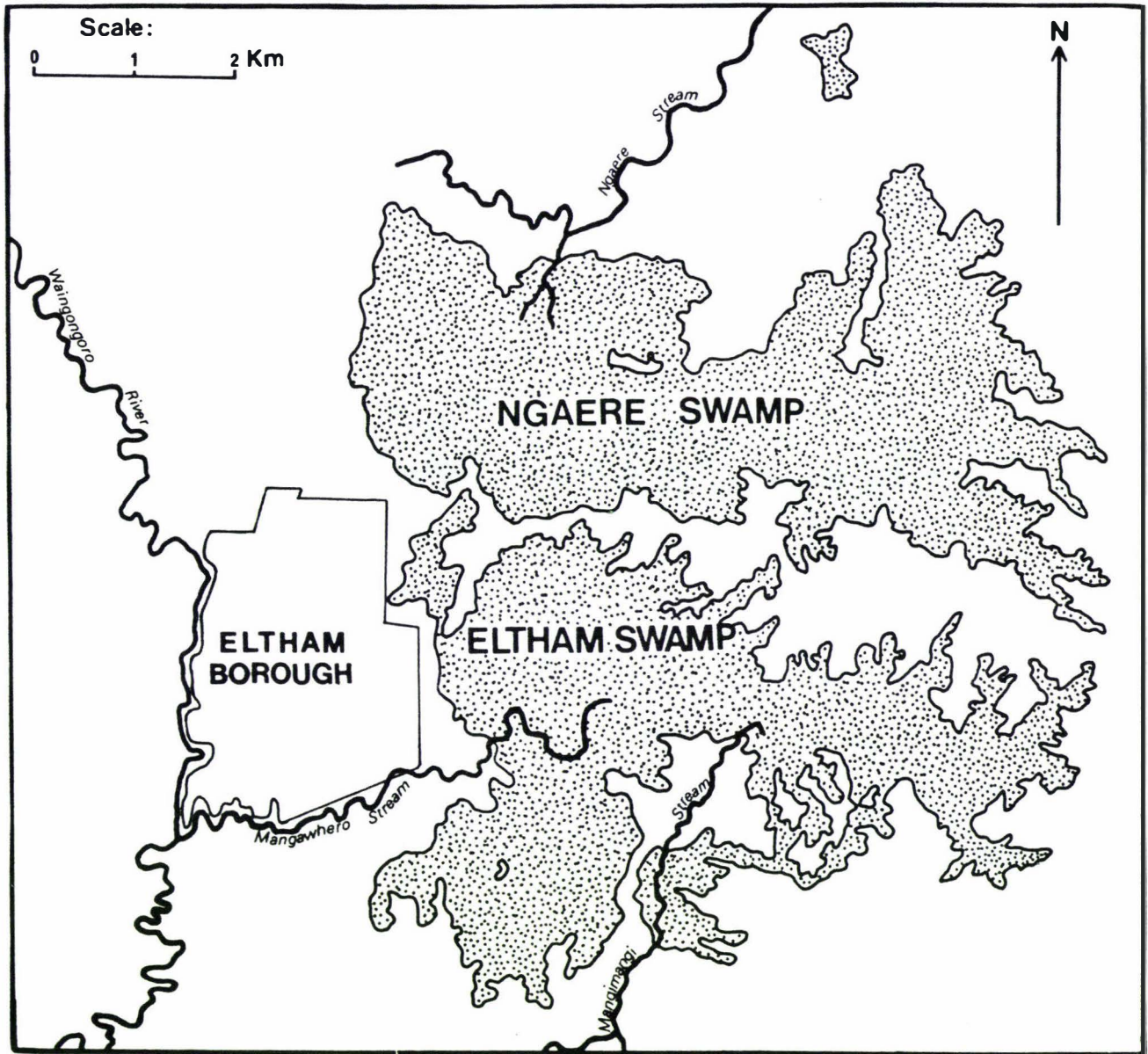


Figure 2.3

Location of the Ngaere and Eltham Swamps



Plate 2.10

View north of the Ngaere Swamp from Rawhitiroa Road,
at N119/890483.

Stratford hill soils are mapped in the background and
Eltham peat in the foreground.



Plate 2.11

Exposed roots of a Dacrycarpus dacrydioides
(Kahikatea) due to
subsidence of the Eltham
peat of approximately
1 m (3').

View at N119/896476 on
the western margin of
the Eltham Swamp.

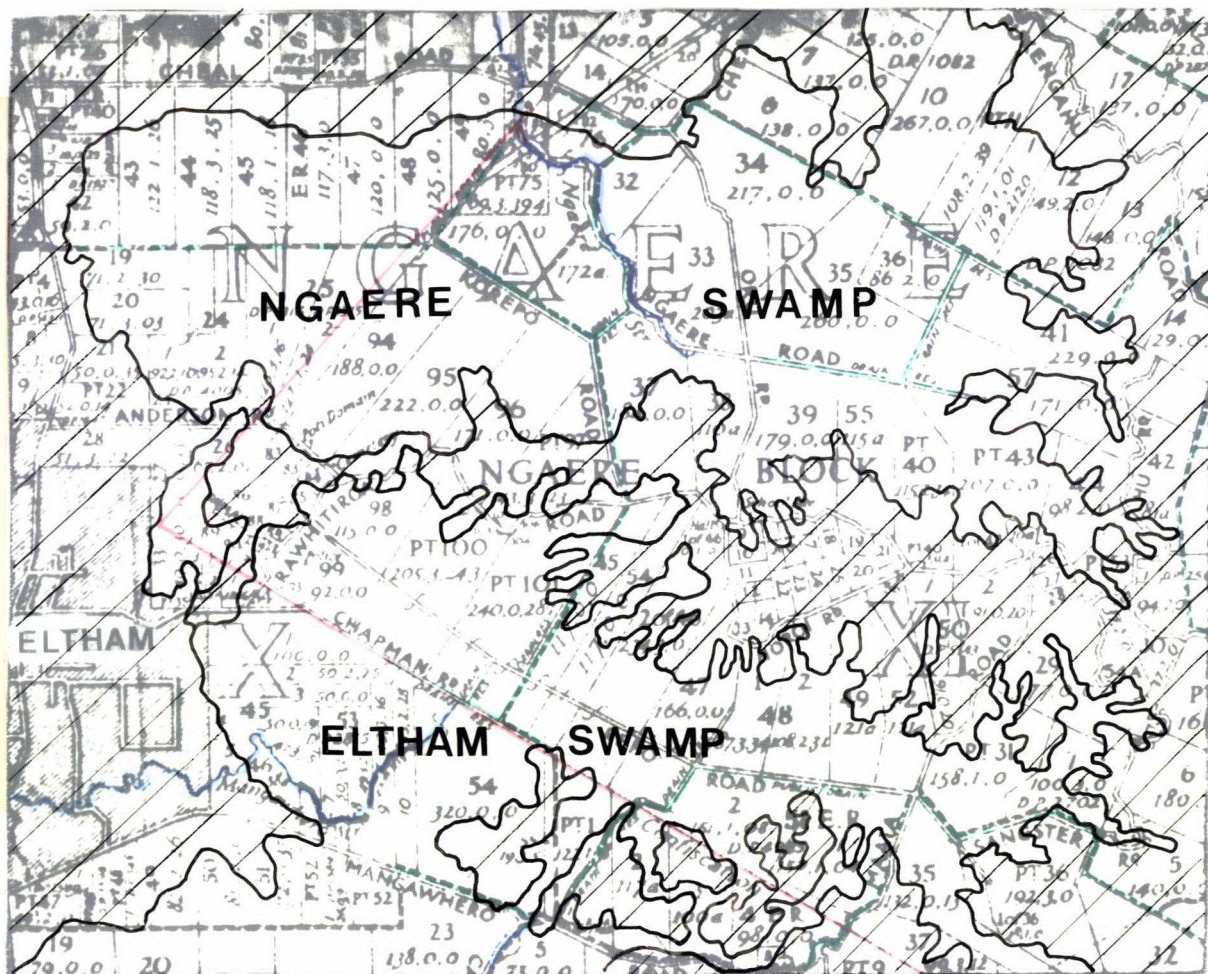





Figure 2.4

Ngaere section survey map (1895)

Key

-  - Drain reserve
-  - Public drain

 - Confiscation line, representing the boundary of an angled area running from White Cliffs, North Taranaki to a point just east of Eltham and then south-east to Waitotara. Land outside this angled area was confiscated from the Maoris for European land settlement. The land was later bought from the Maoris when Rawhitiroa was opened up for European settlement.

-  - Stream

Drainage District was 9,800 acres, of which 5,000 acres was swamp. During World War II a considerable amount of maintenance work had to be delayed.

By the early 1950's approximately 3,500 acres of the area was still non-productive. In 1958, a comprehensive improvement scheme was drawn up and approved for subsidy. This involved enlarging and regrading of the main drains to obtain the maximum fall and also providing subsidiary drains. Although the scheme was costly it could be economically justified. A local dairy company survey showed that even with undrained areas included, the average dairy farm on the Swamps could produce 7,000 lb of butterfat per annum more than non-swamp farms in the area. The final phase of drainage work was completed in 1964 and involved culvert crossings to side drains along one side of all main drains to facilitate access of machinery for future maintenance. Maintenance has involved cleaning and spraying of drains to control and eradicate noxious weeds, such as Salix discolor (pussy willow), Ulex europaeus (gorse) and Rubus fruticosus (blackberry). In certain areas the Swamps still remain in an undeveloped state, with stumps of Dacrydium colensoi (silver pine), Leptospermum scoparium (manuka), Laurelia novae-zelandiae (pukatea) and Dacrydium cupressinum (rimu) scattered on the surface.

As the process of draining and developing the land into dairy pasture has proceeded, so consolidation by cattle has accompanied subsidence. The land has now subsided 4.6m (15') or more in places, as evidenced by gleyed soils now occurring on well drained sites adjacent to the Swamps. Circuit drains constructed over 70 years ago are visible crossing ridges, now 3m (10') above the present swamp level. The exposed roots of trees near the Swamps margins (Plate 2.11) indicate a lowering of approximately 1m (3') of the swamp level. This subsidence is a problem and drains often require re-deepening to maintain effectiveness. The main limitations today for intensive use are presence of timber, poor drainage and difficult engineering properties, especially low bearing strength.

Genesis of the Swamps

The Ngaere and Eltham Swamps occur along the contact between the younger volcanic surfaces of the Egmont ring plain and the older deeply dissected Eltham Lahar surface (Figure 2.5). Two small outlying areas of swamp also exist north of the Ngaere Swamp, near Midhirst and east of

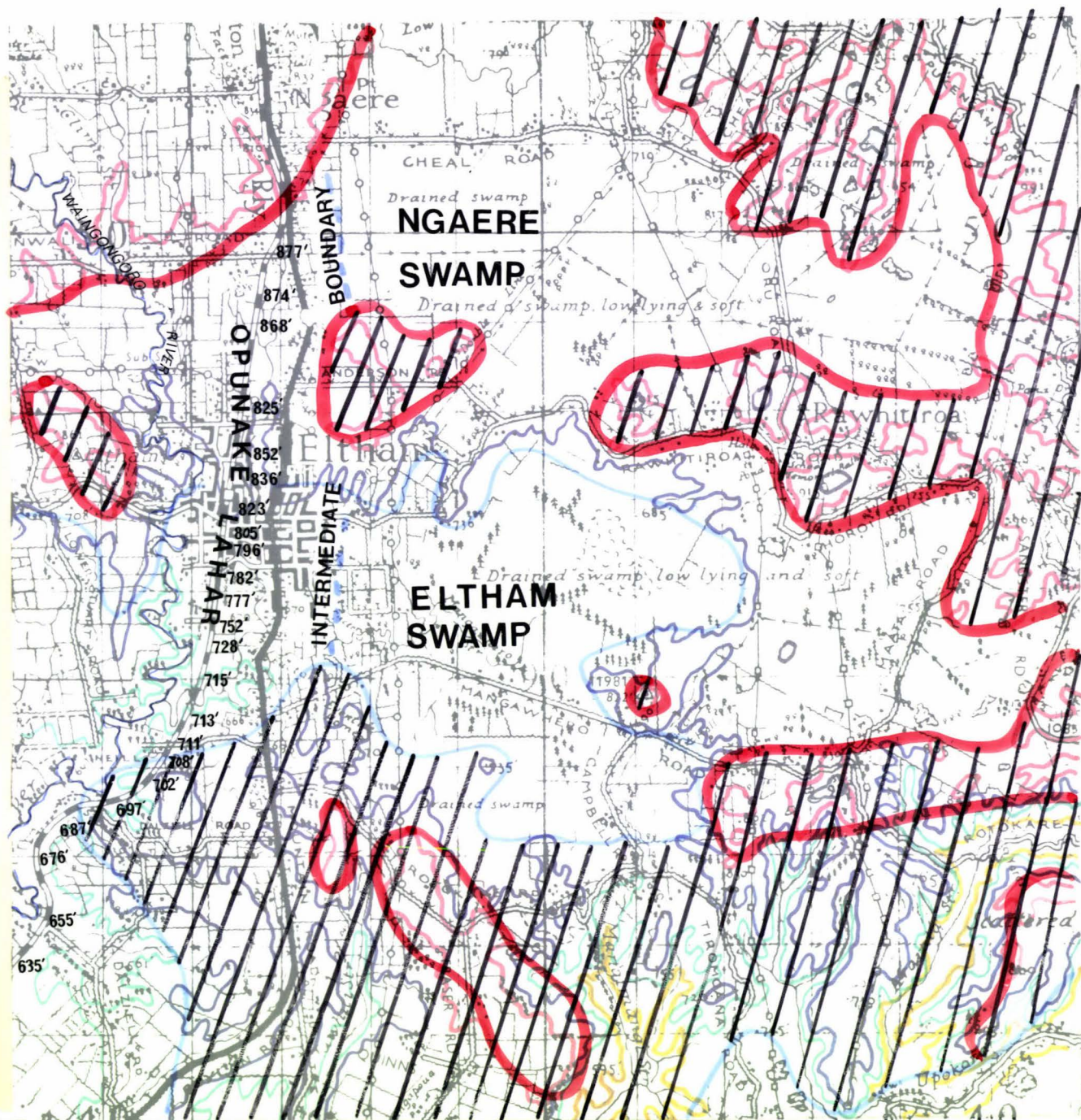


Figure 2.5 Contour map of Ngaere and Eltham Swamps at 100' intervals

Key to base map

- - 900'
- - 800'
- - 700'
- - 600'
- - 500'

Key to overlay

- 635'–877' - Spot heights along railway
- - Generalised 800' contour
- - Generalised 700' contour
- ▨ - Older dissected Eltham lahar surface. In north bounded by generalised 800' contour and in south bounded by 700' contour. In west bounded by Stratford Formation.

Ratapiko Road.

All the swamps appear to have formed by laharic debris flowing down the Waingongoro River and accumulating in the mouths of tributary valleys to the east. This blocked the valleys that were draining across the Stratford Formation (greater than 50,000 years B.P.) to the west, where water then accumulated, accompanied by organic matter and tephra. Since the Pungarehu Formation (about 23,000 years old) was directed to the west and did not flow down the Waingongoro River, it seems likely that the Opunake Formation caused the blockage.

Soundings through peat to solid ground, by the Eltham Drainage Board, have revealed an average depth of 12m.

McGlone and Neall (1983, pers. comm.) examined the stratigraphic variation in vegetation in the Ngaere Swamp by means of detailed palynological identification.

Various zones were recognised ranging in depth from Zone 1 at 9.3 - 8.3m (13,000? - 12,600 years B.P.) through to Zone 7 at 0.60m, post-3,300 years B.P. During Zone 1 a wet sedge swamp occupied the site, with herb-rich grassland and shrubs dominant and tall shrubland absent. However, it is estimated that around 12,600 - 11,200 years B.P. (Zone 2) podocarp-hardwood trees and shrubs began to appear. The transition from grassland through a very brief shrubland phase to tall podocarp-hardwood forest was rapid, with the total time for replacement probably less than 1,000 years. No major changes in the forest dominants occurred during Zones 3 and 4. During Zone 5, at 6.3 - 2.2m, (estimated to be between 9,300 - 5,500 years B.P.) there was an increase of Dacrydium cupressinum and a reduction of the previously dominant Podocarpus spicatus, reflecting a major change in forest composition. The main environmental factor behind the change was climatic, in which the rainfall was as high or higher than that of the present, the winters mild and the summers warm and moist. This swamp forest remained dominant with Dacrydium colensoi, silver pine, reaching a period of peak abundance, which ended by about 3,300 years B.P. (Zone 6). It is significant that silver pine is not found growing in Taranaki at present. Stumps of silver pine still litter the surface and are concentrated in certain parts of the swamps, for example near Hu Road. During Zone 7 there was an increase in the Dacrydium cupressinum, together with tree and ground ferns suggesting not only a sudden change in forest composition on, or close to the site investigated, but also a drier surface on the mire.

Classification of Eltham peat

There have been numerous criteria used to classify organic soils, Farnham and Finney (1965) made an extensive review of the various criteria for classifying organic soils. Previous systems include:

- 1) Topographical features (e.g. Shaler, 1890)
- 2) Surface vegetation features (e.g. Heinzelman, 1963)
- 3) Chemical properties (e.g. Nygard, 1954)
- 4) Botanical origin (e.g. Davis and Lucas, 1959)
- 5) Morphology (e.g. Veatch, 1953)
- 6) Genetic processes (e.g. Kubiena, 1953)
- 7) Pedological methods (e.g. Harris, 1968)

Problems of terminology have arisen since the parent material is also the concern of the peat botanist, who classifies peat in two ways. There is a broad classification for peat accumulations and there is a more specific one for the peat material itself. At a high level of classification Eltham series can be defined as local or basin peat, while at a more specific level it can be considered mesotrophic or intermediate in fertility.

An appreciation of peat as a soil, with pedological horizons, as opposed to a mere organic material deposit, requires an understanding of the process of decomposition. This involves horizons of active humification towards the surface, an horizon of anaerobic decay below, with a transition horizon inbetween. The fact that peat is an accumulating body means that each layer has undergone a certain amount of humification whilst near the surface. The presence in the Swamps of soft, decomposing logs, with well preserved wood structure indicates that anaerobic decay is an important yet relatively slow process.

There are several methods for measuring the amount or degree of decomposition, for example, maximum saturated water-holding capacity, bulk density, sodium pyrophosphate solubility and the amount of plant fibre and its durability (Avery, 1973; Canada Department of Agriculture, 1970 ;

U.S. Soil Taxonomy, 1975). Fibres are defined as recognisable plant tissue, excluding live roots and wood fragments larger than 20mm in cross-section, which cannot be crushed or shredded in the hand and that are retained on a 100-mesh sieve (0-15mm openings). The O horizon is a master horizon, which is subdivided according to the degree of decomposition of the organic matter as shown by the amount and durability of plant fibre present. Following the Canadian system, which has been adopted in New Zealand for organic horizons, these are designated as shown below by the standards set in U.S. Soil Taxonomy.

- Of - Fibric horizon, an O horizon containing large amounts of well preserved fibre.
- Om - Mesic horizon, an O horizon exhibiting an intermediate degree of decomposition. Fibre content is less than for a fibric horizon.
- Oh - Humic horizon. This is a well decomposed O horizon in which the original structures of organic material are unrecognisable. The horizon is usually black and the fibre content minimal.

The terms fibric, hemic and sapric have been applied by U.S. Soil Taxonomy with the same meaning as the above designations.

Differences in the degree of decomposition together with variations in plant remains confirm that the vegetative cover and conditions for decomposition have altered throughout the development of the Swamps. The upper mass of peat is derived from woody plants and can be described as a forest peat, while at depths of 8 - 9m the material is sedge peat.

Organic soils tend to have very weakly expressed morphology that is distinguished mainly on the basis of organic matter content, degree of decomposition and consistence. In the case of the Eltham peat, tephra beds are also present forming mineral horizons.

In the Eltham series the humified upper horizons contrast strongly with the lower part of the profile. The upper 0.40m comprises dark reddish-brown to dark brown peat, with moderately to strongly developed fine, nutty structure giving a friable consistence. The many to abundant roots are often iron stained. In many profiles charcoal is present from the

fires that followed clearance. The subsoil tends to be very dark brown to black becoming a dark reddish-brown structureless peat with depth. However, on drying, in ditch exposures the peat shrinks forming a strongly developed coarse blocky structure (Plate 2.12). The partly decomposed fragments of wood, twigs and fibres, which are a feature throughout the profile are concentrated at approximately 0.90m depth. The water-table usually occurs between 0.60 and 1.50m depth.

Pumiceous and lithic lapilli may be concentrated into continuous horizons or pockets in the peat. The lapilli may be greater than 20mm in diameter or reduced to a coarse ash, imparting a gritty feel and speckled appearance. The Burrell Lapilli (c. 330 years B.P.) occurs in the upper horizons, with the Kaupokonui tephra (c. 2,000 years B.P.) and Maketawa tephra (c. 3,100 years B.P.) below. The distinctive and scoriaceous Manganui tephra, which has been dated c. 3,300 years B.P., has been identified at a depth of approximately 0.60 to 0.70m, where it forms a gravelly horizon. The tephras p2 (c. 4,500 years B.P.) and p1 (c. 5,150 years B.P.) occur at a depth of approximately 1m and are strongly weathered (Figure 2.6). The presence of bands of tephra in these profiles creates distinct textural discontinuities.

The system of organic soil classification that appears in U.S. Soil Taxonomy (Soil Survey Staff, 1975) is the result of many modifications and changes. The Histosol order is now defined on the thickness of organic materials over limnic materials, mineral materials, water or permafrost. A control section has been established for their taxonomy. It is either 130cm or 160cm thick, depending on the kind of material, provided that no lithic or paralithic contact, thick layer of water or frozen soil is encountered within those limits. The control section has been divided into three tiers: surface, subsurface and bottom tiers.

The Eltham peat is classified at the suborder level as a Saprists on the basis of its moisture regime and by the degree of decomposition of the organic materials. Saprists are saturated with water for six months or more of the year, or have artificial drainage. Sapric soil materials are the most highly decomposed of the organic materials and normally have the smallest amount of plant fibre, the highest bulk density and the lowest water content on a dry-weight basis at saturation. The bulk density is commonly 0.2 or more and the Eltham series is no exception (Table 2.6). The sodium pyrophosphate colour test was carried out, according to U.S. Soil Taxonomy on samples of the Eltham peat. The colours obtained were all characteristic of sapric material.



B1 4 cms .

PEAT

Kk 6 cms .

PEAT

Mt 8 cms .

PEAT

Mn 14 cms .

Plate 2.12

Section exposed in ditch on Sharp's property at N119/889456 showing:-

- B1. - Burrell lapilli
- Kk. - Kaupokonui tephra
- Mt. - Maketawa tephra
- Mn. - Manganui tephra

Figure 2.6

PROFILE OF ELTHAM PEAT NEAR RAWHITIROA ROAD AT N119/901469

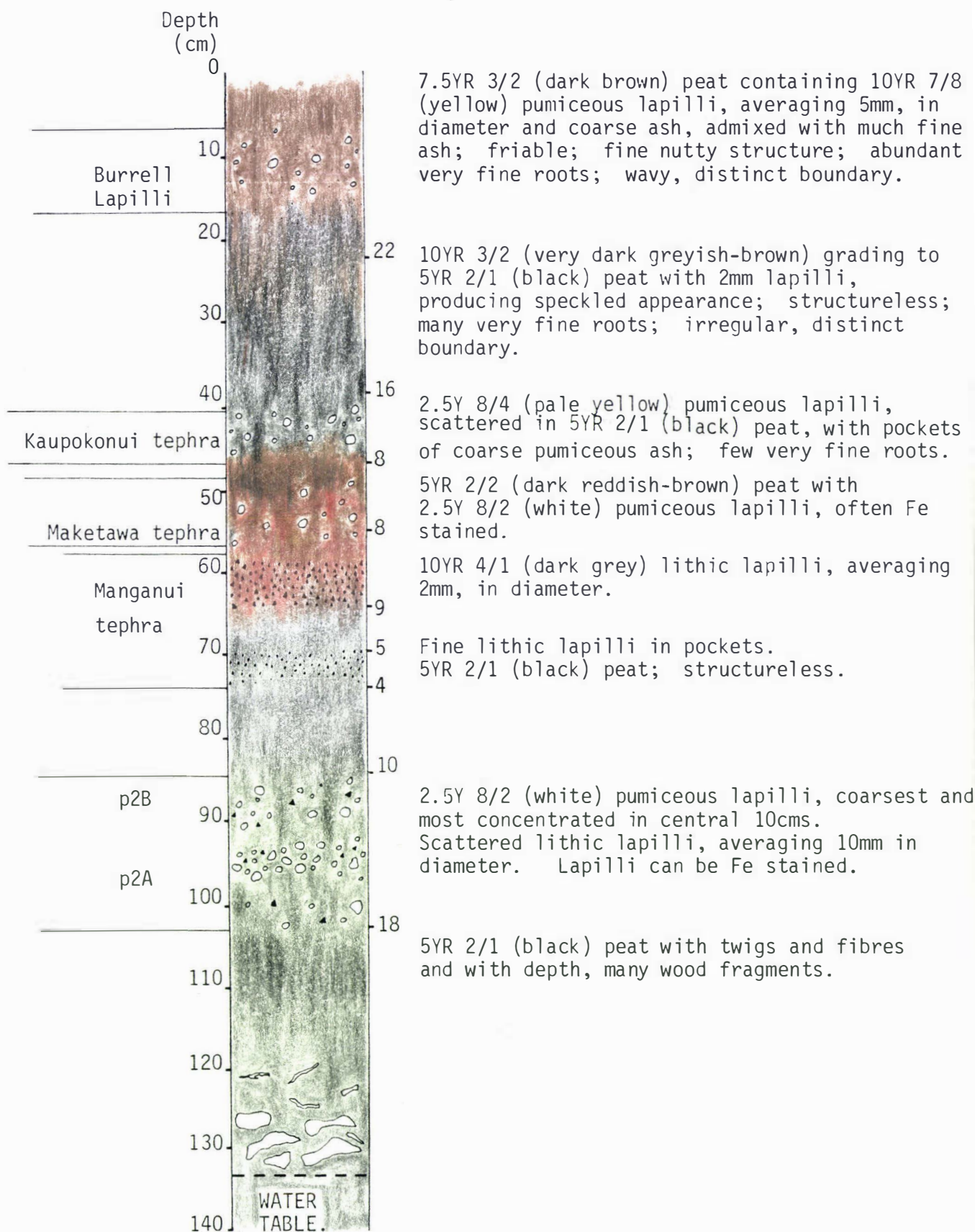


Table 2.6

BULK DENSITY VALUES FOR THE ELTHAM PEAT

Horizon	Horizon depth (cm)	Sample depth (cm)	Bulk density (Mg/m ³)
Ap	0-20	6-9	0.55
		10-13	0.49
Oh1	22-30	23-26	0.30
		27-30	0.26
Oh2	30-52	37-40	0.42
		41-44	0.30
Bh1	52-65	53-56	0.20
		57-60	0.18
Bh2	65-100	78-81	0.26
		82-85	0.32

At the great group level this soil is a Medisaprist, on the basis of the soil temperature regime, which is important since it influences the rate of decomposition of the organic material and absence of humilluvic material.

At the subgroup level it is a Fibric Terric Medisaprist. It is Fibric because the peat has more than 12.5cm of the sub-surface and bottom tiers consisting of fibric materials. It is Terric because there is a mineral layer 30cm or more thick which has its upper boundary in the control section below the surface tier. There is also a mineral layer between 5 and 30cm thick within the organic materials and two or more thin, continuous mineral layers are present in the control section, below the surface tier. Terric subgroups can be further subdivided into families by the criteria specified for Histosols. At the family level it is medial and mesic. It is medial because less than 35% (by volume) is greater than 2mm and its water retention at 15-bars is 12% or more on previously dried samples and its water retention at 15-bars of undried samples is ^{between} 30 and 100%. It is mesic because the mean annual temperature is higher than 8°C but lower than 15°C.

Thus, the Eltham series is classified according to Soil Taxonomy as a Fibric Terric Medisaprist (medial, mesic).

CHAPTER 3

CHAPTER 3

TEPHROCHRONOLOGY
OF CENTRAL TARANAKI1. INTRODUCTION






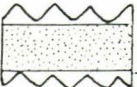
Mt. Egmont is a 2518m high andesitic stratovolcano that has formed over the last 100,000 years (Neall, 1972). Over this time the andesitic eruptions have been intermittent in occurrence, resulting in extrusion of lava flows, airfall tephra, pyroclastic flows and the formation of lahars and associated floods. Lahars and pyroclastic flows, formed by collapse of segments of the stratovolcano, are the most voluminous deposits and have produced a gently dipping constructional surface surrounding Mt. Egmont which has been termed the ring plain.

Previous tephrochronological work around Mt. Egmont was concentrated to the north and west where the major stratigraphy of the principal late Quaternary tephra and nuée ardente deposits was established. Ten formations of ash and lapilli, including the Oakura and Okato Tephra which comprise the "Egmont Shower" of Grange and Taylor (1933), were named by Neall (1972).

The tephrochronological work in this study is centred on a detailed stratigraphic investigation of tephra distributed to the east of Mt. Egmont in late Quaternary times and generally known as the "Stratford Shower". The majority of units are defined informally and are either named or numbered. Detailed descriptions of units from the uppermost tephra p2, to the lowermost tephra Mahoe tephra, are included. The tephra recognised as occurring within the originally defined Stratford Shower range from the Kaupokonui tephra (youngest) to the E3 tephra (oldest) (Table 3.1).

Isopach maps are presented and provisional correlation to the north is attempted.

Table 3.1 Chronology and distribution of principal Quaternary volcanic deposits in central and eastern Taranaki

COMPOSITE COLUMN	TEPHRAS		LAHAR AND ALLUVIAL DEPOSITS		CHRONOLOGY
	STRATIGRAPHIC UNIT	PRINCIPAL LITHOLOGIES AND DISTRIBUTION	STRATIGRAPHIC UNIT	PRINCIPAL LITHOLOGIES AND DISTRIBUTION	(after Neall 1972,1979) units dated by radio-carbon methods in years B.P.
	TAUPANE ash Buried soil Tephric loess	thin airfall coarse ash above 720m			1755AD
	3 Unnamed ashes				
	AOKAUTERE ASH	Rhyolitic ash, from the Central North Island			NZ 1056A (19,850 ± 310)
			PUNGAREHU FORMATION	laharic breccia and conglomerate	NZ 1623B (22,700 ± 600)
	KORU TEPHRA Koru ash Koru lapilli		OPUNAKE FORMATION	laharic conglomerate and sandstone with interbedded peat, sand and silt lenses	NZ 331A (34,400 ± 1500)
	OMAHINA TEPHRA	Rhyolitic ash, from the Central North Island	STRATFORD FORMATION	laharic conglomerate and breccia with lignite lenses terrestrial mud, sand and silt	> 50,000 yr. B.P.
			ELTHAM FORMATION	(Formations present in Taranaki but not present in Eltham County)	Mid-Pleistocene

Scale:
cm.
0
10

2. DEFINITIONS AND TERMINOLOGY

There have been many attempts to standardise the nomenclature of pyroclastic materials (Wentworth and Williams, 1932; Fisher, 1961, 1966; Cole and Kohn, 1972). In 1979, the IUGS Subcommittee on the Systematics of Igneous Rocks published a nomenclature for classifying pyroclastic rocks, which has been used in this study. The terms used here are defined as follows;

Pyroclasts

Wentworth and Williams, (1932) defined "pyroclastic" as "an adjective applied to rocks produced by explosive or aerial ejection of material from a volcanic vent". There are two fundamental types of pyroclastic rock, depending upon whether they are airfall tephras deposited from eruptive clouds by aerial ejection or flow deposits erupted in the forms of pyroclastic flows. The IUGS classification uses "average diameter" instead of the "median diameter", because the grain size will usually be estimated visually (Table 3.2).

Lapilli

Pumiceous lapilli are characterized by numerous small cavities presenting a spongy appearance whereas lithic lapilli are of stone.

Tephra

The term "tephra" was introduced by Thorarinsson (1944) and was later defined by him as "a collective term for all the clastic volcanic material, which during an eruption is transported from the crater through the air corresponding to the term lava to signify all the molten material flowing from the crater" (Thorarinsson, 1954).

The term implies no particular grain size and is of airfall origin.

"Cream cakes"

This is an informal term previously used in the Central North Island (Healy, 1964) to conveniently refer to the occurrence of discontinuous layers or patches of ash of much lighter colour than the bed enclosing them. They have a characteristic "cake" appearance and form distinctive horizons, especially in weathered exposures, and appear to represent patches of undisturbed ash in an old soil zone. They are found at the

Table 3.2

Granulometric classification of pyroclasts and
of unimodal, well sorted pyroclastic deposits

(average) clast size	pyroclast	pyroclastic deposit	
		mainly unconsolidated tephra	mainly consolidated: pyroclastic rock:
64mm	bomb, block	agglomerate, bed of blocks or bomb, block tephra	agglomerate, agglutinate, pyroclastic breccia
2mm	lapillus	layer, bed of lapilli or lapilli tephra	lapilli tuff
0.063mm	ash grain	coarse ash	coarse tuff
	ash particle (dust particle)	fine ash (dust)	fine tuff (dust tuff)

(ash) tuff

upper contact of E4 (Figure 3.7) and may also be found in the central member of E4. They may be found as a thin "ledge" below the buried soil formed on the E3 tephra and as a massive structure above E3 (Figure 3.10). They are also found as a discontinuous band above E2.

"Pocketing"

The term "pocketing" is used to refer to the variability in thickness of some of the beds. Measurements of bed thickness were therefore taken at the point of maximum thickness of a layer. It is at this point that all the unit is preserved, elsewhere it may have been removed or have landed on a vegetated surface. Alternatively, the thicker portions may be zones of accumulation.

"Spalling"

The term "spalling" is used to describe the way in which a band of tephra frets and falls out in vertical exposures parallel to the bedding.

3. HISTORICAL BACKGROUND AND PREVIOUS WORK

The importance of soil forming volcanic ash showers was recognised at the start of soil survey in New Zealand (Taylor, 1930; Grange and Taylor, 1931). This background meant that pyroclastic deposits were initially regarded as soil parent materials rather than as lithostratigraphic units. The application of radiocarbon dating to late Quaternary stratigraphy, in the 1950's, stimulated research in tephrochronology and the relationship between the soil pattern and volcanic deposits, most of these studies tending to concentrate in the Central Volcanic Region.

In Taranaki, A.W. Burrell, in 1883, was first to recognise the field evidence of recent activity from Mt. Egmont, namely the presence of pumice fragments lodged in the forks of living trees. Later, in 1929, a Maori oven was discovered by workmen when they were constructing Pembroke Road. The oven was buried beneath a pumiceous lapilli which was named after Burrell (Oliver, 1931).

Grimmett and Brogan (1933) noted that "scoria lapilli" were easily visible in Taranaki and were present in sufficient quantity for the soils to be classified as being of a coarse nature. In addition, they were

aware of the fact that deposits become progressively finer in texture, as they were spread outwards from Egmont.

In the first soil survey of Taranaki (Grange and Taylor, 1933) three main tephra-showers were recognised as soil forming: (i) the Egmont (ii) the Stratford and (iii) the Burrell showers. The showers were assumed to be younger than the mudflow deposits of the Opunake and Okato districts but this has subsequently been found to be only partly true. In their 1933 account, Grange and Taylor mention that the Stratford Shower overlies the Egmont Shower and that it was deposited by westerly winds so that it was spread mainly east of Egmont. The Stratford Shower was mapped from a point 6km south of Waitara to a point 5km north of Normanby, while the Egmont Shower was mapped to the north and south of these ^{points.} No type localities were ever designated but 0.3m of Stratford Shower was described as resting on the considerably older Egmont Shower, at the Demonstration Farm at Stratford. Here was recorded:

Stratford Shower	{	75mm dark brown coarse sands
	{	150mm dark brown to brown coarse sands
Egmont Shower	{	75mm brown gravelly sandy loam on dull brown sandy loam

In 1962, Wellman tentatively correlated an ash at a coastal section, 7km north of Cape Egmont, with the Stratford Ash. According to Wellman, the ash was 150mm thick at the section, andesitic in composition and of a coarse sand grade. Wellman's 'Stratford Ash' overlies the Stent Ash and underlies the Taupo Pumice, and from its stratigraphic position Wellman considered the ash to date at approximately 1,000 years B.P. Neall (1979) described the same Holocene coastal section and re-interpreted Wellman's Stratford Ash as the Oakura Tephra, of considerably greater age.

In Druce's (1966) study, which involved tree ring dating of Recent Egmont eruptives, a sequence of tephtras was determined (p4, p3, p2 and p1) from exposures on the Stratford Plateau Road. Druce correlated the tephtra sequence with the Stratford Ash. Isopach maps of post-1500 A.D. tephtras (i.e. post-Stratford Shower tephtras) were a valuable feature of Druce's work. In 1968, Gibbs summarised the broad distribution of the Burrell and Stratford ashes with a 75mm isopach and placed an unknown thickness boundary for the Egmont Ash.

The work of Druce, together with that of Tonkin (1970) and Topping (1972) established the stratigraphic relationships of the last nine eruptions from Mt. Egmont, which are grouped into three formations (Table 3.1).

It was from this work that the separate status of the Tahurangi (1755 A.D.), Burrell (1655 A.D.) and Newall (prior to 1604 A.D.) Formations was recognised.

Work on the Stratford Shower was limited and it was not until the soil survey of Stratford County (Aitken et al., 1978) that subdivisions of the Shower were attempted.

In Stratford County, Rowan and Lowgarth soils were separated because they were derived from an unnamed, lithic lapilli deposit, younger than the "Stratford Ash". This deposit has been informally referred to as the Manganui tephra by Whitehead (1976) and dated between (NZ3423C) at 3110 ± 160 years B.P. and (NZ3353C) at 4030 ± 110 years B.P. Earlier workers had included the Manganui tephra in the Stratford Ash. Whitehead mapped the Manganui tephra and the distribution indicated that the source vent was Fanthams Peak.

Neall's (1972) work, which was concentrated to the north and west of Mt. Egmont, was concerned with the stratigraphy of the principal late Quaternary tephras and nuée ardente deposits. The work named ten formations and members of ash and lapilli, occurring below the Newall Formation. The newly named tephras included the "Egmont Shower", which Neall divided into two separate formations. The Oakura Tephra (upper) was considered to be less than (NZ1144A) $6,970 \pm 760$ years B.P. and the Okato Tephra (lower) between NZ1144A and (NZ942A) $16,100 \pm 220$ years B.P.

The pumiceous lapilli deposits recognised in the present study as occurring within the originally defined Stratford Shower range from the Kaupokonui tephra (youngest) to the E3 tephra (oldest). The lapilli are creamy coloured and less weathered, compared with E2 and older units. Units below and including E2 would have been grouped into the Egmont Shower on the basis of their orange and more weathered appearance (Table 3.1).

It is the tephras present to 1m depth which are critical to the mapping of the soils in Eltham County. For ease of reference the Kaupokonui, Maketawa and Manganui tephras are here collectively referred to as the *young lapilli showers*.

The 250mm isopach map of the *young lapilli showers* combined with the depth of volcanic ash above laharic deposits has been used in this soil survey to separate the Lowgarth and Stratford series (Figure 3.1). The same isopach has been used in combination with drainage and leaching to separate Riverlea from Kahui series, Makaka from Tipoka series and Mangawhero from Awatuna series.

4. METHOD OF STUDY

Approximately 100 sections were studied in an area south of Inglewood and east of Awatuna (Figures 3.2 and 3.3).

The investigations were all facilitated by several major road cuttings along the main Opunake and Eltham roads. In addition, numerous minor exposures were examined along intersecting roads and on farm properties during the course of soil mapping. Investigations were also carried out within Egmont National Park.

Stable sites on the landscape were chosen for detailed descriptions and the tephras were characterised by Munsell colour, texture, consistence, proportion of lithic and pumiceous lapilli and general appearance. Where the stratigraphic sections were close together correlations between the tephras was relatively straightforward. However, with increasing distance apart, and also with increasing distance from Mt. Egmont, variations caused by differential weathering and by merging of tephra beds and formations meant that field correlation depended upon the presence of marker beds. In order for a tephra to act as a reliable marker bed it must be preserved over a wide area as a distinctive and recognisable deposit, identifiable where it occurs in isolation and distinguishable from associated tephra layers. In addition its approximate age should be known.

The Manganui tephra acts as the best marker bed in the top 0.5m of most sections. It is an airfall, scoriaceous, fine lapilli and ash. The lapilli are all lithic and have distinctive, prominent phenocrysts. The tephra has been dated between (NZ3423C) 3110 ± 160 years B.P. and (NZ3353C) 4030 ± 110 years B.P.

The unit E4 acts as a marker bed for the lower part of the

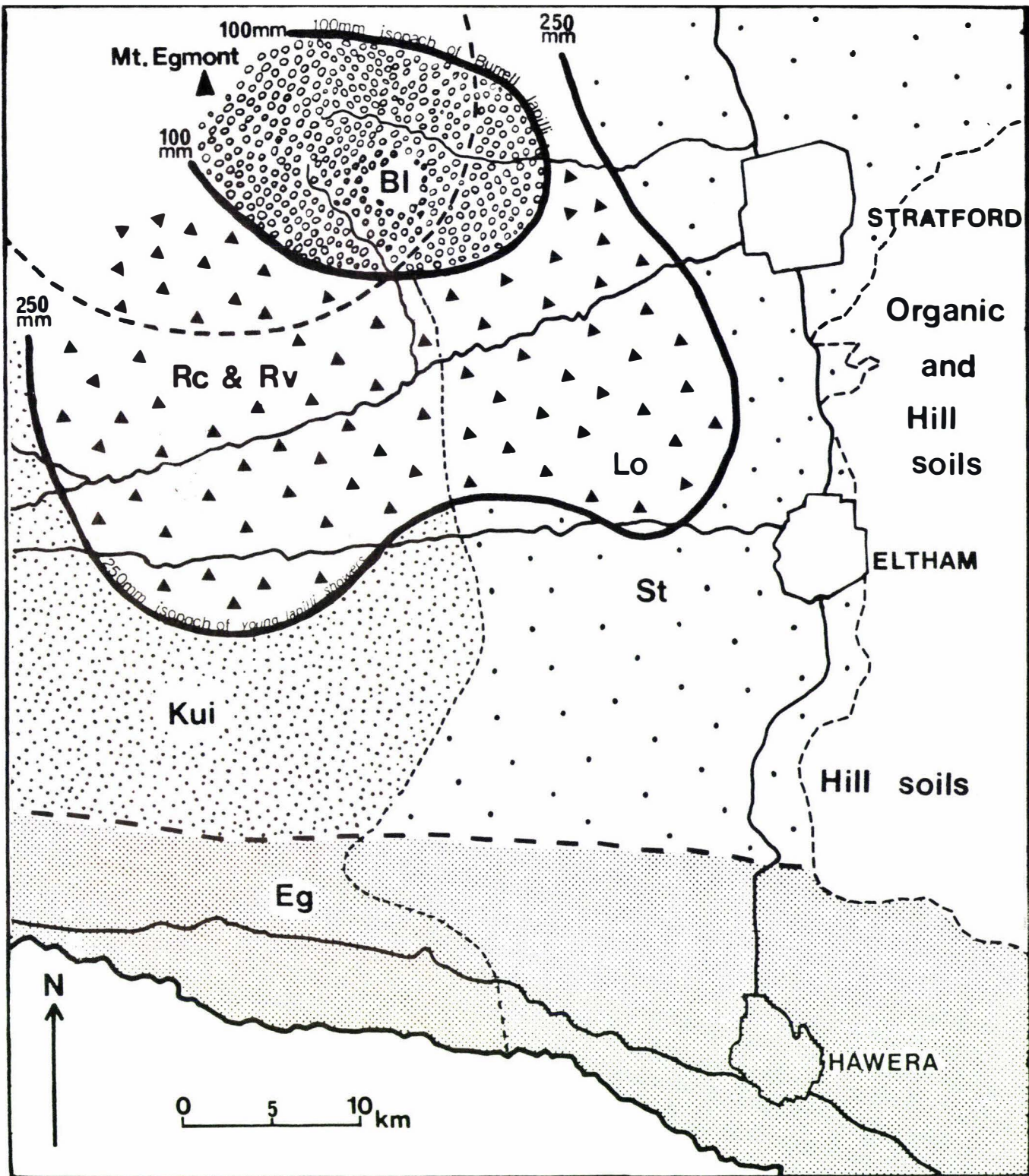








Figure 3.1 Distribution of well drained soils of central and southern Taranaki as governed by the distribution of tephra

- | | | | |
|---|--|--------------------------------|---|
|  | - Burrell lapilli | B1 - Burrell soil | Kui - Kahui soil |
|  | - > 250mm young lapilli showers | Rc - Rowan soil | St - Stratford soil |
|  | - < 250mm young lapilli showers +p2,p1(Druce,1966) | Rv - Riverlea soil | Eg - Egmont soil |
|  | - < 250mm young lapilli showers +p2,p1(Druce,1966)E5,E4. | Lo - Lowgarth soil |  |
| | | -- - Gradational soil boundary | - Laharic debris at < 2m depth |
| | | |  |
| | | | - Undifferentiated older ash |

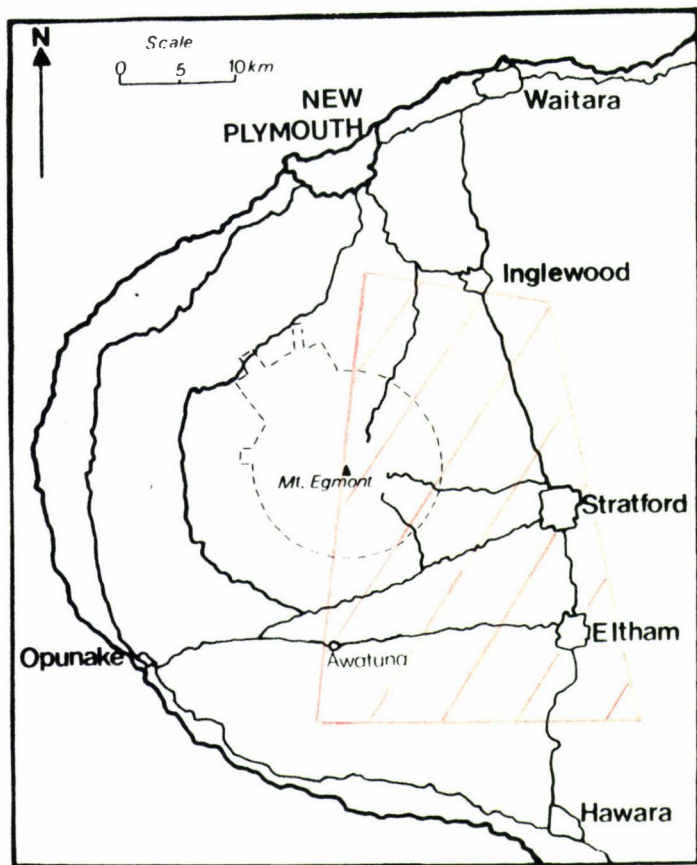


Figure 3.2 Locality map of Taranaki
showing study area

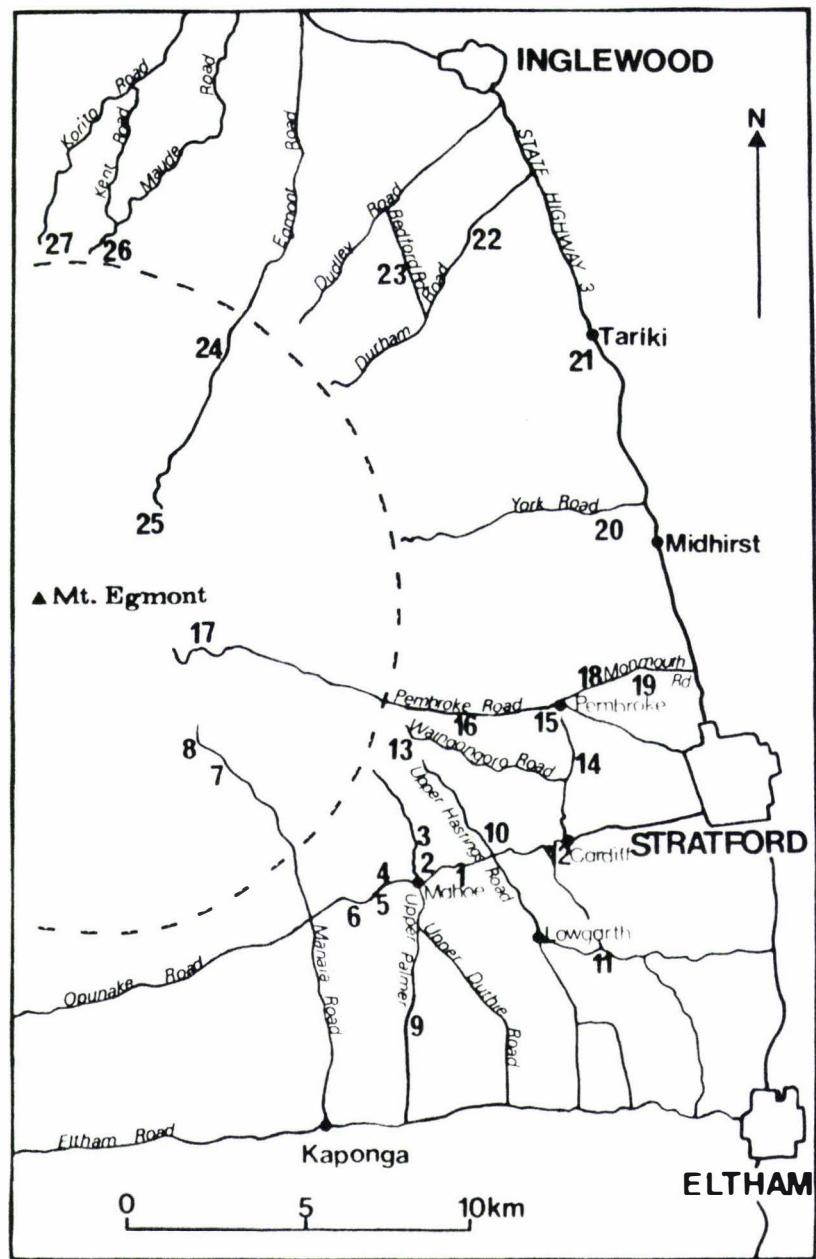


Figure 3.3
Stratigraphic sections
referred to in text

(for locality details
see Appendix I).

stratigraphic sections. It has not yet been dated but its age has been estimated, by correlation to the north and west of the study area, at greater than (NZ3352B) 5140 ± 150 years B.P. and less than (NZ1781C) 7320 ± 110 years B.P., based on its position below the Korito Tephra and above the Opua Formation. It is characterised by its "spalling" central member.

5. STRATIGRAPHIC UNITS

The formation is the primary formal unit of lithostratigraphic classification and a member is its formal lithostratigraphic subdivision of lower rank (Hedberg, 1976). The thickness of a formation follows no standard and may range in thickness from several centimetres to many metres. In addition, a formation need not be divided into members unless a useful purpose is served.

A tephra formation is usually defined from the lower contact of its least weathered basal layers, which usually rest upon older, more weathered layers forming a paleosol on an older formation (Vucetich and Pullar, 1964). The upper contact of such formations, with a weathered paleosol horizon, determines the base of the next formations.

It would be convenient to regard the product of a single eruptive phase, separated by appreciable time breaks from the beds above and below, as a formation but in practice this may be difficult. In the case of E2, further subdivision of the unit was not carried out. The unit E2 is probably the result of either several "showers" or a closely spaced series of intermittent eruptions.

The majority of units are informal and numbered. The "p" symbol was used by Druce (1966), while the upper case "E" is after Eltham County. Any informal names that have been given to tephra units are derived from local geographic sites, for example Mahoe tephra. The units described in detail are all lithologically distinctive and mappable.

6. SYSTEMATICS

Tephra below the Manganui marker bed are described in the order of youngest, (p2) to oldest (Mahoe tephra), because with increasing age they are less distinctive, more weathered and become more difficult to correlate.

The type sections are all located on accessible, well exposed sites on the ring plain. Sites close to source, in the Egmont National Park, were not chosen since the greater thickness of the tephras, intercalation of other near source deposits and the general inaccessibility, made such sites unsuitable. Reference localities are designated, in order to show lateral variation that may be present.

Thickness in millimetres are used to determine the isopachs presented (Figures 3.4 - 3.11). The majority of the isopach lines have been constructed using the more reliable thick values since it is difficult to obtain reliable thicknesses for thinner tephra layers, with distance from source. Gentle depressions and gullies were avoided so that erosion and overthickening were kept to a minimum.

i. LATE QUATERNARY TEPHRAS OF CENTRAL TARANAKI

p2

The unit p2 was first recognised by Druce (1966). It comprised his uppermost unit in the "Stratford Ash". The unit has been subdivided into two members p2B and p2A because in sections near to source two separate, but closely spaced, bands of tephra can be recognised. The two bands merge with distance from source. The unit p2 has been correlated with Neall's (1972) Inglewood Tephra, which has been dated (NZ5527C) at younger than 4490 ± 160 years B.P.

The Manganui tephra forms the upper contact of p2B and has been dated between (NZ3423C) at 3110 ± 160 years B.P. and (NZ3353C) at 4030 ± 110 years B.P. The basal contact of p2B is marked by the buried soil above p2A lapilli member.

CRITERIA: The member p2B is distinguished by its 10YR 8/2 (white) pumiceous lapilli and blocks and minor grey, dense andesite lapilli, which average 20mm in diameter, as recognisable in locations between Stratford and Egmont National Park.

The member p2A is distinguished by 10YR 8/3 (very pale brown) pumiceous lapilli and is separated from p2B by a buried soils formed from coarse ash (Plate 3.1).

TYPE SECTION: The type section is designated on Opunake Road, 0.6km from Mahoe at Grid Reference N119/741530^{*}. Here there are two well exposed road cuttings on the south side of the road where p2B reaches 100mm in thickness and p2A 200mm.

DISTRIBUTION AND SOURCE: p2 is of airfall origin from Mt. Egmont. Isopachs constructed for this unit include both p2B and p2A, with possibly thin minor contributions of Kaupokonui (p4) and Maketawa (p3) tephra. The isopachs show a broad distribution to the south-east of Mt. Egmont (Figure 3.4), with the 250mm isopach extending from near Kaponga, in the south to Stratford, in the east.

REFERENCE LOCALITY: A cutting on Monmouth Road, 1km east of Pembroke crossroads, at N119/813603, on the south side of the road, shows P2B and p2A occurring up near the topsoil.

VARIATION: The pumiceous lapilli are usually loose and well rounded, with negligible ashy matrix. However, in the south where p2B and p2A are thin and difficult to distinguish apart, they merge into white coarse lapilli, referred to as p2, occurring within a friable yellowish-brown ash.

Where p2B and p2A occur under strongly leached soils they are stained dark brown or red by iron/organic illuvial deposits.

p1

The unit informally designated p1 lies beneath p2 and above E5. It was first recognised by Druce (1966). The upper and basal boundaries are distinct but irregular.

The unit p1 has been correlated with Neall's (1972) Korito Tephra, which has a coarse sandy appearance in the east of Taranaki. It has

* Grid reference based on the national thousand-yard grid of the 1:63,360 topographical map series (N.Z. MSI). In this study the maps used were published in 1976.



Manganui
tephra

p2B

p2A
buried soil

p2A
lapilli

p1
buried soil

p1
lapilli



p2B
eroded

p2A

p1
buried soil

p1
lapilli

E5
buried soil

Plate 3.1

Section exposed on Opunake Road, 0.6 km from Mahoe, at N119/741530, showing details of tephras p2 and p1.

This is the type section for p2B, p2A and p1. Length of tape is 1 m.

Plate 3.2

Detail of tephras p2A and p1 (Korito Tephra) Section exposed near Tariki, between State Highway 3 and Railway line at N109/815703.

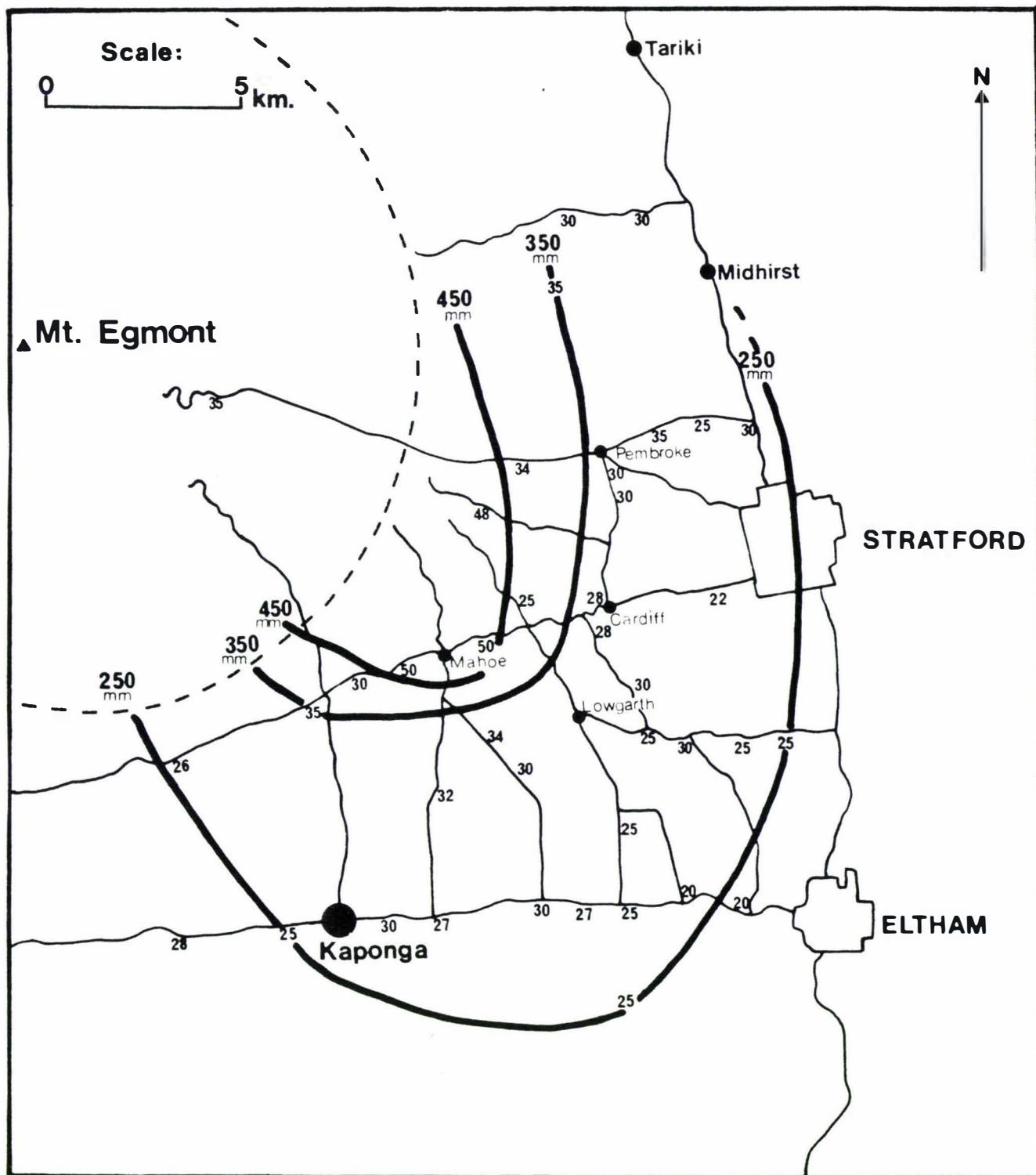


Figure 3.4

Isopach map of unit p2

been dated (NZ3352B) at younger than 5140 ± 150 years B.P.

CRITERIA: The unit is distinguished by 10YR 8/2 (white) pumiceous lapilli, 20mm or less in diameter and contains more lithic lapilli than p2B and p2A (Plate 3.2). It is bounded above and below by buried soils.

TYPE SECTION: The type section is designated on Opunake Road, 0.6km from Mahoe at N119/741530. The two cuttings are well exposed and on the south side of the road and the thickness of p1 varies from 80-100mm.

DISTRIBUTION AND SOURCE: p1 is directed to the south-east of Mt. Egmont, in a similar distribution to that of p2 (Figure 3.4). It is 250mm in thickness in the vicinity of Kaponga and an airfall origin from Mt. Egmont is probable.

REFERENCE LOCALITIES: Two reference localities are designated. The first is a road cutting on Upper Hastings Road, 0.5km from Opunake Road at N119/769544, where p1 is exposed in the east side of the road.

The second section is on the south side of Monmouth Road, 2.7km from its junction with State Highway 3 at N119/815604 (see Section 18, Appendix III).

E5

Unit E5 is informally designated below p1 and above E4. The upper boundary is irregular whereas the basal boundary is distinct and wavy.

The unit has been tentatively correlated with part of the Oakura Tephra, which is dated at greater than 5,000 and less than 7,000 years B.P.

CRITERIA: The unit consists of three informal members:- an upper, spalling layer, comprising 10YR 5/1 (grey) pumiceous lapilli, averaging 5mm in diameter and lithic lapilli, averaging 10mm in diameter. A middle layer of speckled 10YR 4/4 (dark yellowish-brown) coarse ash, averaging 60mm in thickness, separates the upper lapilli member from a basal lapilli of 10YR 8/1 (white) pumiceous and lithic lapilli, greater than 20mm in diameter (Figure 3.5 and Plate 3.3).

TYPE SECTION: The type section is designated on Upper Palmer Road, east

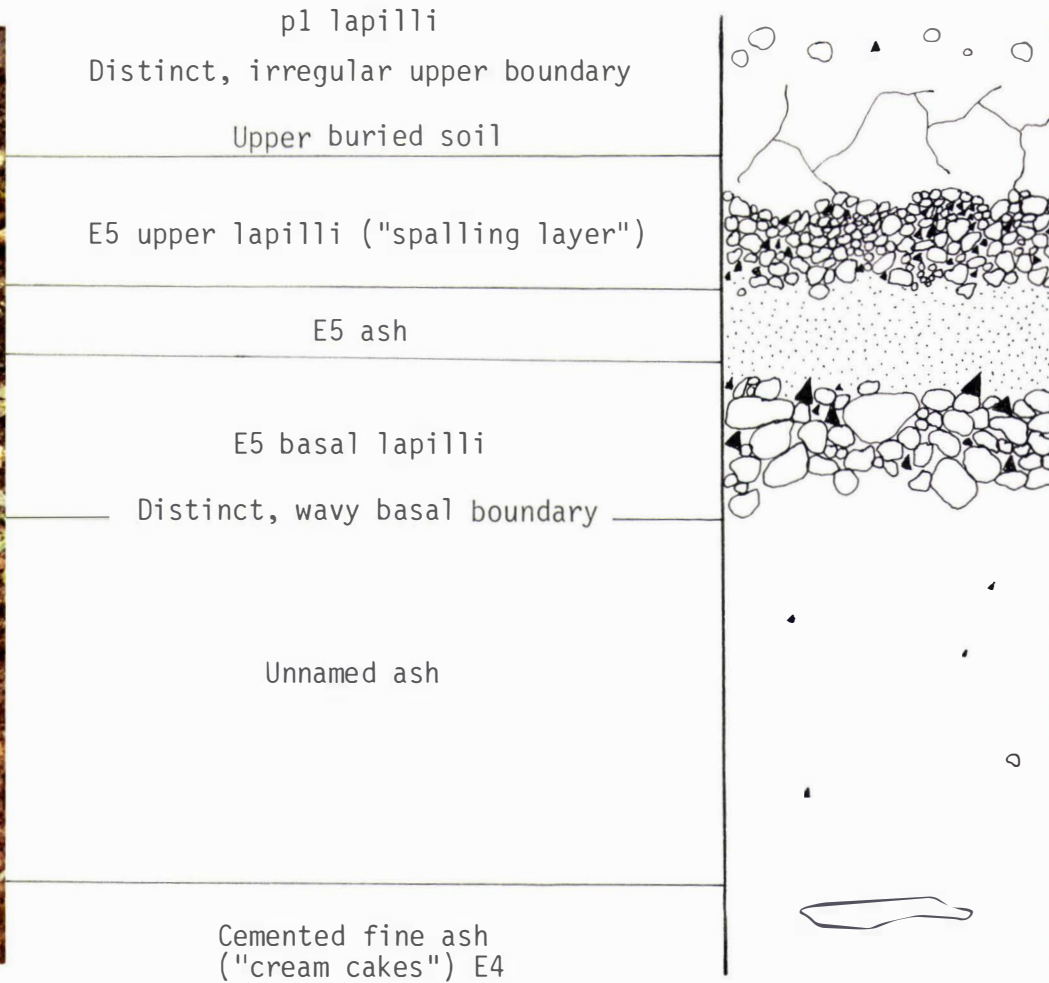
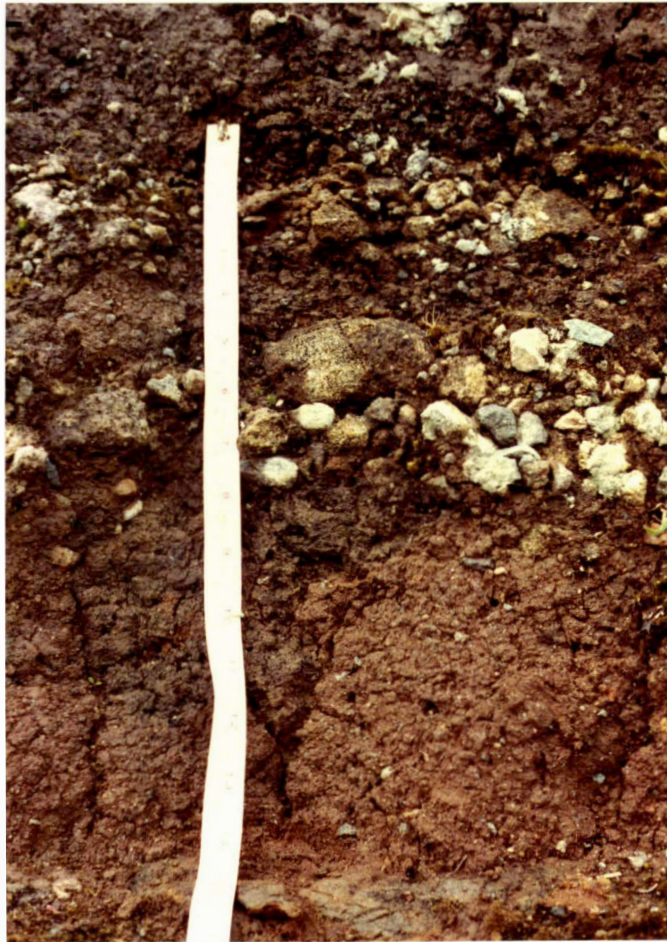


Plate 3.3

Detail of section exposed at Mahoe, on Opunake Road at N119/754532.

bank by the Mangatoki Stream bridge, 1km from the junction with Opunake Road at N119/746545.

DISTRIBUTION AND SOURCE: The isopach map shows the axis of distribution of E5 to be directed south-east from Mt. Egmont, through Mahoe to Lowgarth, with the 100mm isopach passing through Kaponga and Stratford (Figure 3.6).

REFERENCE LOCALITIES: Three reference localities are designated. The first two are road cuttings on Opunake Road; (i) 0.4km from Mahoe in the north road bank at N119/744533. (ii) 0.8km from Mahoe on the south side of the road at N119/738528. A third reference locality is within a cutting on Upper Hastings Road, 0.5km from Opunake Road, at N119/769544.

VARIATION: A section at the top of Waingongoro Road at N119/748586 shows blocks of pumice in the basal layer. Towards the south, the upper spalling layer decreases in grain size to a 10YR 5/6 (yellowish-brown) coarse ash and may pocket.

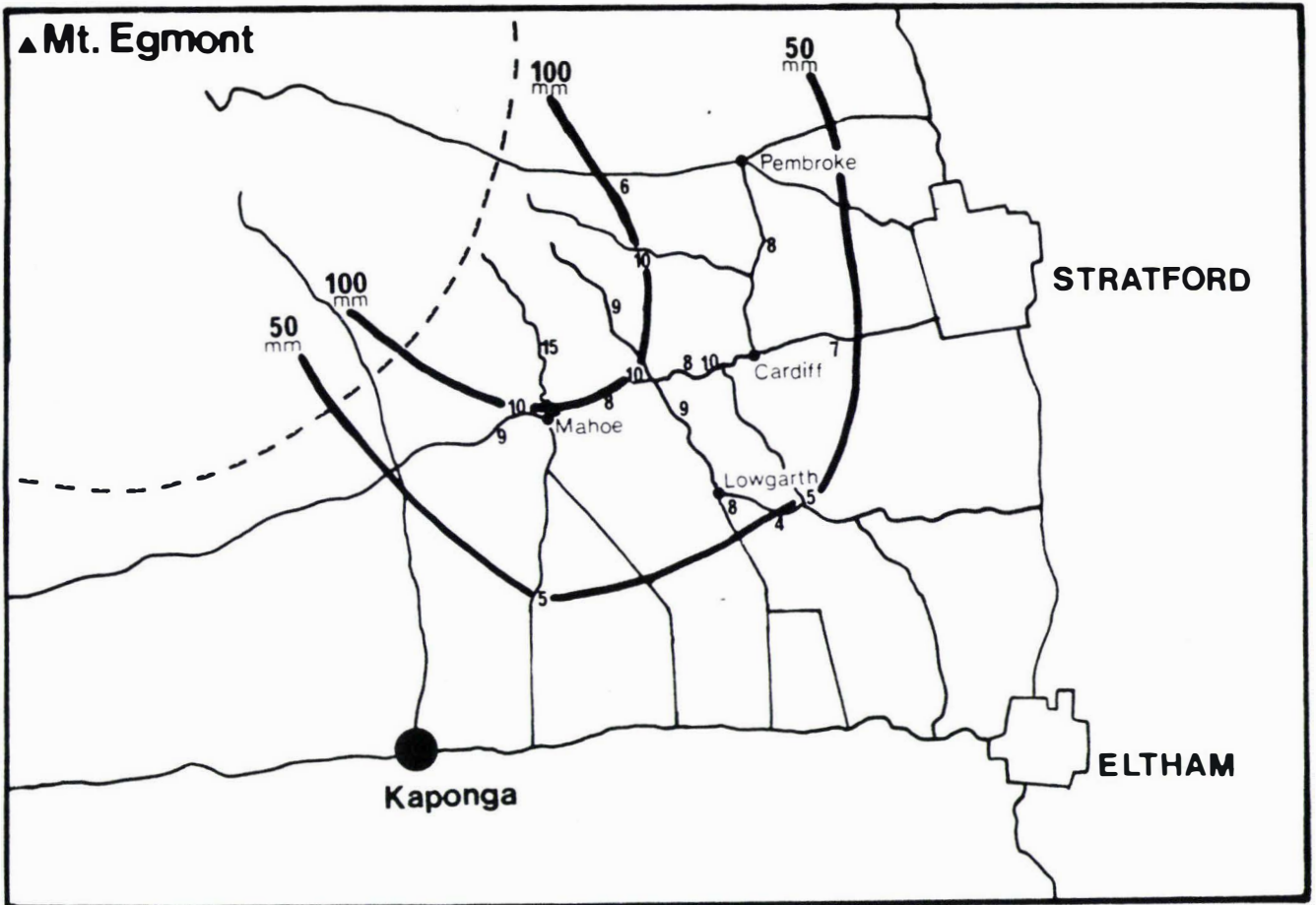
E4

This unit lies beneath E5 and above E3 and acts as an important marker bed, facilitating correlation throughout the western parts of Eltham and Stratford Counties. The upper contact is bounded by a discontinuous layer of cemented fine ash or "cream cakes". The lower contact is wavy and distinct, upon a buried soil developed on the E3 tephra.

CRITERIA: The upper member is predominantly lithic towards the top and contains in addition 7.5YR 5/6 (strong brown) pumiceous lapilli averaging 20mm in diameter with pumiceous blocks concentrated on top.

The central member characteristically "spalls" and is internally stratified, with the upper part containing pumiceous lapilli, averaging 20mm and less in diameter and the lower part containing mainly small lithic lapilli, averaging less than 10mm in diameter.

The basal member has an upper lithic rich layer overlying a basal pumiceous layer 10YR 6/4 (light yellowish-brown) averaging 20mm in diameter, with minor lithic lapilli (Figure 3.7 and Plates 3.4 and 3.5).



Upper lapilli

Figure 3.6 Isopach maps of unit E5

Basal lapilli

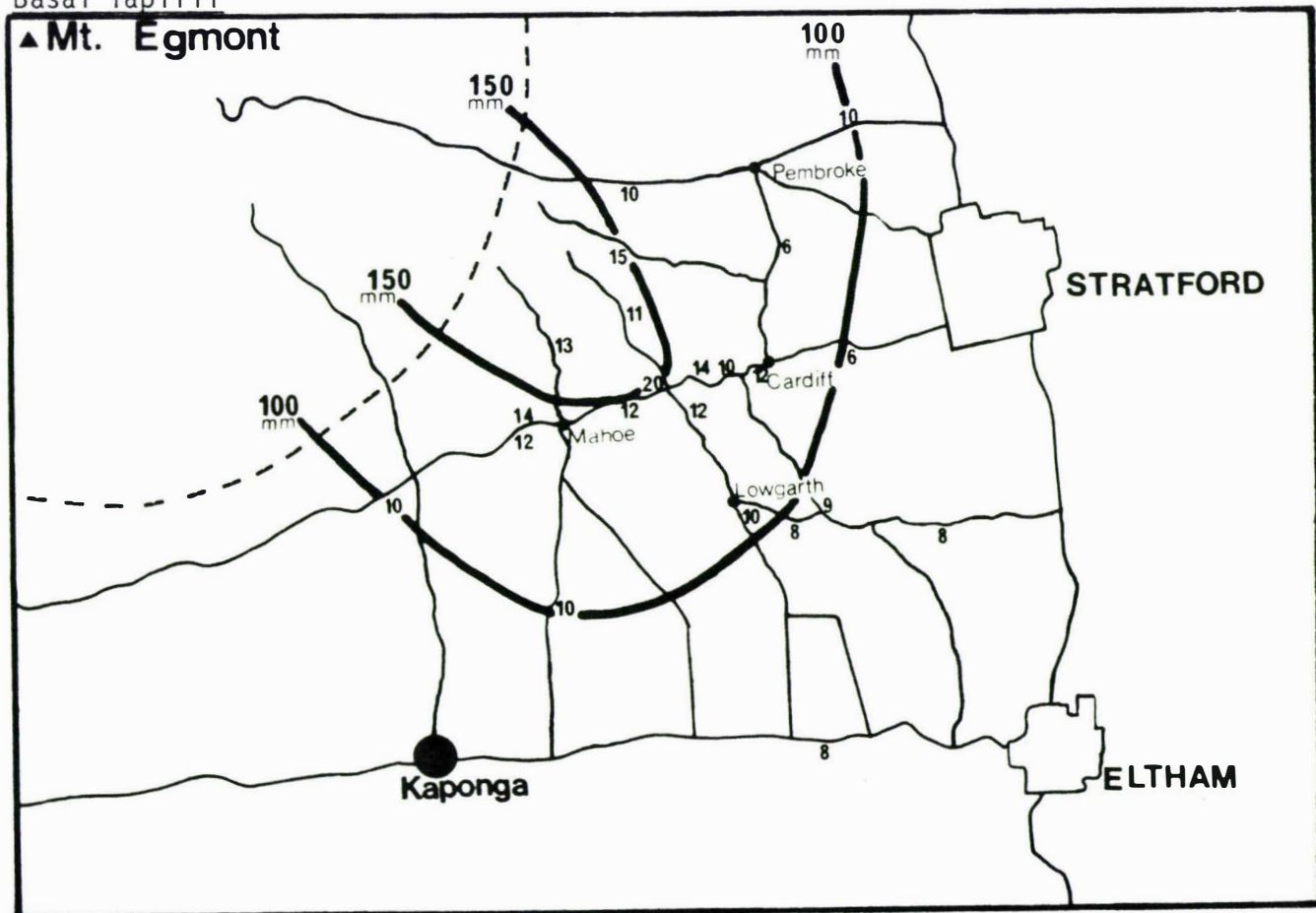




Plate 3.4

View of section exposed on Opunake Road, adjacent to Mangatoki Stream at N119/757532.

This is the type section for E4 tephra (directly above 1.52 m tape). The central, iron-stained "spalling" member of E4 is prominent here.

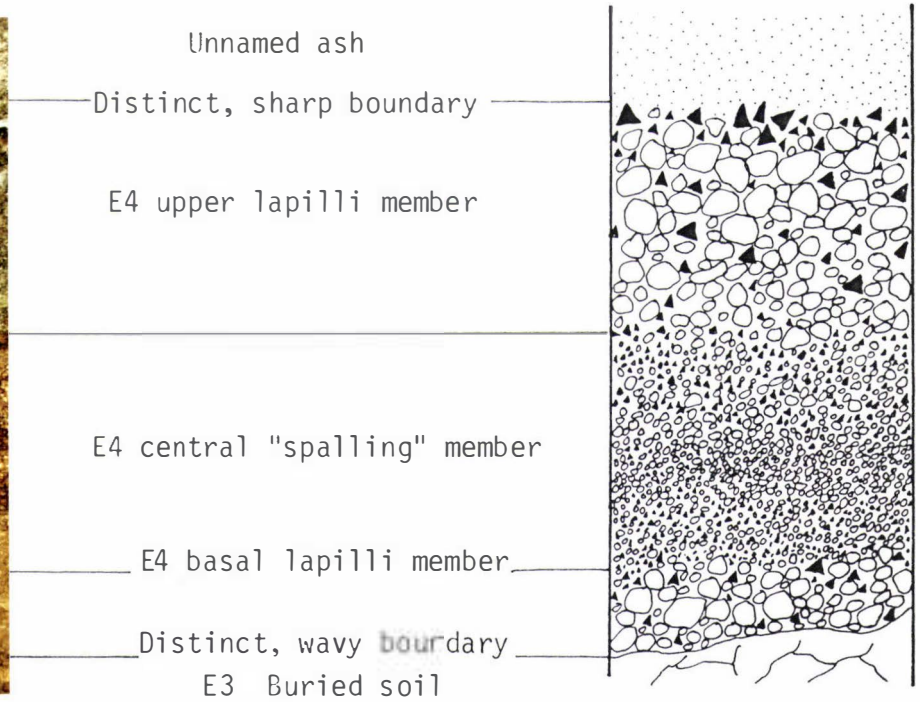
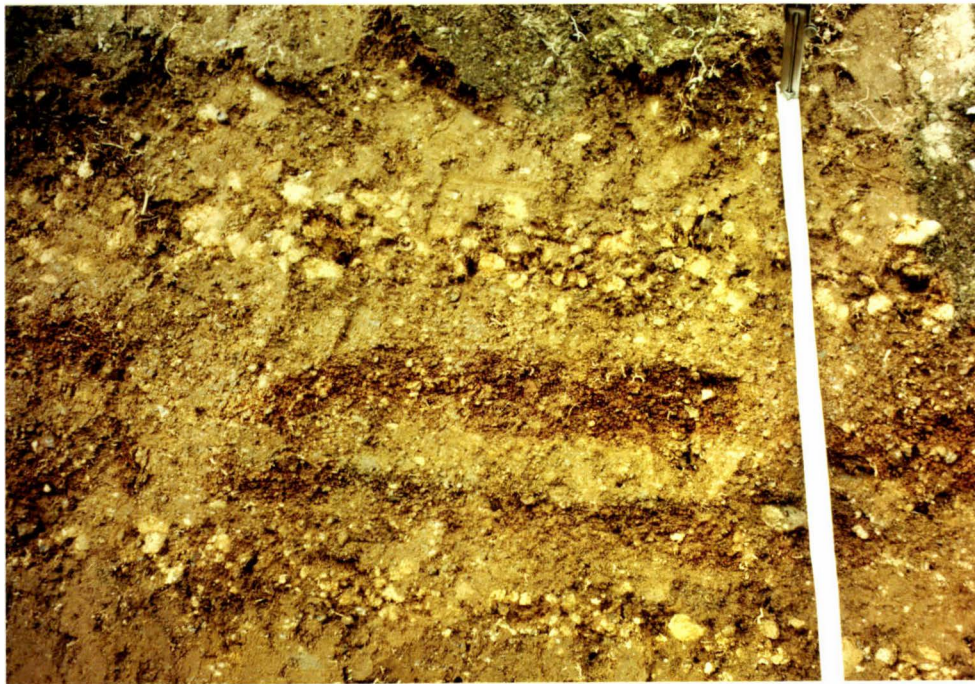






Plate 3.5 Detail of E4 tephra on Waingongoro Road, at N119/748586

Figure 3.7 Appearance of unit E4

-  - Pumiceous lapilli
-  - Lithic lapilli
-  - Buried soil
-  - Coarse ash

TYPE SECTION: The type section is designated on Opunake Road, adjacent to Mangatoki Stream at N119/757532 (see Section 1, Appendix III). There are extensive exposures either side of the road with the best section located on the south side furthest away from the bridge. It is at this section that the unit averages 600mm in thickness.

DISTRIBUTION AND SOURCE: The isopach map shows an axis of distribution to the south-east of Mt. Egmont, with a maximum thickness of 700mm in the vicinity of Mahoe (Figure 3.8).

E4 is of airfall origin from Mt. Egmont.

REFERENCE LOCALITIES: Three reference localities are designated. The first two are on the south side of Opunake Road, 0.4km from Mahoe, at N119/744533 and 0.8km from Mahoe at N119/738528. Both sections are well exposed and demonstrate the "spalling" character of the central member.

The third reference locality is at Pembroke, on the east bank of Cardiff Road at its junction with Pembroke Road at N119/802596. This section best displays the special case of a layer of "cream cakes" in the middle of the central member, as described below.

VARIATION: At certain localities and, in particular at Monmouth Road, Pembroke crossroads, Cardiff Road, Finnerty Road, Eltham Road and Palmer Road, a distinct horizon of "cream cakes" can be found in the centre of the spalling layer. The spalling layer can be excessively iron stained over 400m elevation and can pocket, as for example at the exposure 0.6km from Cardiff on Opunake Road above the Waingongoro Stream at N119/797550.

Near its outer limit of positive recognition, to the south along Eltham Road, E4 resembles a coarse ash, containing an occasional pumiceous block, with fine lithic lapilli representing the spalling part.

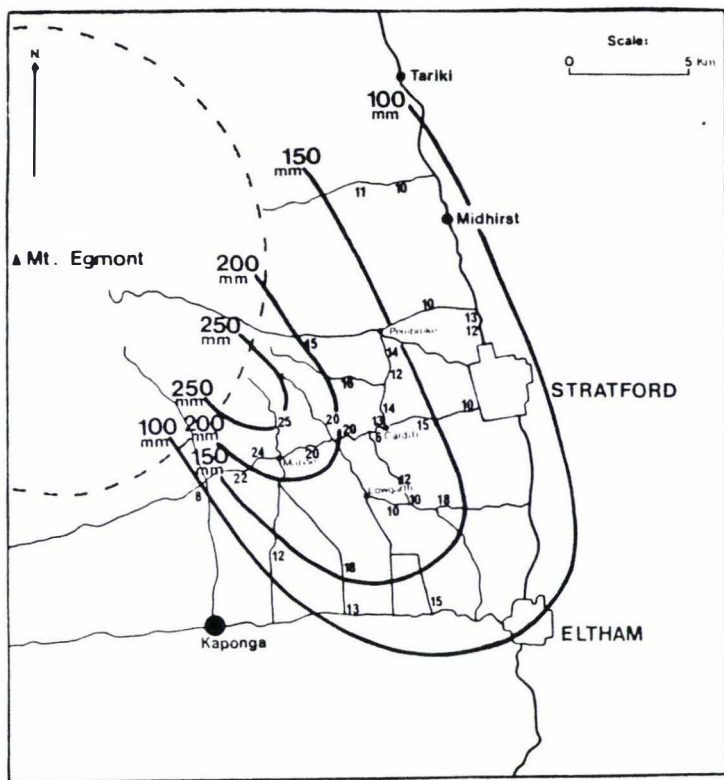
E3

The unit E3 is regarded as the lowermost unit to have been included within the original concept of the Stratford Shower.

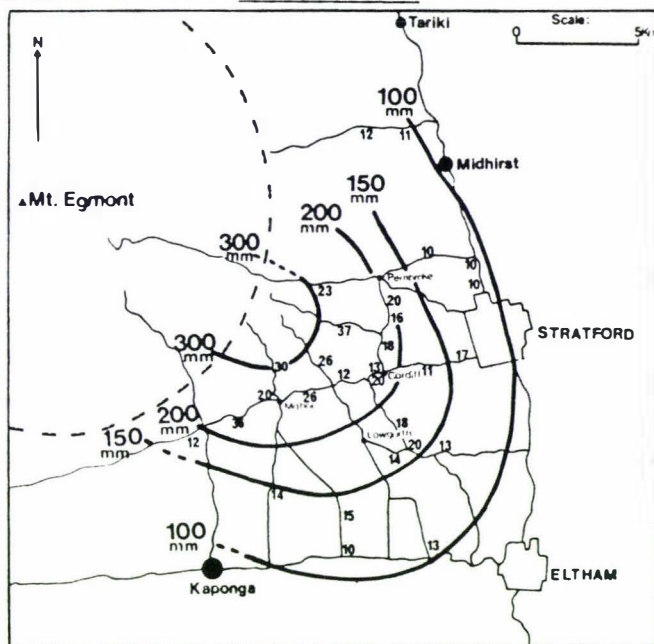
The tephra has been correlated from Eltham County to northern Taranaki (Figure 3.9).

E3 is separated from E4 by a 10YR 5/8 (yellowish-brown) ash in

E4 Upper lapilli



E4 Central



E4 Basal lapilli

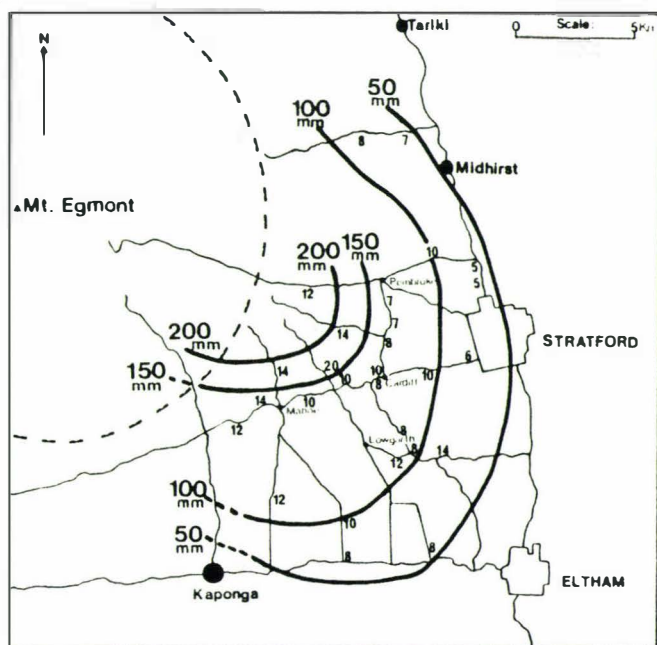


Figure 3.8

Isopach maps of unit E4

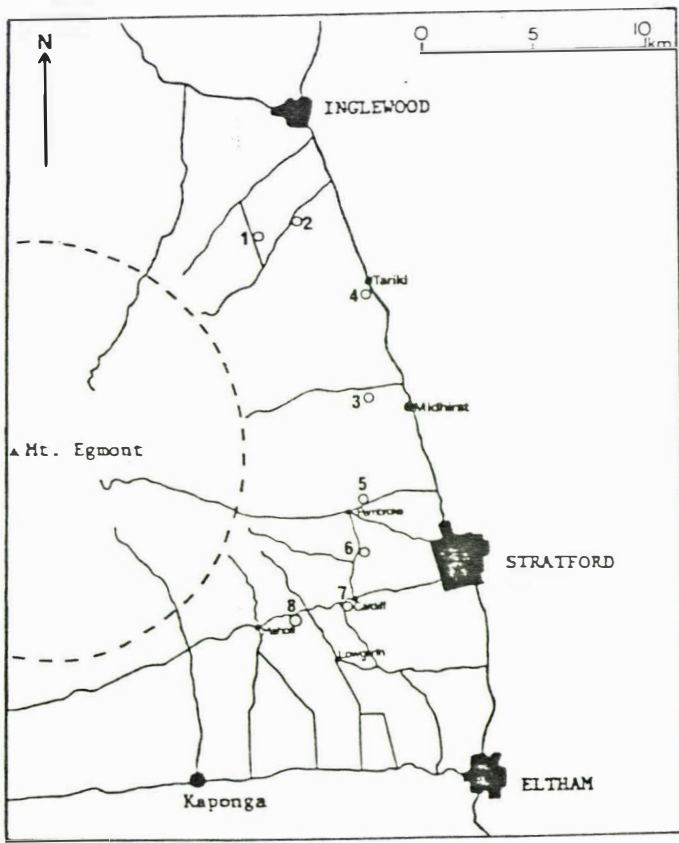
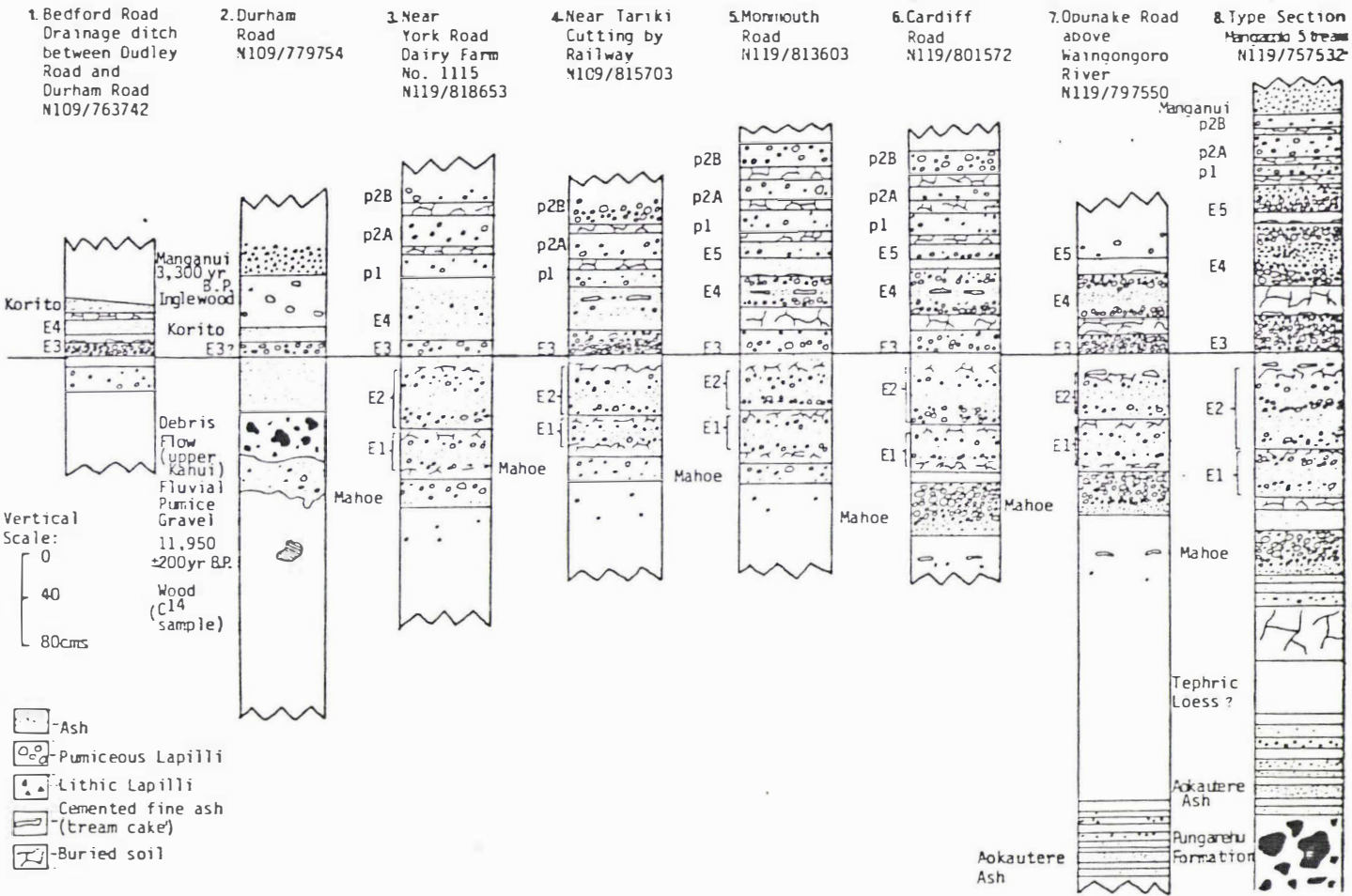


Figure 3.9 Correlation columns 1-8 from near Inglewood to Type Section, Manqatoki Stream

which a buried soil has developed. The lower contact is a distinct, wavy boundary.

CRITERIA: The unit is distinguished by a discontinuous layer of 2.5YR 4/2 (weak red) cemented fine ash ("cream cakes"). The loose, densely packed pumiceous lapilli beneath are inversely graded and vary in colour from 10YR 8/1 (white) to 7.5YR 5/6 (strong brown) and in size from 10 to 20mm diameter. Lithic lapilli less than 20mm in diameter are concentrated in the upper part of the tephra (Figure 3.10 and Plate 3.6).

TYPE SECTIONS: Two type sections are designated. The first is in the east road bank along Upper Palmer Road, at the Kapuni Stream bridge at N119/746497. The second type section is designated beside State Highway 3, near Tariki, in a cutting by the railway line at N109/815703.

DISTRIBUTION AND SOURCE: Isopachs indicate a bi-lobed distribution to the south-east and east from Mt. Egmont. This indicates E3 was probably two closely spaced airfall eruptions (Figure 3.11).

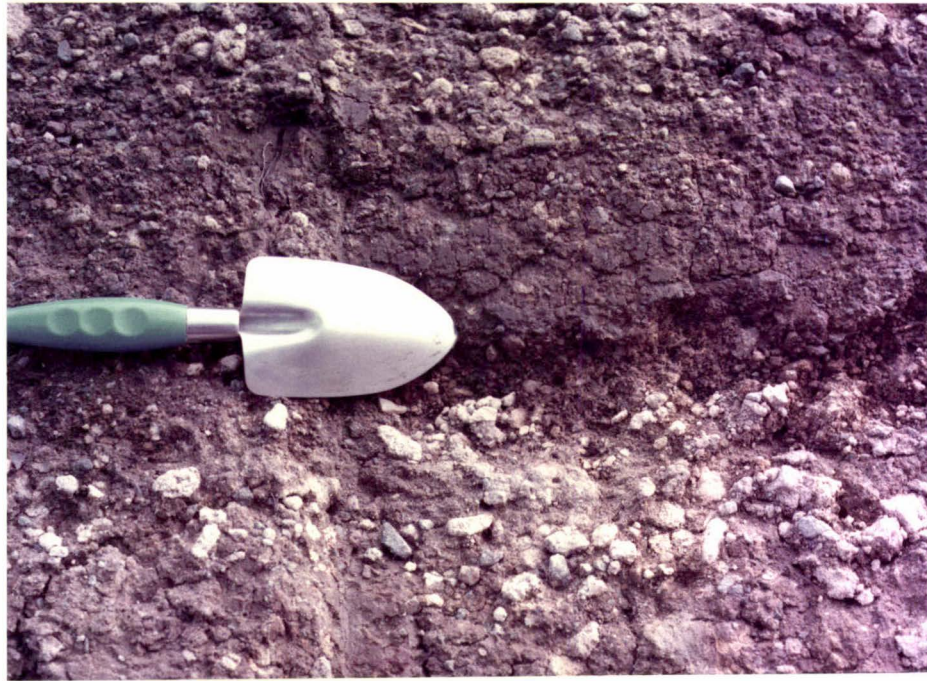
The 150mm isopach extends approximately 16km to the south-east and 19km to the east of Mt. Egmont.

REFERENCE LOCALITIES: Two reference localities are designated. The first is on Opunake Road, adjacent to Mangatoki Stream at N119/757532 (see Section 1, Appendix III). The best exposure is located on the south road bank furthest away from the bridge, where the unit averages 350mm in thickness. The second reference locality is on Monmouth Road, 1km east of Pembroke at N110/813603. There are less lapilli and more coarse ash in E3 at this exposure compared with the first reference locality.

VARIATION: The E3 tephra does pocket and may alter from loose pumiceous lapilli with negligible matrix to become finer and form a coarse ash in the east near Cardiff. The "cream cakes" structure above the pumiceous lapilli becomes massive, averaging 60 to 80mm in thickness, close to source, along Waingongoro Road.

In the south-west on Eltham Road, E3 is still recognised by the presence of distinctive, weak red "cream cakes".

A thin "cream cake" ledge, less than 70mm in thickness, may also



E4 basal lapilli

Sharp, wavy boundary

Buried soil

Discontinuous layer of "cream cakes"

E3 lapilli

Distinct, wavy boundary

Unnamed ash

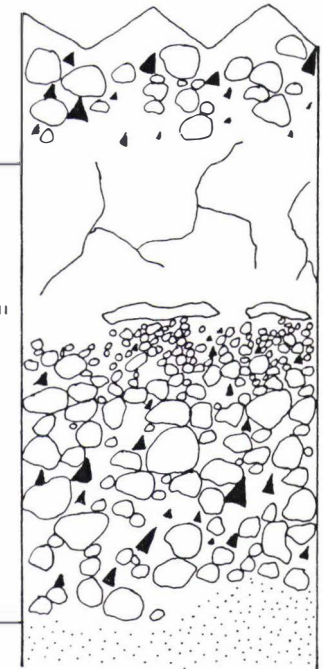







Plate 3.6 Detail of E3 tephra on Pembroke Road,
1.5km south from Barclay Road,
at N119/778597

Figure 3.10 Appearance of unit E3

-  - Pumiceous lapilli
-  - Lithic lapilli
-  - Buried soil
-  - Coarse ash
-  - Cemented fine ash

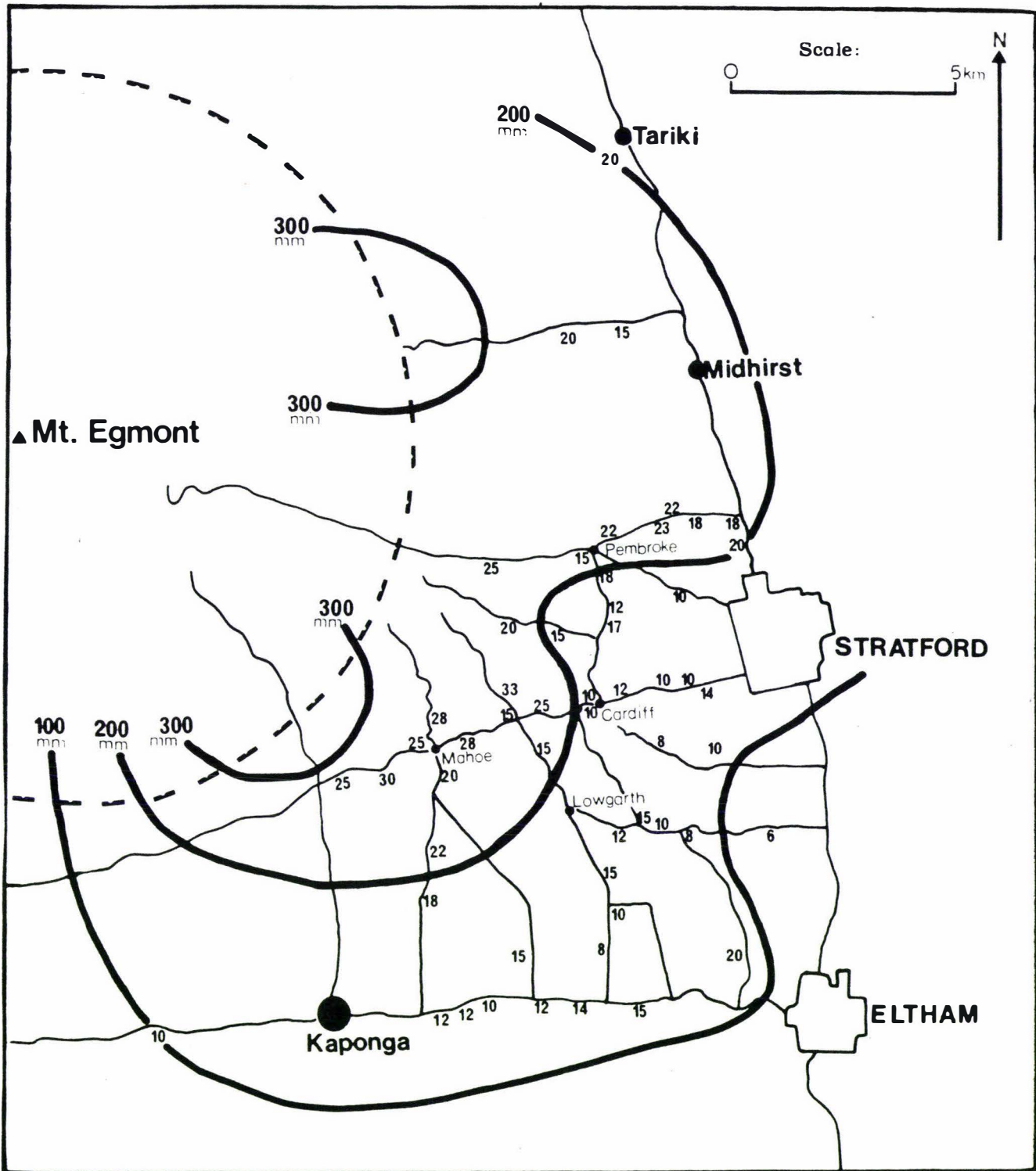


Figure 3.11

Isopach map of unit E3

occur below the buried soil, at the top of E3, with pumiceous lapilli grading downwards to fine pumiceous and lithic lapilli directly beneath (Figure 3.10).

In the north, near Inglewood, there can be a lower member of the E3 tephra, which is absent in the south. It comprises a band of closely packed pumiceous lapilli, 10mm and less in diameter, with a few lithic lapilli, less than 10mm in diameter. The pumiceous lapilli are strongly weathered and form a coarse ash at the base.

Correlation of E3 was possible up to a distance of approximately 20km south from Mt. Egmont.

E2

E2 covers a sequence of airfall tephtras that are exposed beneath E3 tephra in deep road cuttings. E2 can be recognised from the tephra above by its prominent iron stained lapilli. The upper contact of the E2 buried soil is below an unnamed ash and is indistinct. The lower boundary is a distinct bank of coarse pumiceous lapilli.

CRITERIA: There is an alternating sequence of lapilli and ash. A prominent band of coarse strongly weathered pumiceous lapilli and blocks, with minor lithics occurs underneath a lithic lapilli-studded coarse ash. A firm, sandy loam ash separates a very prominent, iron stained, coarse pumiceous lapilli, 5YR 5/8 (yellowish-red) band, which is finer, less than 20mm in diameter, towards the top and in places loose and containing lithic lapilli (Figure 3.12 and Plates 3.7 and 3.8).

TYPE SECTION: The type section is designated 0.6km from Cardiff, in the south road bank, on Opunake Road, above the Waingongoro Stream at N119/797550.

REFERENCE LOCALITIES: Two cuttings are designated on Monmouth Road, the first 1km from Pembroke at N119/813603, in the south road bank. The second cutting occurs 2.7km from the junction with State Highway 3, at N119/815604 and is on the south side of the road (see Section 18, Appendix III). A third cutting on Pembroke Road, 1.5km south from Barclay Road is also designated at N119/778597 and is on the south side of the road.



E2 buried soil

E2

E1 buried soil

E1

Plate 3.7

View of section exposed on Pembroke Road, 1.5 km south from Barclay Road at N119/778597.

This is a reference locality for E2.



Unnamed ash
 Indistinct boundary
 E2 Buried soil
 Lithic lapilli-studded coarse ash
 Prominent band of strongly weathered pumiceous blocks and lapilli, with minor lithics
 Lithic lapilli band
 Prominent basal lapilli
 Distinct wavy boundary
 E1 Buried soil

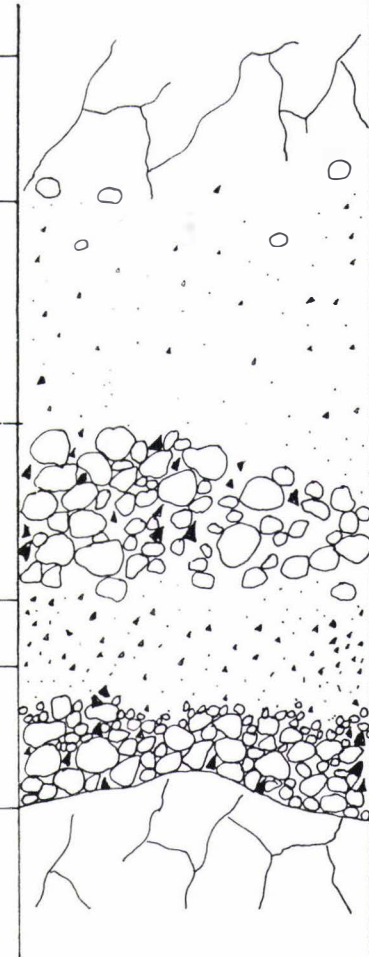


Figure 3.12

Appearance of unit E2

Plate 3.8

Detail of E2 at the type section, on Opunake Road above the Waingongoro Stream, at N119/797550.

DISTRIBUTION AND SOURCE: There is not enough data for isopach maps to be drawn.

The unit E2 is probably the result of either several 'showers' or a closely spaced series of intermittent eruptions.

E1

E1 occurs below E2 in deep road cuttings. The lapilli are heavily iron stained and there is a prominent basal band composed of loose, yet closely packed pumiceous lapilli, which has been correlated with Neall's Ahuahu Lapilli. The lower boundary is distinct and wavy.

CRITERIA: A distinct band of coarse pumiceous lapilli, loose with a little coarse ash, occurs below a buried soil. In the upper part a coarse sandy loam ash, with a few lithic lapilli, 10mm in diameter, grades to a basal band of pumiceous blocks and lapilli and fine lithic lapilli, 5mm and less in diameter, with many mafic crystals (Figure 3.13).

TYPE SECTION: The type section is designated 0.6km from Cardiff, on the south side of Opunake Road, above the Waingongoro Stream, at N119/797550.

DISTRIBUTION AND SOURCE: There is not enough data for isopach maps to be drawn. E1 is of airfall origin from Mt. Egmont.

REFERENCE LOCALITIES: Two reference localities are designated. The first is on Opunake Road, adjacent to Mangatoki Stream at N119/757532 (see Section 1, Appendix III). The unit averages 400mm in thickness, on the south exposure, at the section furthest away from the bridge.

The second cutting is on Finnerty Road at the junction with Ronald Road at N119/810516.

VARIATION: Away from source the pumiceous and lithic lapilli are progressively reduced to scattered blocks and coarse ash which become obscure.

Along the Eltham Road, between Kaponga and Palmer Road, E2 and E1 have a double-banded appearance caused by the two prominent pumiceous and lithic lapilli bands.

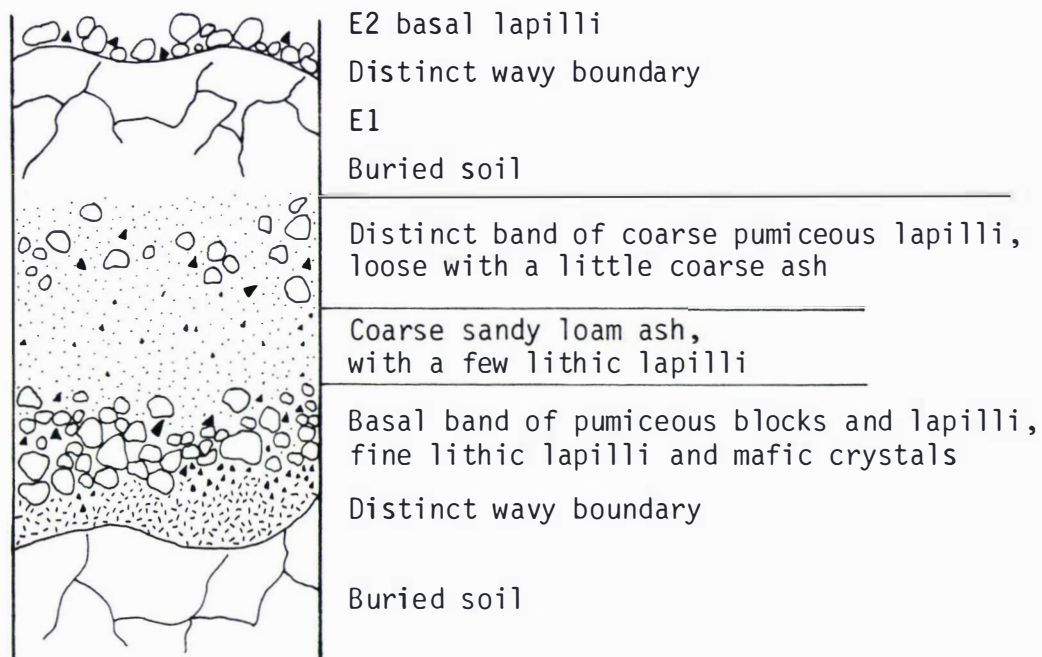


Figure 3.13

Appearance of unit E1

<u>Key</u>		- Buried soil
		- Pumiceous lapilli and blocks
		- Lithic lapilli
		- Mafic crystals
		- Coarse ash

Mahoe tephra

The unit is a prominent tephra at approximately 3m depth in most exposures. The name of this tephra formation comes from the area known as Mahoe, 10km south-west of Stratford, where the tephra is well exposed.

CRITERIA: The closely packed pumiceous lapilli, 7.5YR 5/8-5/6 (strong brown) are firm and have a distinctive 10YR 4/1 (dark grey) internal colour, with a honey-comb appearance. Numerous lithic lapilli, averaging 20mm or greater in diameter, grade downwards to very fine 2 - 5mm lithic lapilli, which form a distinct undulating lower boundary.

The horizon is characteristically loose and strongly iron stained, with 5YR 4/6 (yellowish-red) coatings (Figure 3.14 and Plate 3.9).

TYPE SECTION: The type section is designated on Opunake Road, 0.8km from Mahoe, in the south road bank, at N119/738528. The unit averages 350mm thickness at this cutting.

REFERENCE LOCALITIES: Four reference localities are designated. The first cutting is on Finnerty Road, at the junction with Ronald Road, in the north bank, at N119/810516. The second cutting is 0.6km from Cardiff, on the south side of Opunake Road, above the Waingongoro Stream at N119/797550.

The third cutting is on the south side of Monmouth Road, 1km from Pembroke crossroads at N119/813603.

The fourth cutting is designated beside State Highway 3, near Tariki, in a section by the railway line at N109/815703, where the unit averages 200mm in thickness.

VARIATION: The unit can contain scattered "cream cakes" for example, at the type section exposure, and the fine lithics at the base often pocket, as for example on Opunake Road, adjacent to Mangatoki Stream at N119/757532.

The lithic studded ash, between E1 and Mahoe sometimes contains a minor band of medium pumiceous lapilli, which remains unnamed.



E1 basal band of pumiceous blocks and lapilli, fine lithic lapilli and mafic crystals

Buried soil in unnamed ash
Distinct, wavy boundary

Mahoe tephra

Distinct, undulating boundary
Unnamed ash

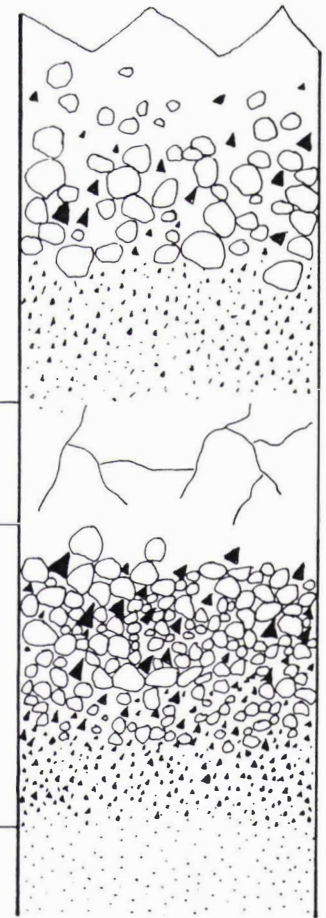


Figure 3.14 Appearance of the Mahoe tephra

Plate 3.9

Reference locality for the Mahoe tephra. The cutting is on Opunake Road, 0.6km from Cardiff, above the Waingongoro Stream at N119/797550

Omahina Tephra

The Omahina Tephra is an important stratigraphic marker, in the south-east of the study area, where it has been identified at two localities. It is a distinctive white, rhyolitic clay and is probably the airfall equivalent of one of the central North Island ignimbrite sheets.

The Tephra has been fission track dated at c. 370 Ka B.P. (Pillans, 1981). Pillan's work has shown that the Tephra overlies wave-cut surfaces within pre-Kaiatea III and Kaiatea III terraces but is absent from within the younger Brunswick cover beds. This indicates that the cutting of pre-Kaiatea III and Kaiatea III surfaces predates the existence of the Omahina Tephra.

The Tephra has been found in the south-eastern hill country of Eltham County, on Rotokare Road at N119/904423 and on Tirimoana Road at N119/922415. The Tephra is well exposed at the latter location (Plate 3.10) where it is 80 to 100mm thick, occurring above volcanic breccias that probably were derived from the Kaitake centre.

ii. THE WESTERNMOST OCCURRENCES OF AOKAUTERE ASH AND IMPLICATIONS FOR THE LATE QUATERNARY IN TARANAKI

The Aokautere Ash (Cowie, 1964) is a rhyolitic ash now recognised as the lower member of the Kawakawa Tephra Formation (Vucetich and Howarth, 1976). The name Kawakawa Tephra is applied where the presence of two or more members of this formation can be demonstrated stratigraphically.

The upper Oruanui Breccia Member, middle Scinde Island Ash Member and Aokautere Ash all originated from the same volcanic episode, centred in the Lake Taupo area, approximately 20,000 years ago.

At the type section on Whangamata Road (N93/373458) the Aokautere Ash Member comprises multiple bedded medium to coarse ash of airfall origin. There is a radiocarbon age (NZ1056A) of 19850 ± 310 years B.P. for wood below the ash (Nairn, 1971).

At least 100mm of the ash was deposited over much of the central and eastern North Island. Pullar and Birrell (1973) indicated that the



Plate 3.10

Section exposed on Tirimoana Road at N119/922415
showing the Omahina Tephra interbedded in andesitic ashes.
The underlying breccia is seen to the right of picture.

most westerly occurrences of 100mm thickness to be in the Wanganui and Otorohanga districts. Previously a 900mm deposit of the ash was recognised by J.F. Aitken near Turuturumokai Pa, Hawera, which led to the discovery of further sites, east of Hawera. Recently a more widespread distribution to the west of the source area has been established in the Eltham-Mahoe-Awatuna district (Appendix II). These are the westernmost localities yet known for the Aokautere Ash and occur between 200-450m elevation and in close proximity to Mt. Egmont (Figure 3.15).

It is significant that in the Hawera area the Ash is overlain by tephra and tephric loess and occurs at depths of 1.5-2m, while to the west, in Eltham County the Aokautere Ash has been located up to 7.5m from the surface beneath a deep tephra sequence with some tephric loess.

The appearance of the Aokautere Ash at Opunake Road near Ronald Road at N119/795550 is:-

80mm thickness thinning to 60mm of 7.5YR 6/4 (light brown) pumiceous sand with a diffuse upper boundary and sharp undulating lower boundary (Plate 3.11).

The distinctive and often conspicuous appearance of the Aokautere Ash as a time plane facilitates the dating of laharic deposits. The Ash occurs less than 1m above volcanic breccias to the south-east of Mt. Egmont and these breccias can be correlated with the Pungarehu Formation, dated (NZ1623A) at $22,100 \pm 600$ years B.P. These surfaces were formerly mapped as Lepperton Lahars (Hay, 1967) and ascribed to a frigid climatic period prior to the Stratford Lahars, which were known to be older than 45,000 years (Grant-Taylor, 1970). These dates are no longer tenable. The former collapse of Mt. Egmont about 22,000 years ago must now be regarded as having been a much larger event than was previously appreciated, probably representing a Bezymianny-type explosion and collapse.

The thickness of tephric and associated materials excluding laharic and alluvial deposits, that have accumulated above the Aokautere Ash, in Taranaki, have been plotted (Figure 3.16). Where the Aokautere Ash has not been positively identified data on the thickness of materials above the Pungarehu Formation (c. 22,000 years old) and the Saunders Ash (c. 17,000 years old) have been included. The isopachs for these materials indicate that during the last 20,000 years there has been more than 7m accumulation of tephra in the vicinity of Mt. Egmont.

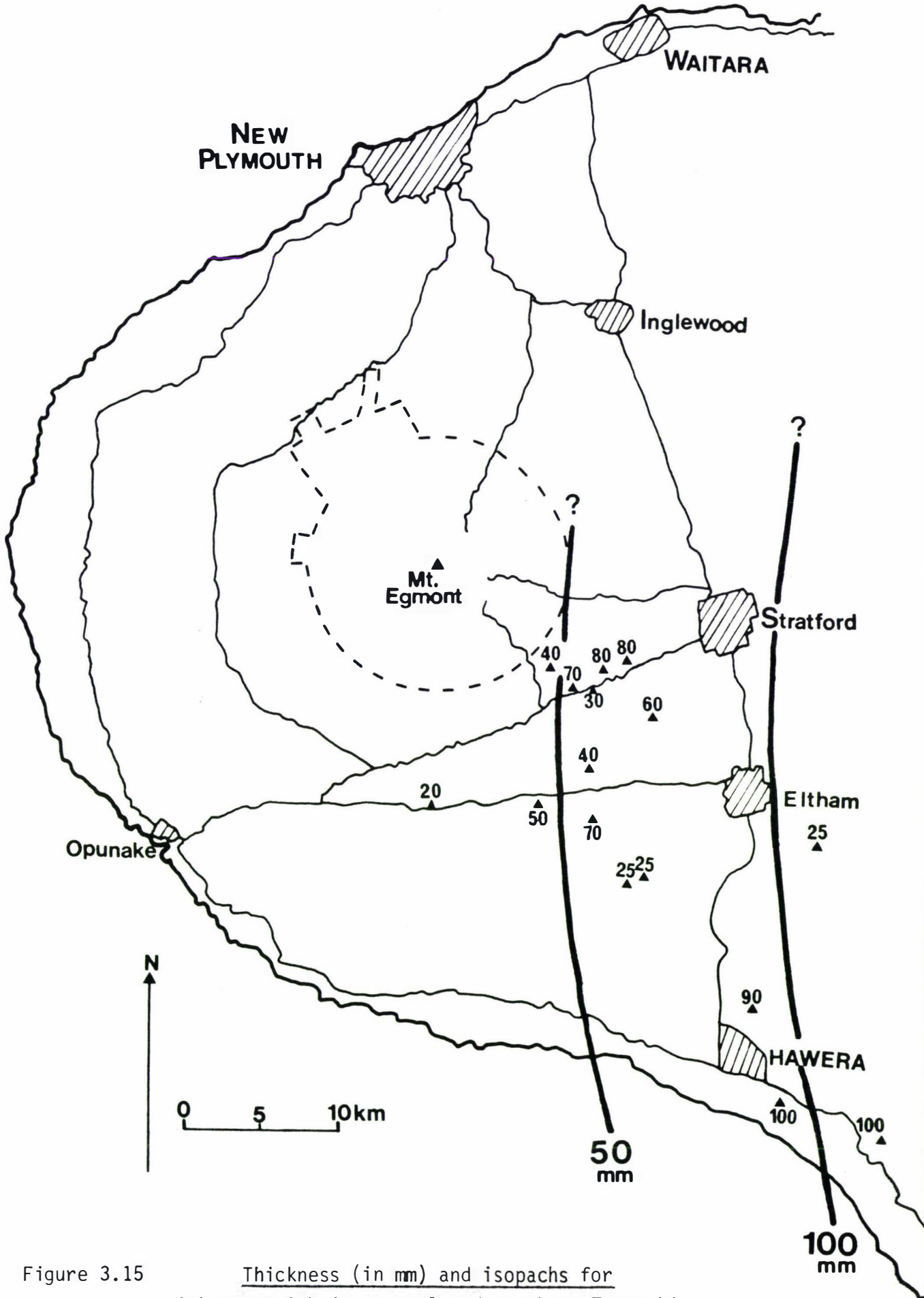


Figure 3.15 Thickness (in mm) and isopachs for Aokautere Ash in central and southern Taranaki



Scattered coarse pumiceous lapilli
10YR 4/2 speckled ash
Densely packed pumiceous lapilli with fine lithic lapilli
10YR 6/4 fine ash
Densely packed pumiceous lapilli Speckled 2.5Y4/4 ash with pumiceous and lithic lapilli
Pumiceous lapilli with lithics
Lithic studded 10YR 5/6 ash
Scoriaceous lithic lapilli
10YR 5/4 and 10YR 4/1 fine ash
Aokautere Ash
Lithic studded ash

Plate 3.11

Section exposed in paddock adjacent to Opunake Road, near Ronald Road at N119/795550.

The Aokautere Ash is 80 mm thickness thinning to 60 mm, with a sharp base at a depth of 7 m.

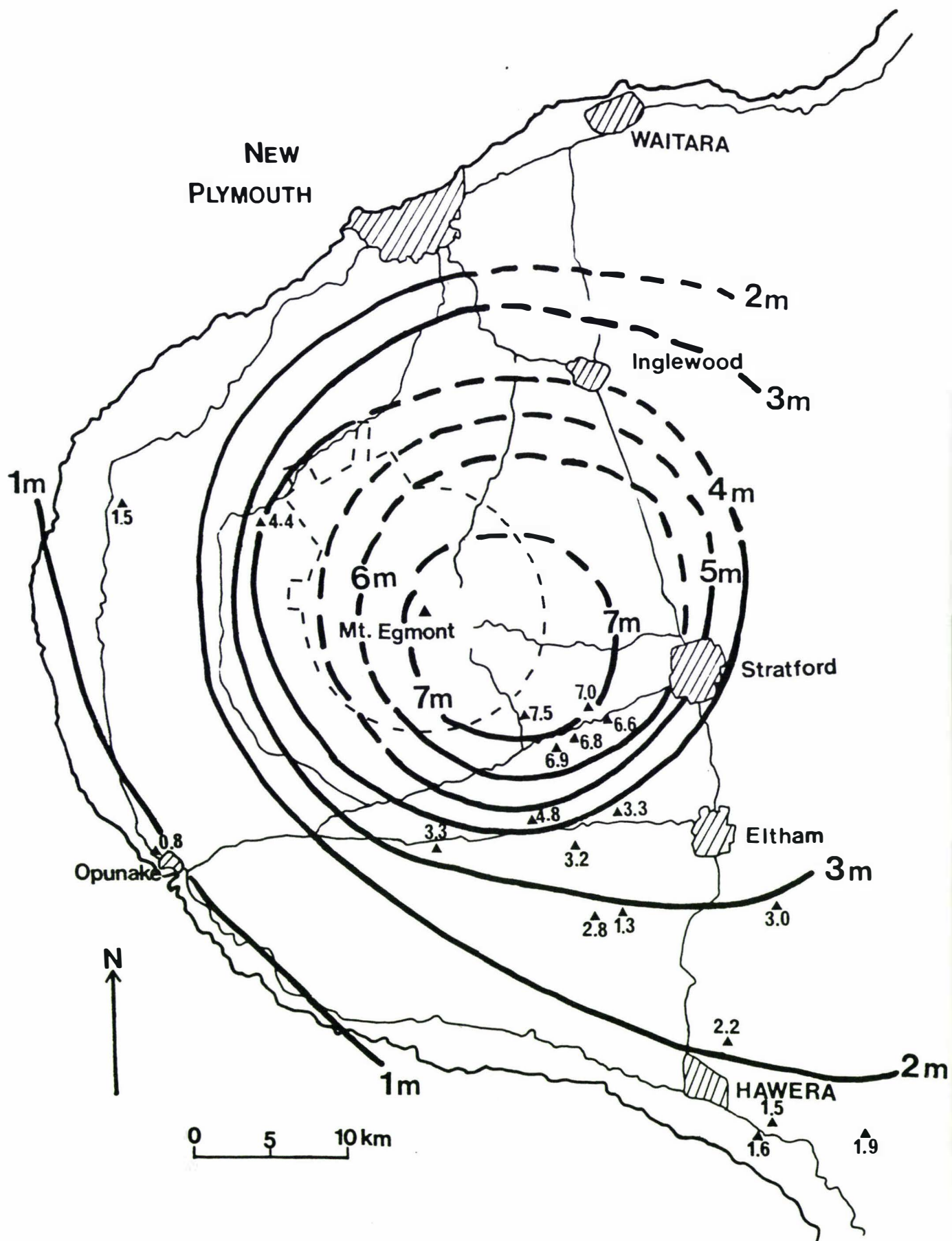


Figure 3.16 Isopachs (at 1m intervals) of tephric materials post-20,000 years B.P., in Taranaki

Thicknesses are plotted from ground surface to the base of the Aokautere Ash. Lahar and alluvial deposits have been excluded from thickness values. Thicknesses west of Mt. Egmont, where Aokautere Ash has not been identified, are based on locally dated deposits of similar age to the Ash.

CHAPTER 4

CHAPTER 4

MINERALOGICAL IDENTIFICATION
OF CENTRAL TARANAKI TEPHRAS1. PREVIOUS WORK

In an early account of the eruptive rocks of New Zealand, Hutton (1889) referred to the volcanic rocks of Mt. Egmont as hornblende, augite and olivine andesites. Later, Marshall (1908) named them hornblende-augite andesites although mentioning that hornblende is completely resorbed in some of them. Marshall, also described augite-free hornblende andesites from the Kaitake and Pouakai Ranges and identified olivine in some of the andesites from Mt. Egmont. Clarke (1912) noted the occurrence of hypersthene in some of the Taranaki andesites but recognised only hornblende and augite andesites in rocks described as agglomerates near New Plymouth. Morgan and Gibson (1927) found hypersthene was not present in any of the thin sections of andesites they observed from Egmont Subdivision. They noted that augite was common to all andesites from Egmont and that hornblende never exceeded augite and was absent from some of the andesites. They also described hornblende augites, some with biotite, and others without augite from the Pouakai Range. Attention was also drawn to the frequent occurrence of xenoliths, particularly of other andesites, in the lavas.

Gow (1967, 1968) attempted to show the major trends of petrographic variation in Egmont andesites by examining detrital andesite boulders from the Rapanui Formation. In addition to the commonly acknowledged hornblende andesites Gow identified several other varieties, including augite andesites completely devoid of hornblende and basaltic andesites containing up to 7% modal olivine. In his detailed petrological study a classification based on the relative abundance of ferromagnesian phenocrysts was adopted. Gow noted that hypersthene andesites were not present and in most of the andesites examined in thin section the composition of plagioclase, augite and hornblende tended to remain constant. This he interpreted as indicating that the variation in chemistry was probably due to differences in the proportions of principal minerals as opposed to any significant change in the composition of the minerals.

All the principal Taranaki tephras are characterised by abundant augite, titanomagnetite and rare hornblende in the heavy mineral assemblages. Analysis of the major and minor elements of titanomagnetites in twelve tephras from northern Taranaki enabled five groups of tephra to be distinguished (Kohn and Neall, 1973). These groups are characterised by specific abundances of chromium, vanadium, nickel, cobalt and manganese. However, individual tephra marker beds, which were capable of being distinguished on field criteria, were not able to be resolved by their titanomagnetite chemistry or optical methods. Bulk chemical analyses offer relative dating estimates due to the rapid weathering of glass in these tephras.

Although criteria such as stratigraphic position and general macroscopic features have enabled tephra to be distinguished within 25km of source, problems of identification arise at greater distances. Here there is increased variability in lithology and weathering appearances of a tephra so that correlation is often only tentative.

The main purpose of this study was to attempt to positively identify and characterise specific central Taranaki tephras using chemical and mineralogical methods. As a final aim, an attempt was made to correlate six tephras found in a drillhole in Eltham Swamp with tephras mapped in northern Taranaki.

2. X-RAY FLUORESCENCE SPECTROMETRY

Introduction:

X-Ray Fluorescence (XRF) analyses were conducted to detect any major chemical differences that may characterise tephra from Mt. Egmont. Samples of seventeen relatively unweathered, coarse tephras, each from at least two different sites near to source, were selected (Table 4.1). Samples were all pumiceous lapilli, with two exceptions of lithic lapilli, the first being the Manganui tephra, the second being the unnamed lithic lapilli above the Aokautere Ash, which for convenience is hereafter referred to as the post-Aokautere lithic lapilli.

Method:

The samples were ground and prepared as lithium borate glass fusion discs, following the procedure of Norrish and Hutton (1969). The discs were

Table 4.1 Major element analyses by X-ray Fluorescence
of a tephra sequence in Taranaki

*Total Fe as Fe₂O₃

†Weight loss following ignition at 1000°C
for 1 hour. All percentages expressed
on oven dried (105°C) basis.

Sample number	Tephra	Locality number (See Appendix 1)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ *	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	MnO	P ₂ O ₅	LOI†	Total	Parker's Index
1.	Kaupokonui	25	55.60	17.65	6.32	2.46	6.35	4.50	2.94	0.79	0.13	0.30	1.57	98.61	87
2.	Kaupokonui	7	51.70	17.40	8.48	3.53	7.65	3.70	2.20	0.95	0.16	0.29	1.17	97.77	84
3.	Kaupokonui	1	49.80	18.00	8.20	3.72	7.40	3.80	1.98	0.96	0.16	0.34	4.89	99.25	79
4.	Maketawa	17	53.40	18.00	7.43	3.23	7.55	4.66	2.21	0.80	0.15	0.26	1.49	99.18	91
5.	Manganui (Upper)	8	46.90	15.95	10.92	6.55	11.0	3.48	1.39	1.19	0.16	0.24	0.23	98.01	90
6.	Manganui (Lower)	8	47.12	16.45	10.92	6.10	10.72	2.76	1.44	1.24	0.14	0.24	0.38	97.51	82
7.	p2B (Dark)	24	54.55	19.40	7.01	2.55	7.67	4.47	2.05	0.80	0.14	0.30	2.07	101.00	83
8.	p2B (Light)	24	52.62	19.21	7.42	2.50	8.00	3.46	1.91	0.85	0.17	0.31	1.71	98.16	74
9.	p2B	5	53.00	19.70	6.27	1.74	6.73	4.70	1.97	0.70	0.15	0.30	4.16	99.42	80
10.	p2A	24	52.40	18.75	7.67	2.95	8.30	5.50	2.10	0.88	0.16	0.33	1.06	100.10	96
11.	p2A	5	52.90	19.20	6.67	2.20	7.09	3.46	2.03	0.79	0.17	0.33	3.55	98.39	72
12.	p2A	17	56.10	18.50	5.68	1.76	6.48	4.70	2.37	0.63	0.16	0.29	1.88	98.55	84
13.	p1	24	53.80	18.66	7.00	2.38	7.48	4.00	2.25	0.85	0.15	0.30	1.58	98.45	83
14.	p1	8	51.90	19.50	7.45	2.50	7.69	3.40	1.96	0.86	0.15	0.34	2.77	98.52	74
15.	p1	5	49.60	20.22	7.84	2.75	7.85	3.40	1.70	0.92	0.15	0.37	4.23	99.01	75
16.	p1	9	50.00	20.00	7.34	2.25	7.07	3.50	1.72	0.85	0.15	0.23	5.07	98.18	73
17.	Post Aokautere lithic lapilli	1	49.20	18.80	10.00	4.10	8.70	4.20	1.41	1.17	0.17	0.26	1.73	99.74	86
	NIM G ^a		75.97 ± 0.74	12.29 ± 0.20	1.95 ± 0.03	< 0.01	0.80 ± 0.01	3.59 ± 0.50	5.09 ± 0.08	0.09 ± 0.01	0.01 ± 0.01	0.02 ± 0.01	0.70	100.51	
	NIM G ^b		75.70	12.08	2.00	0.01	0.78	3.36	4.99	0.09	0.02	0.01	0.70	99.74	

* Mean values and standard deviations obtained for NIMROC granite
NIM-G (5 analyses) during this work. Reported values for
NIM-G (Steel and Hansen, Geostandards Newsletter, October 1979).

$$\text{Parker's Index} = \frac{(\text{Na})_a}{0.35} + \frac{(\text{Mg})_a}{0.9} + \frac{(\text{K})_a}{0.25} + \frac{(\text{Ca})_a}{0.7} \times 100$$

To convert oxide to element x by 0.7419(Na), 0.8302(K), 0.7147(Ca)
and 0.6031(Mg).

produced in duplicate, with similar discs made as blanks. The XRF analysis was conducted by Mr. J. Hunt, Soil Bureau, DSIR.

Results:

Results of the analyses are given in Table 4.1. There is a marked difference in values obtained for lithic lapilli compared with pumiceous lapilli. This reveals that the Manganui tephra and post-Aokautere lithic lapilli are basaltic in composition, with lower SiO_2 , Al_2O_3 and K_2O values and higher MgO , CaO and Fe_2O_3 ($\text{FeO} + \text{Fe}_2\text{O}_3$) values than the pumiceous tephtras. These differences in major element chemistry are reflected in the mineralogy, with olivine occurring in the lithic lapilli but absent from the pumiceous lapilli.

In contrast, the XRF analyses of pumiceous lapilli are similar to previous analyses of Egmont andesites. The K_2O and Al_2O_3 contents of the pumiceous tephra are high being distinctly higher than those from the Tongariro andesites of the central North Island volcanic zone. Egmont andesites contain appreciably more alumina (over 16% than most andesites (Gow, 1968), hence the basic members trend into the high-alumina basalt field (Figure 4.1). There is a marked variance in the K_2O contents of the pumiceous lapilli. The Kaupokonui, p2A and p1 tephtras would on their combined K_2O and SiO_2 contents be classified in the high-alumina basalt region, while the Maketawa and p2B tephtras are in the low-silica andesite region. However, these values may also be explained by loss of SiO_2 during weathering. The higher K_2O values would support the idea that weathering has been minimal and these are realistic high-alumina basalts.

Discussion:

In order to differentiate whether the analyses represent high-alumina basalts or weathered andesites, it is necessary to investigate the degree of weathering of the samples.

A reliable index of weathering for silicate rocks where hydrolysis is the main cause of silicate weathering (Neall, 1976) is Parker's Index (P.I.). It relates the atomic mass to atomic proportions of Na, K, Ca and Mg, which are considered to be the most mobile and thus sensitive of the major elements to weathering (Parker, 1970). From the XRF analyses, P.I. was determined for each sample (Table 4.1).

The rate of tephra weathering is thought to be determined primarily by precipitation (Ruxton, 1968) but is also influenced by soluble organic compounds derived from vegetation (Antweiler, 1981).

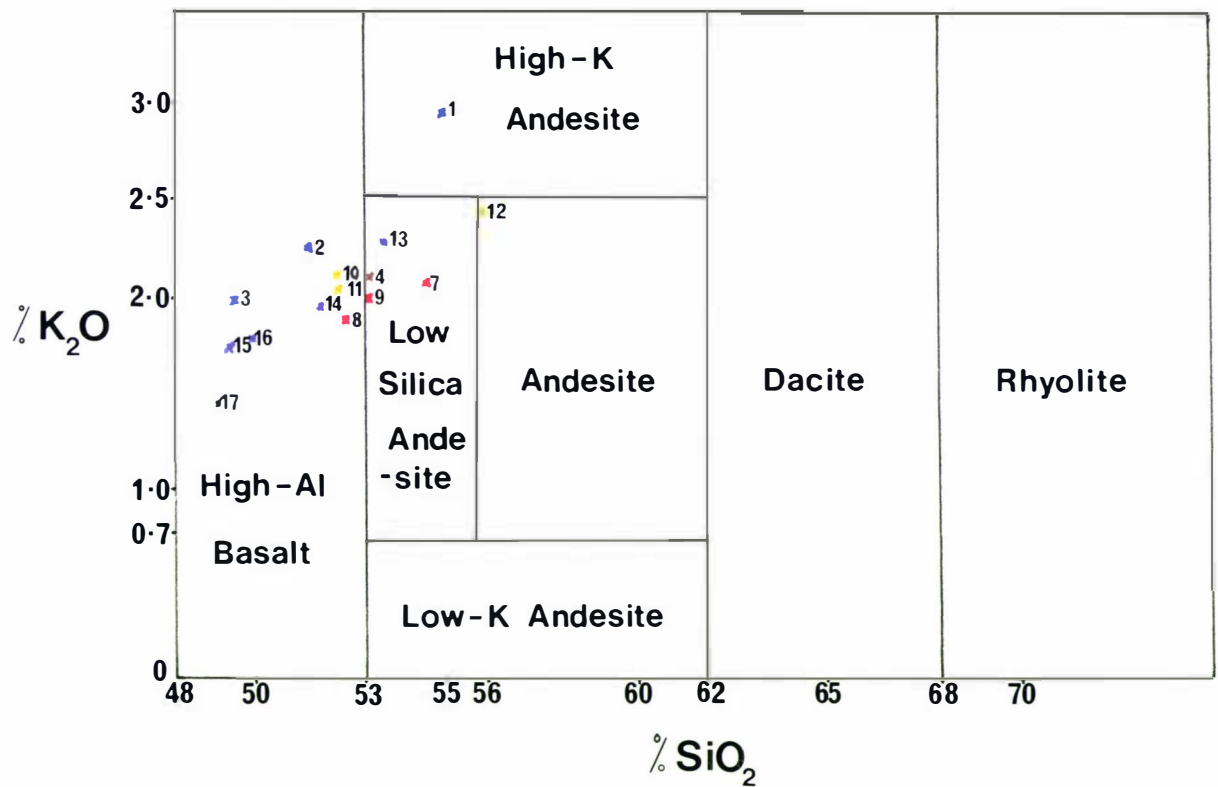
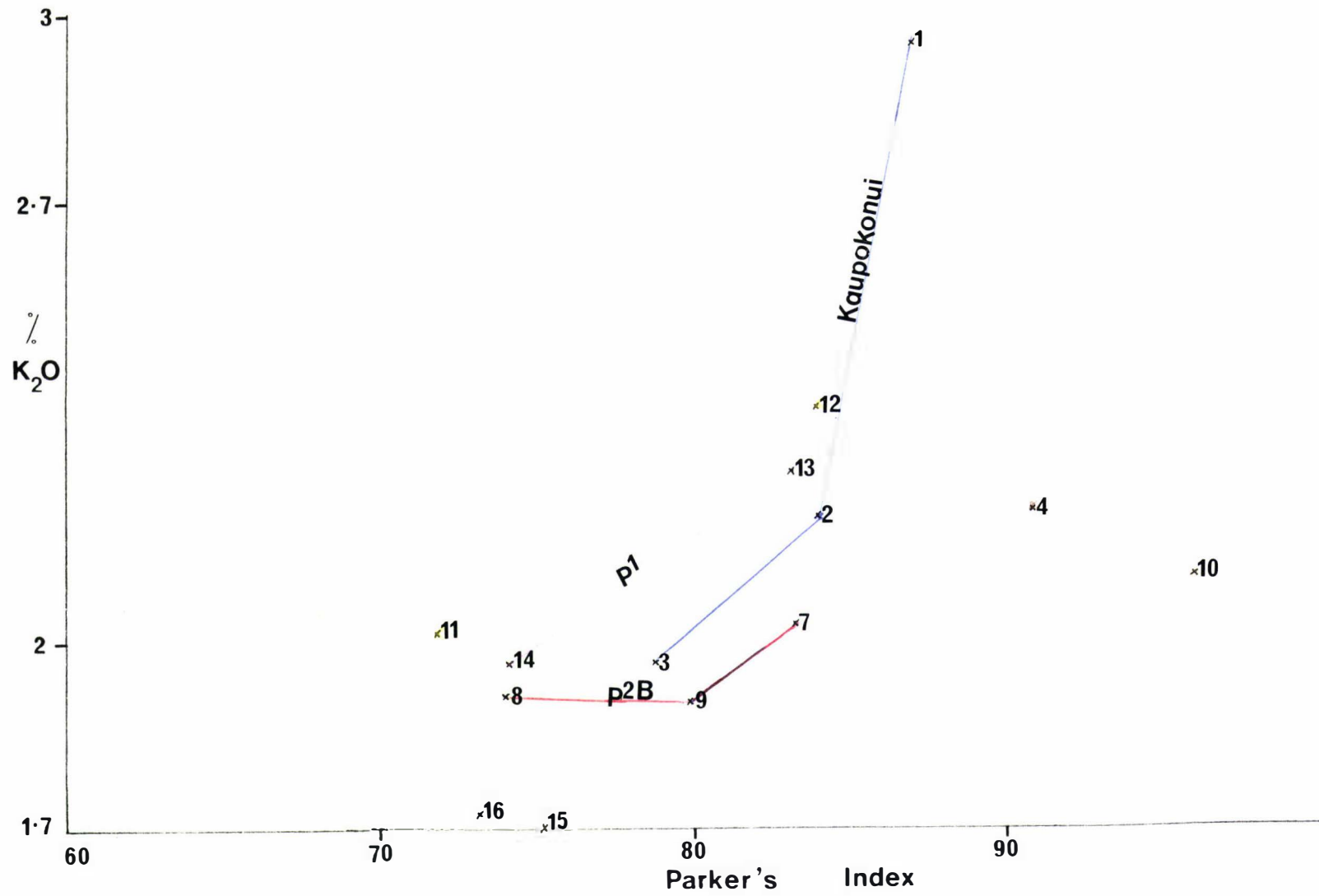


Figure 4.1 Classification of rocks "typically associated with andesites in orogenic areas"
 (after Taylor S.R., 1969 p45)

Figure 4.2

Parker's index versus % K₂O for the pumiceous lapilli



An inverse relationship between elevation and exchangeable Mg content was observed by Turner et al., (1978) that was attributed to differences in soil texture and rainfall with distance from Mt. Egmont because of greater leaching of Mg at higher elevations. In this study coarse, near to source tephras occurring in high rainfall areas (>2600mm) showed higher P.I. values than distal tephras of the same age, in lower rainfall areas (Table 4.1). For example, tephra p1 (samples 13-16) shows such a trend of decreasing P.I. with increasing distance from source (Figure 4.2), suggesting that decreasing grain size and increasing mean annual temperature has a far greater effect on the weathering of pumiceous lapilli than rainfall in Taranaki.

Thus, analyses of the distal tephras (samples 3,9,11,15,16,17) are less likely to be reliable indicators of original rock composition compared to the near to source (samples 1,2,4,5,6,7,8,10,12,13,14) coarser tephras. This suggests that samples 3 (Kaupokonui), 11 (p2A) and 15,16 (p1) are not realistic high-alumina basalts.

3. CHEMICAL ANALYSES OF TITANOMAGNETITES FROM TARANAKI TEPHRAS

Introduction:

The purpose of this investigation was to use elemental variation in titanomagnetite composition as a means of identification of the pumiceous lapilli described and mapped in this study. Induction coupled plasma emission (ICP) at DSIR, Palmerston North was a readily available means for a multielement analysis. Thus, this investigation became a pilot study into the use of ICP on the element contents of titanomagnetite.

Titanomagnetite was chosen since it is common to all the tephra samples and it has been shown to be relatively stable during weathering (Aomine and Wada, 1962; Ruxton, 1968). In addition, it can be simply extracted in a relatively pure form with the use of a magnet, and its range in chemical composition is considerable (Ewart, 1967; Momose et al., 1968; Duncan and Taylor, 1968).

Samples collected for this study were from locations both close to and distal from source (Table 4.2). Samples 25-29 were from northern Taranaki.

Table 4.2 Chemical analyses of titanomagnetites from Taranaki tephras

Sample number	Group	Tephra + locality no. (See Appendix I)	Elements (ppm)						
			Co	Cr	Cu	Mn	S	Sr	Zn
1		p2B 24	185	223	161	5725	854	35	1008
2		p2B 17	133	115	131	9023	816	27	1385
3	A	p2B 5	137	110	132	8248	904	34	1302
4		p2A 24	244	297	178	6444	820	44	1159
5		p2A 5	192	261	348	7578	811	21	1284
6		p2 16	146	409	181	8647	848	32	1375
7		p1 24	201	295	164	5732	737	38	1032
8	B	p1 5	213	182	252	6298	822	36	1322
9		p1 16	136	141	175	8567	918	39	1446
10		E5 1	175	190	273	6692	709	28	1240
11	C	E5 6	171	191	138	7044	750	28	1229
12		E5 12	164	192	94	6720	707	17	1163
13		E4 Upper 1	212	127	171	5950	726	44	1128
14		E4 Upper 12	196	126	<65	6120	625	23	1084
15	D	E4 Central 1	216	185	128	5516	650	33	1064
16		E4 Central 12	(304)	(926)	(132)	(7739)	(539)	(117)	(11340)
17		E4 Basal 1	156	<85	186	5942	686	30	1170
18		E4 Basal 12	174	<85	122	6448	610	13	1157
19		E3 1	166	116	81	5642	649	33	1088
20	E	E3 6	193	151	88	5088	631	35	992
21		E3 16	173	172	<65	5230	639	17	1023
22		Mahoe 1	304	359	187	4122	692	14	856
23	F	Mahoe 6	293	150	207	4404	643	24	885
24		Mahoe 12	306	126	287	4361	688	13	952
25		Inglewood 26	196	302	170	6344	714	22	1208
26		Korito 26	125	182	<65	4848	<346	32	756
27	U	Korito 27	196	121	135	6397	657	18	1160
28		Lower Korito ? 23	214	164	206	6217	729	15	1172
29		E3 23	246	318	308	5590	692	27	1091
30		E2 12	314	240	300	4963	695	20	1021

Experimental procedure:

The samples were ground in an agate mortar and a Frantz Isodynamic separator was used to separate ferromagnesian minerals in the size range 2-4 ϕ (250-63 μ). Titanomagnetite was extracted by a hand magnet and the titanomagnetite concentrates purified by repeated grinding under acetone followed by further repeated magnetic separations.

The titanomagnetite samples were fused with a lithium tetraborate flux, composed of:-

- 60 parts $\text{Li}_2\text{B}_4\text{O}_7$ (previously heated to 450 $^{\circ}\text{C}$ for 2 hours)
- 10 parts Li_2CO_3 (heated to 200 $^{\circ}\text{C}$ for 1 hour)
- 1 part RbI

The sample and flux were mixed thoroughly in a ratio of 1:10 (0.1g sample to 1g flux) and placed in a covered platinum crucible heated over a butane air burner. When fusion was complete the base of the crucible was plunged into cold water to shatter the bead and facilitate its removal. Crucible and bead were then placed in 25 mls of concentrated HCl in a plastic beaker and about 50 mls. de-ionised water added. The beaker was placed on a magnetic stirrer until the bead had dissolved and then the solution was filtered into a 250 mls volumetric flask. The beaker was washed and rinsed with de-ionised water to make up to 400 mls volume. In addition to machine standards, six blanks were also included. Of these one was spiked with 1 ppm Co, Ni, Cu and Cr, the other with 0.5 ppm Co, Ni, Cu and Cr.

The instrumental determinations were carried out by Dr. J. Lee, Applied Biochemistry Division, DSIR, using an Applied Research Laboratories model 34000 inductively coupled argon plasma-optical emission spectrometer (I.C.A.P. - O.E.S.) with 23 element capability. The elements analysed were:- Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Si, Sn, Sr, Zn.

Instrumentation:

The I.C.P. differs from classical flame, spark and arc discharges in the way in which free atoms are excited. When the sample aerosol is introduced into an inductively coupled radio frequency argon plasma "torch" an emission spectra from atoms and ions can be observed. Magnetic fields readily interact with plasmas and the high frequency currents around the enclosing quartz torch generate an oscillating magnetic field in the plasma. The interaction results in temperatures between 6,000 $^{\circ}$ and 10,000 $^{\circ}$ K causing the sample to be vaporized and excited so that chemical

interactions are negligible. The spatial structure of the plasma allows the atomic emission to be observed above the high background of the plasma itself, enabling large signal-to-noise ratios to be obtained. The practical significance of the plasma source is that analytical sensitivities equivalent to those from the atomic absorption method and often improved for some elements, are achieved with a wider and linear concentration range, in some cases up to five orders of magnitude.

The use of a polychromator for observing the emitted spectra means that the metals or metalloids can be determined simultaneously at the ultratrace, trace, minor and major concentration levels, under one set of experimental parameters.

Interferences may arise from transport, spectral or scattered light effects. A computer controlled moveable primary slit enables the immediate vicinity of any line to be scanned for possible interferences. The coefficients describing the analyte/interferent response functions are stored in an analytical task file and are employed automatically during analysis routines. Reagent impurities are also assessed and corrections made from stored data.

Changes in the physical properties of solutions aspirated into the plasma affect the emission intensities. Viscosity, surface tension and density all have an effect on droplet size and the amount of analyte reaching the observation zone in the torch. In addition it has been shown that an increase in acid concentration of a solution generally results in a decrease in the net intensity of analyte emission (Dahlquist and Knoll, 1978).

Matrix elements can be expected to be a source of potential interference. Efforts were made to minimise matrix effects by dilution. This can, however, result in lowering the original analyte concentration below detection limits. In addition the effect of high levels of certain elements result in plasma fluctuations and suppression or enhancement of analyte signals.

Results:

The results of the analyses are given in Table 4.2. Only those elements that were found to be of quantitative use are shown.

Higher chromium and copper values were found in this study compared with the same tephra analysed by spark emission spectrometry in Kohn and Neall's (1973) study. This is probably a result of the differing analytical techniques used.

Canonical variate analysis was applied to look for combinations of the elements, which maximise the ratio of between-group variance to within group variance. Figure 4.3 indicates how well the groups of tephra can be separated using values of manganese and zinc. Group B (p1 tephra) is the only group on the graph, in which the plotted points were scattered. The other groups show a linear trend with age, with the youngest tephra, p2, having higher values of manganese and zinc and the oldest tephras having lower values.

The identity of samples 28 and 29 from Bedford Road, northern Taranaki was uncertain. The graph indicates that tephra sample 28 could well belong to group D (E4 tephra) and confirms that tephra sample 29 was E3. The titanomagnetite composition of samples 25-27 from northern Taranaki, did not allow firm correlation to be made.

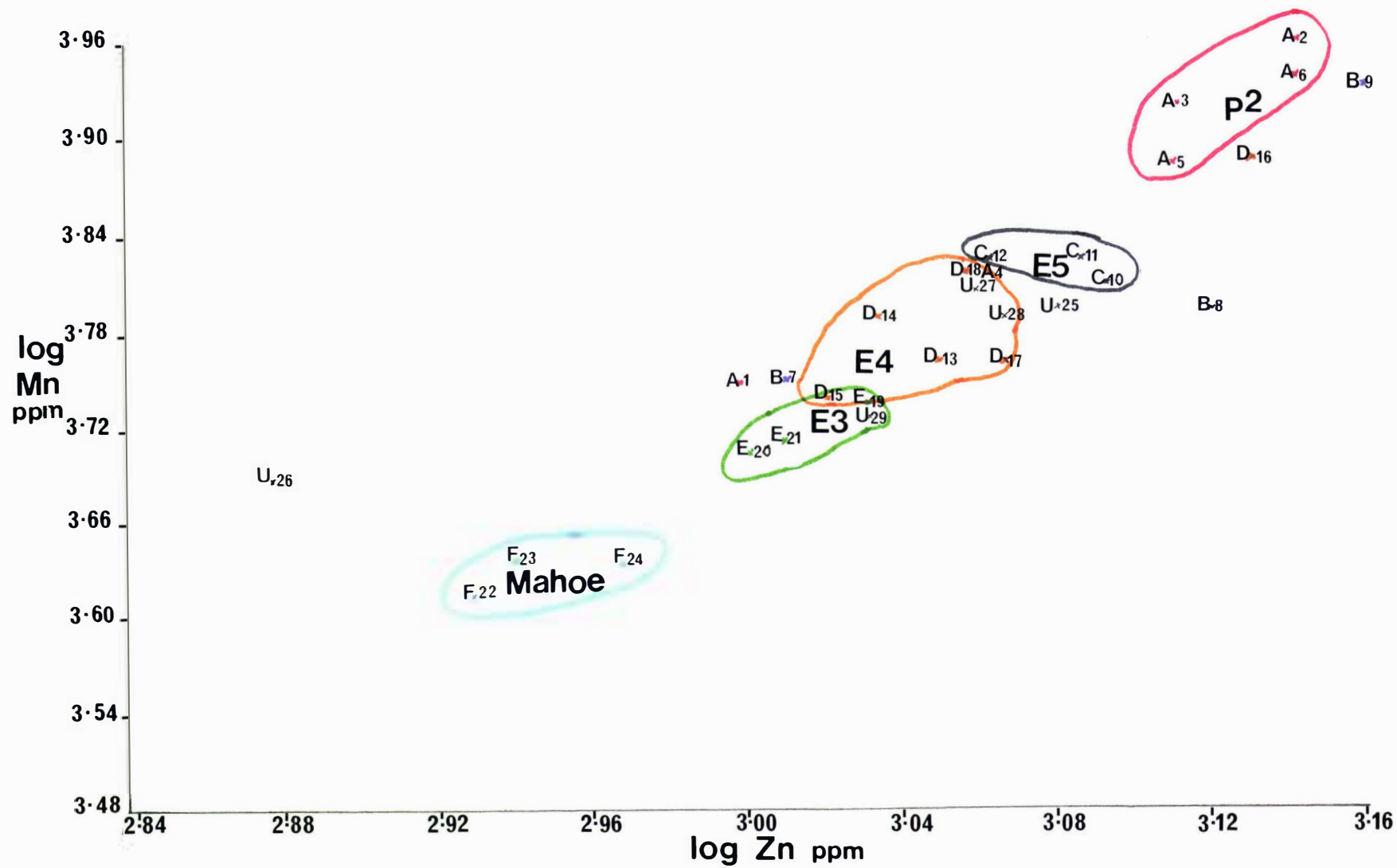
The extreme variability of chromium has been noted by Duncan and Taylor (1968) who concluded that it might be useful in the stratigraphic correlation of products of a single eruption. Kohn and Neall (1973) found chromium to be between three to eight times higher in Tongariro titanomagnetites compared with titanomagnetites from Taranaki and successfully applied chromium values to confirm tephra correlation. In this study chromium was also found to be the most valuable element both between and within groups but was not helpful in distinguishing these particular tephras.

Ratio-ratio plots for transition metals e.g. $\frac{\text{Ti}}{\text{V}}$, $\frac{\text{V}}{\text{Mn}}$ and $\frac{\text{Co}}{\text{Mn}}$ were used by Kohn (1970) as a means of discriminating between tephras. The choice of ratio appears to have been determined by whether it distinguished tephras and not as Hodder (1981) has pointed out, for any thermodynamic criteria. In Kohn and Toppings (1978) work it appears plots of vanadium versus chromium are indicative of a systematic difference in magmatic composition between upper and lower members of the Taupo sub-group. However, in this study, vanadium, titanium and zirconium could not be analysed on the ICP in Palmerston North.

There is less compositional difference in titanomagnetites from andesitic than with rhyolitic tephras. This may be consistent with andesites being the products of small eruptions where expulsion from the magma chamber has not perturbed the parent magma (Hodder, 1981). This is consistent with the mineralogical homogeneity in Egmont andesites noted by Gow (1968).

Figure 4.3

Discrimination diagram using log Mn versus log Zn to separate the Taranaki tephras



Discussion:

Particular elements or element ratios are expected on the basis of crystal field theory to be indicative of magmatic processes prior to eruption (Hodder, 1981).

If the crystal field stabilisation energies (CFSE) for tetrahedral sites in the magma is subtracted from the CFSE for octahedral sites in the crystal, a value for the "site preference energy" for an octahedral site may be obtained for any transition element (Burns and Fyfe, 1964). The octahedral site preference energies of divalent ferromagnesian trace elements, Ni and Co, exceed the site preference energies of Fe^{2+} and similarly the site preference energies of trivalent ferromagnesian trace elements Cr, Mn, V and Ti exceed that of Fe^{3+} . Consequently the proportion of ferromagnesian trace elements is greatest in the early-crystallising and least in the late-crystallising magnetite.

According to Ewart (1963) titanomagnetites and ilmenite are generally the first minerals that co-precipitate from central North Island magmas. Elements concentrated within the titanomagnetites therefore probably reflect the availability of elements which can be favourably incorporated into the lattice, making them sensitive recorders of changes in magma composition. In Egmont titanomagnetite analyses this element variability was most noticeable with Mn, Zn, Cu, Cr and Co.

4. MINERALOGY OF THE TEPHRA SEQUENCE

Introduction:

An investigation of the mineralogy of the tephra sequence was conducted to determine the dominant ferromagnesian assemblages for correlation purposes and to discover any trends in assemblages with time.

The samples chosen were representative of each tephra being investigated. Sixteen well drained sites were selected for correlation in Eltham, Stratford and Inglewood Counties (Table 4.3).

In addition samples were examined from a drillhole in Eltham Swamp (Figure 4.4) and from a section on Durham Road, Inglewood County (Figure 4.5) where seven radiocarbon dates of wood, peat samples place maximum and minimum dates on the ages of the tephras. Hence there is a need to correlate all the tephras to these localities.

Table 4.3 Percentage Augite, Hornblende and Hypersthene
in the tephra sequence

Tephra sampled	Sample locality (Site number see Appendix IV)		Augite %	Hornblende %	Hypersthene %	Total number of grains counted
Kaupokonui	Type section	(1)	69	28	3	312
	Dawson Falls	(8)	72	25	3	317
	North Egmont Track	(25)	75	25	-	449
	Manaia Road*	(7)	69	31	-	426
Maketawa	Type section	(1)	43	57	-	326
	Dawson Falls	(8)	49	51	-	356
	Pembroke Road	(17)	44	56	-	372
p2B	Type section	(1)	33	67	-	550
	North Egmont Track*	(25)	56	44	-	448
	Mahoe	(5)	31	69	-	716
	Monmouth Road	(18)	40	60	-	769
	Tariki*	(21)	32	68	-	532
p2A	Type section	(1)	69	30	1	620
	North Egmont Track**	(25)	54	45	1	526
	Mahoe	(5)	27	72	1	564
	Monmouth Road*	(18)	62	38	-	577
	Tariki*	(21)	49	51	-	530
p1	Type section	(1)	77	23	-	316
	Bedford Road*	(23)	72	26	2	566
	Pembroke Road*	(16)	56	37	7	480
	Mahoe	(5)	61	38	1	955
	Monmouth Road	(18)	62	38	-	333
	Tariki*	(21)	60	40	-	500
E5	Type section	(1)	63	36	1	518
	Upper Palmer Road	(9)	53	46	1	698
	Finnerty Road	(11)	61	39	-	262
	Mahoe	(6)	55	45	-	373
	Monmouth Road	(18)	66	34	-	421
	Opunake Road	(12)	69	31	-	373
E4 Upper lapilli	Type section	(1)	89	11	-	325
	Finnerty Road	(11)	88	12	-	374
	Mahoe	(6)	83	17	-	449
	Monmouth Road	(18)	77	23	-	507
	Opunake Road	(12)	68	32	-	617

*Probable Identification

**Tentative Identification

Table 4.3 contd.

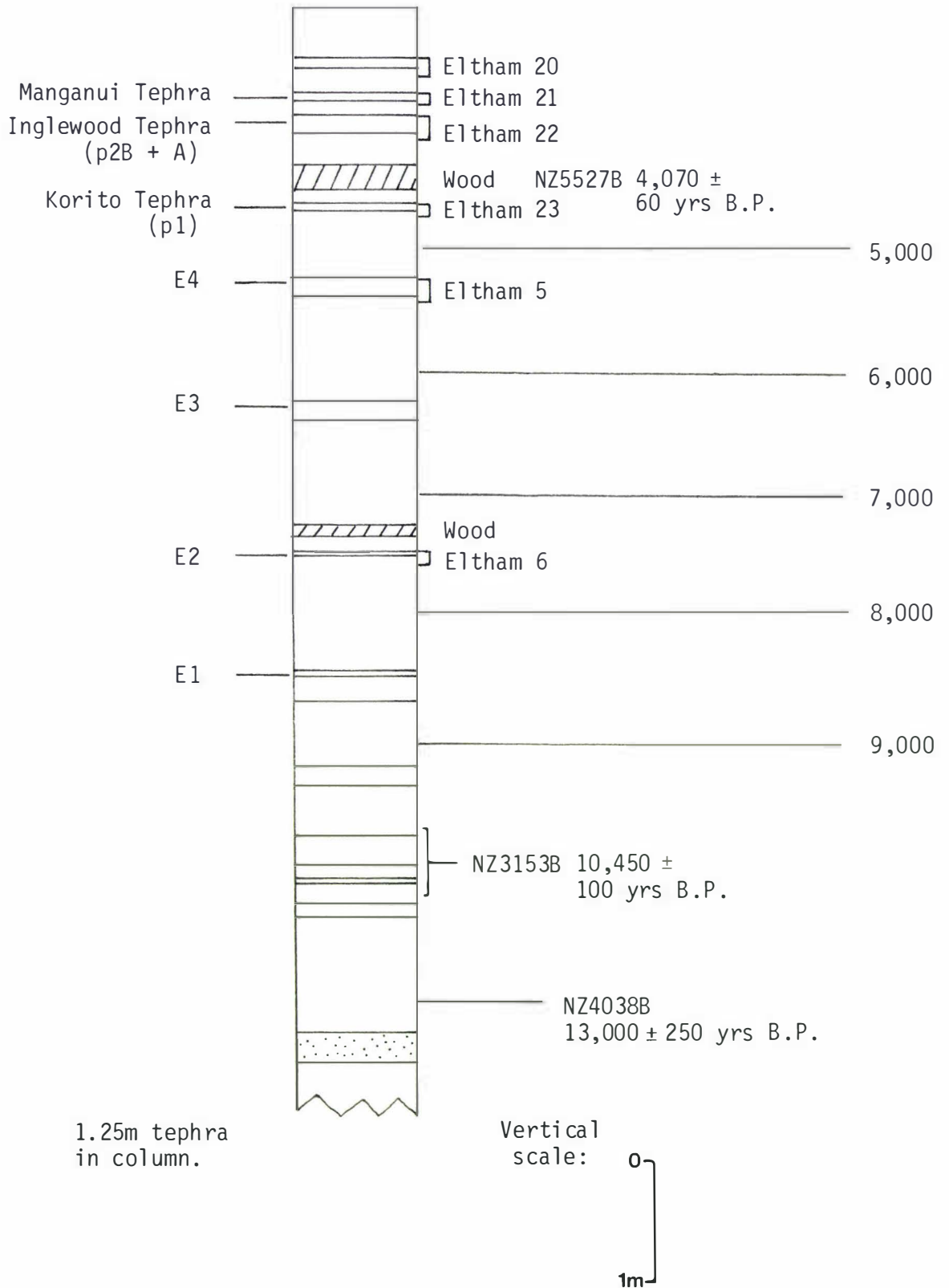
Tephra sampled	Sample locality (Site number see Appendix IV)		Augite %	Hornblende %	Hypersthene %	Total number of grains counted
E4 Central	Type section	(1)	85	14	1	354
	Finnerty Road	(11)	80	19	1	334
	Mahoe	(6)	74	24	1	435
	Monmouth Road	(18)	76	24	-	361
	Opunake Road	(12)	85	15	-	414
E4 Basal lapilli	Type section	(1)	64	35	1	479
	Finnerty Road	(11)	60	40	-	324
	Mahoe	(6)	58	42	-	500
	Monmouth Road	(18)	51	49	-	308
	Opunake Road	(12)	66	34	-	173
E3	Type section	(1)	58	41	1	247
	York Road*	(20)	50	46	4	551
	Pembroke Road	(16)	65	34	1	642
	Finnerty Road	(11)	69	30	1	458
	Mahoe	(6)	89	10	1	282
	Monmouth Road	(18)	58	41	1	397
	Tariki**	(21)	57	38	5	452
	Opunake Road*	(12)	75	23	2	472
E2	Type section	(1)	90	9	1	244
	Finnerty Road	(11)	69	30	1	354
	Mahoe	(6)	86	14	-	414
E1	Type section	(1)	73	23	4	508
	Upper Palmer Road	(9)	78	21	1	367
	Mahoe	(6)	61	38	1	236
	Opunake Road	(12)	59	40	1	595
Mahoe	Type section	(1)	81	15	4	345
	Mahoe*	(6)	74	26	-	198
	Tariki*	(21)	75	19	6	314
	Opunake Road	(12)	82	11	7	323

*Probable Identification

**Tentative Identification

Figure 4.4 Profile of Eltham Peat from Eltham Swamp at N119/901469

Estimated ages of peat based on sedimentation rates between tephras.



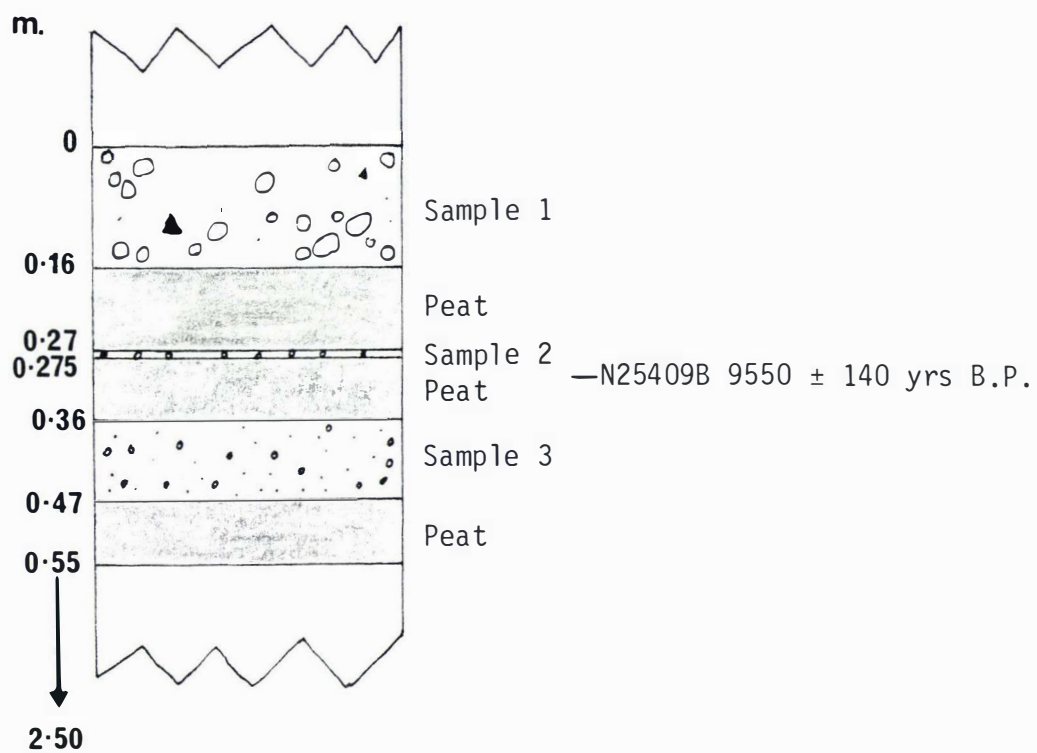


Figure 4.5 Section exposed in upper part of drainage ditch, Durham Road N109/779754 (Q19/144228)

Method:

The pumice samples were each ground, using an agate pestle and mortar, and the heavy minerals separated with bromoform. The 2-4 ϕ (250-63 μ) heavy mineral fraction was mounted in Lakeside and ferromagnesian mineral proportions determined using a Swift point counter.

Results:

The results are shown in Table 4.3 and are based on between 300 and 600 point counts.

The ferromagnesian assemblages comprised hornblende, augite, titanomagnetite and hypersthene. Augite was dominant in the majority of tephra samples, with the exception of the Maketawa and p2B tephtras. Hypersthene was present in negligible amounts and was absent from the Maketawa, p2B and E4 (upper and lower member) tephtras. The titanomagnetite was studied as a separate constituent for trace element analysis and was reported in the previous section.

The mineral ratios for the different tephra are presented in Tables 4.4, 4.5. Figures 4.6 and 4.7 show the range of augite values in the tephra sequence. In the case of the p2A and E3 tephtras, the wide range of ratios made it difficult to distinguish them from the other tephtras. Augite values of the samples from Eltham Swamp and Durham Road were plotted on the graphs and supported the correlations made in Table 4.4.

Discussion:

The mineralogy of Mt. Egmont tephtras is quite distinct from the mineralogy of other centres in New Zealand. Hypersthene andesites, which are present in the Tongariro group of volcanics (O'Shea, 1959; Clark, 1960) appear to be absent from Egmont.

According to Gow (1968) the various types of andesite grade into one another but augite-hornblende andesites are by far the most abundant. The following groups of Egmont andesites, based on the relative abundance of ferromagnesian phenocrysts, have been recognised by Gow:-

1. Augite-hornblende andesite (augite > hornblende)
2. Augite-hornblende andesite (augite = hornblende)
3. Augite-hornblende andesite (hornblende > augite)
4. Augite andesite (devoid of hornblende)
5. Augite-olivine andesite (contains up to 7% modal olivine).

Table 4.4

Ratios of ferromagnesian minerals in the tephra sequence

Tephra	Ferromagnesian ratio* Augite:Hornblende:Hypersthene	Correlation with Gow's (1968) groups	Correlation with Eltham Swamp (Fig. 4.4)	Correlation with Durham Road (Fig. 4.5)
Kaupokonui	Augite > Hornblende >> Hypersthene 7:3	1	-	-
Maketawa	Hornblende > Augite 6:4	3	-	-
p2B	Hornblende > Augite 7:3	3	22	-
p2A	Augite > Hornblende >> Hypersthene 7:3	1	-	-
p1	Augite > Hornblende 7:2	1	23	-
E5	Augite > Hornblende 6:4	1	-	-
E4 Upper	Augite >> Hornblende 9:1	1		
E4 Central	Augite >> Hornblende >> Hypersthene 8:1	1	5	-
E4 Basal	Augite > Hornblende 6:4	1		
E3	Augite > Hornblende >> Hypersthene 6:3	1	-	-
E2	Augite >> Hornblende >> Hypersthene 9:1	1	6	-
E1	Augite > Hornblende >> Hypersthene 7:2	1	-	1
Mahoe	Augite > Hornblende >> Hypersthene 7:2	1	-	-

* Type section tephra values.

Table 4.5 Ratios of ferromagnesian minerals in tephra samples from
Eltham Swamp and Durham Road

	Augite	Hornblende	Hypersthene	Total number counted	Augite:Hornblende
Swamp samples					
20	40%	58%	2%	295	4:6
21	87%	13%	-	305	9:1
22	36%	64%	-	427	4:6
23	62%	38%	-	331	6:4
5	71%	29%	-	357	7:3
6	79%	21%	-	313	8:2
Durham Road samples (Locality site no.22)					
1	70%	30%	-	467	7:3
2	64%	36%	-	340	6:4
3	64%	34%	2%	498	6:3

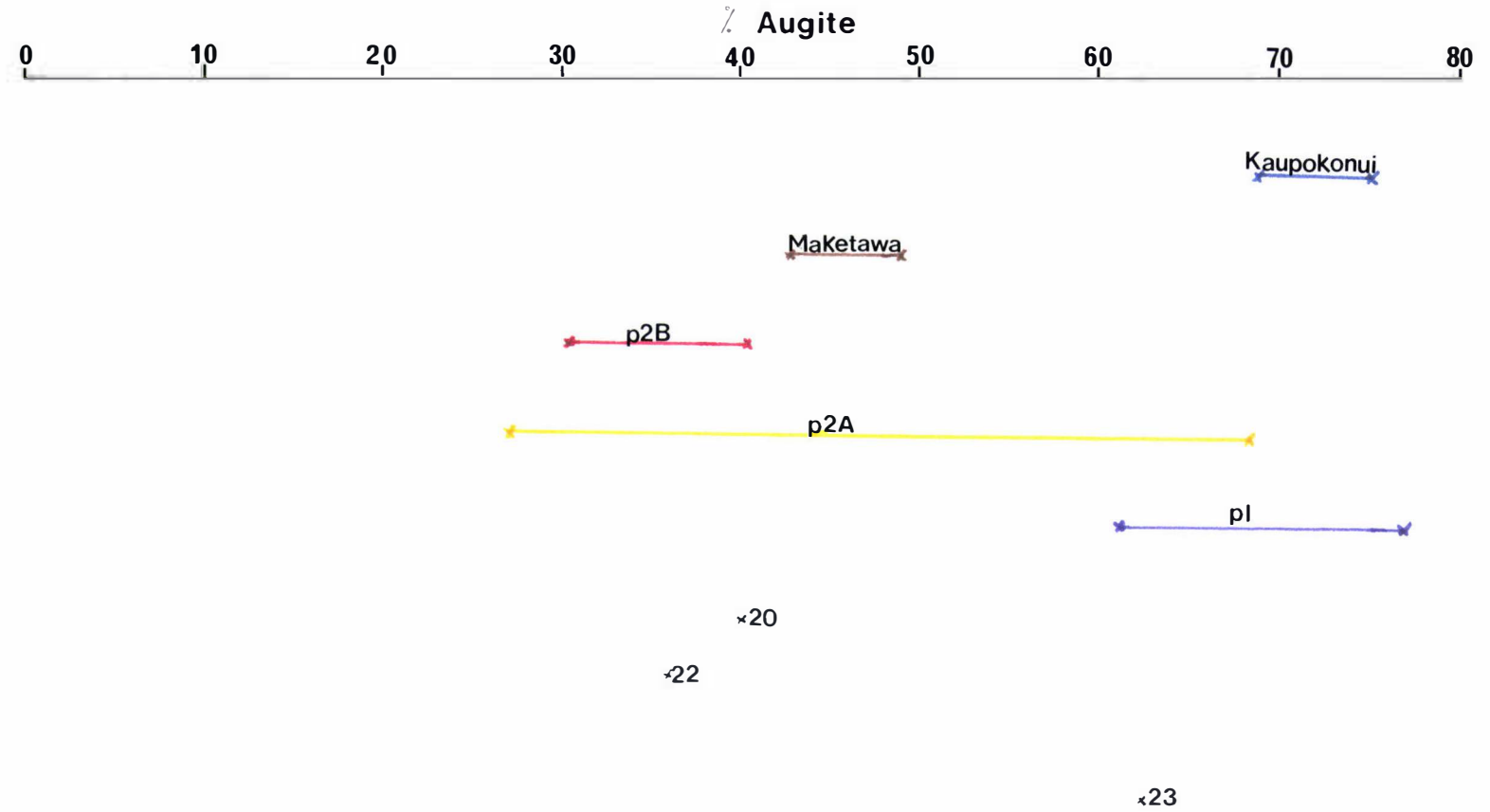


Figure 4.6

Diagram to show range of augite values in the tephra sequence, Kaupokonui - p1

Samples 20, 22, 23 from Eltham Swamp.

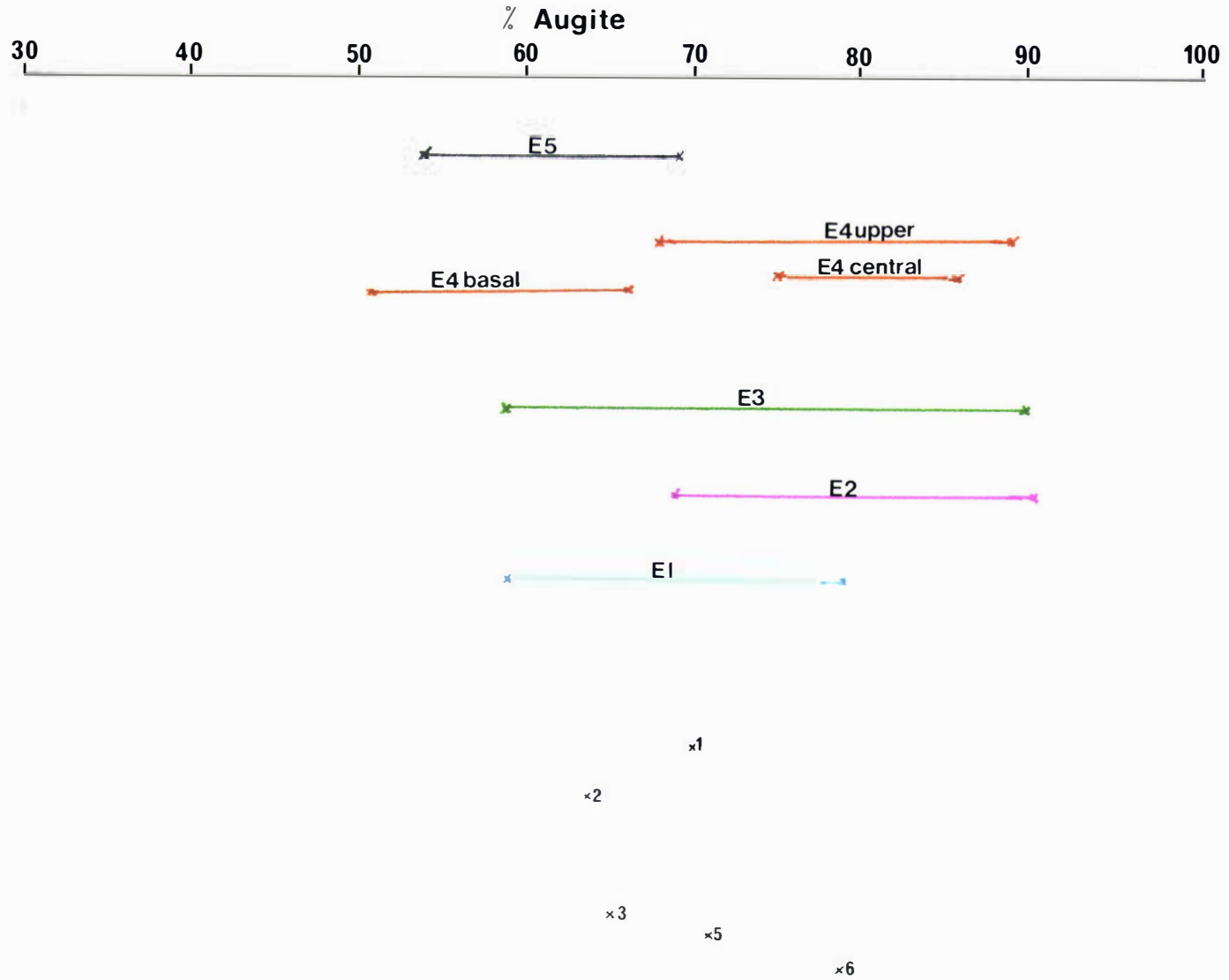


Figure 4.7

Diagram to show range of augite values in pre-p1 tephras

- 1 - 3 - Durham Road samples
- 5 + 6 - Eltham Swamp samples.

The first three of these groups can be related to the tephras in this study (Table 4.4) but groups 4 and 5 are not represented. Olivine observed in the lithic Manganui tephra forms a distinctive mineral marker. Hypersthene was only observed in Gow's group 1 andesites. Table 4.4 indicates that samples 22, 23, 5 and 6 from Eltham Swamp can be tentatively correlated with the p2B, p1, E4 and E2 tephras respectively. Sample 1 from Durham Road, in northern Taranaki, can be tentatively correlated with the E1 tephra. However, the ferromagnesian ratios in samples 2 and 3 did not enable correlations to be made with the older tephras mapped in Eltham County.

5. CONCLUSION

Mt. Egmont is connected with supra-Benioff zone (SBZ) igneous activity, which varies systematically with depth of magma generation along the Benioff zone. Hence problems arise with the nomenclature of SBZ volcanic rocks. It has been shown by Hatherton and Dickinson (1967) that in the circum-Pacific island arcs and active continental margins there appears to be a relationship between the potash content of an andesite volcano and the depth of seismic (Benioff) zone below that volcano. The high potash values in the X-ray fluorescence analysis correlate with the deeper position of the Benioff zone under Mt. Egmont.

The ability of the particular methods to successfully effect identification and correlations of tephra depend on their sensitivity to post-depositional changes, contamination effects and intra-tephra variations being less than inter-tephra differences.

Multicomponent methods allow correlation to be made on the basis of present-day properties of tephras but relative proportions of minerals may be modified by differential weathering and contamination. The trace element content of titanomagnetites method does lessen these effects, although there is a need to consider relative rather than absolute values.

Gow (1968) suggests crystallisation of Egmont tephras has occurred from a uniform magma and the analysis of titanomagnetites in this study indicates a fairly homogeneous magma, with no one element found to vary distinctly. Separation of tephras could be achieved by plotting manganese to zinc values of titanomagnetites.

The original magma composition of pumiceous lapilli is best preserved in the near to source, coarse tephra. XRF analyses were able to characterise such tephra and it was established that decreasing grain size and increasing mean annual temperature and not rainfall have the greater influence on the weathering of pumiceous lapilli in Taranaki. This observation is of considerable importance to tephra weathering studies and the need to obtain unweathered samples representative of former magma compositions.

Correlation was achieved using three groups of ferromagnesian assemblages as defined by Gow (1968) together with stratigraphic position. However, the ferromagnesian assemblages could not be used to correlate to the three samples obtained from Durham Road. The characteristic olivine content of the Manganui tephra, consistent with its basaltic composition, does provide one mineralogically distinctive marker bed.

Confident correlations of andesitic tephra require a multiple criterion approach to tephra characterisation. These studies have shown that tephra identification based on unweathered titanomagnetite composition is one of the most reliable methods for correlation. To a lesser extent dominant ferromagnesian minerals, in combination with stratigraphy and gross differences in bulk chemistry of unweathered tephra may also be used to identify individual tephra from Mt. Egmont.

CHAPTER 5

CHAPTER 5

SOILS OF ELTHAM COUNTY

1. SOIL MAPPING AND TAXONOMIC UNITS

A clear distinction is made in this study between the taxonomic unit, which is categorical in nature and the soil mapping unit, which attempts to represent the real body of soil in the field.

The soil mapping units, which are discrete units on the soil map, are arranged according to their position in the landscape into a physiographic legend (Table 5.1). The mapping units may represent either an area dominated by a single soil or more commonly an area in which two or more soils are found in close association.

The soil taxonomic units, in this survey, are of soil series rank and are arranged in a pedological legend (Table 5.2). A soil series is a grouping of soils with similar profiles, similar temperature and moisture regimes and the same or very similar parent materials. At series level, the taxonomic unit represents a strictly defined central concept, with a defined range of variation.

In this survey the Stratford series, fine topsoil variant, is introduced. This soil unit is too different to be considered a taxadjunct, too extensive to be considered a mapping inclusion, but until now has not been found over a sufficiently wide area to be considered worthy of new series designation.

The limits of the taxonomic unit are controlled by natural factors of soil formation, whereas the limits of mapping units are controlled by additional considerations, which include both the scale and purpose of a soil map. At the scale of mapping employed in this survey of 1:50,000, it is not possible to map every individual kind of soil encountered, so that the mapping units often contain more than one taxonomic unit.

One of the soil mapping units used in this survey is the soil association. The soil association was first introduced in Canada (Ellis, 1932) to represent a drainage sequence of soils on a given parent material. The use of the soil association, in Eltham County, follows this definition with the connotation of a predictable pattern of soils, related to both

SOIL MAPPING UNITS ARRANGED PHYSIOGRAPHICALLY

SOIL OF LOWLAND LAHARIC TERRAIN (generally below 350m)

On flat to strongly rolling land between 90-340m elevation

Riverlea-Makaka association	Rv-Mk	
Riverlea-Mangawhero association		
Kahui-Tipoka association	Kui-Tk	
Tipoka-Kahui association	Tk-Kui	
Makaka-Riverlea association	Mk-Rv	
Lowgarth soils	Lo	
Lowgarth soils, strongly rolling phase	Lo ₁	Lo R
Stratford soils	St	
Stratford soils, strongly rolling phase	St ₁	St R
Stratford soils, fine topsoil variant	St _v	St v

In low-lying areas or in depressions between 120-340m elevation

Makaka-Mangawhero association	Mk-Mw
Mangawhero-Riverlea association	Mw-Rv
Awatuna-Tipoka association	At-Tk
Awatuna-Kahui association	At-Kui
Ngaere-Stratford association	Ng-St

On strongly rolling, hilly land between 120-290m elevation

Lowgarth hill soils	LoH
Stratford hill soils	StH
Stratford hill-Stratford association	StH-St
Stratford hill-Stratford soils, strongly rolling phase association	StH-St ₁

SOILS OF UPLAND LAHARIC TERRAIN (generally above 300m)

On lahar mounds and flat to rolling land between 310-760m elevation

Rowan-Makaka association	Rv-Mk
Rowan-Mangawhero association	Mw-Rv

On lahar mounds between 360-460m elevation

Rowan hill-Mangawhero association	Rv-Mw
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In low-lying areas or in depressions between 220-460m elevation

Mangawhero-Makaka association	Mw-Mk
-------------------------------	-------

On flat to hilly slopes on Mt. Egmont between 760-1,100m elevation

Tahurangi-Tahurangi hill association	Tah-TahH
--------------------------------------	----------

SOILS OF SUBALPINE AND ALPINE TERRAIN (above 1,100m)

On steep and very steep slopes on the very steeply sloping terrain, on the southerly flanks of Mt. Egmont between 1,100-2,518m elevation

unnamed Subalpine soils	S
unnamed Alpine soils	A1

SOILS OF RIVER FLATS AND TERRACES

Hangatahua-Okato association	Hn-Ok
Okato-Hangatahua association	Ok-Hn

SOILS OF DRAINED SWAMPLAND

Eltham soils	Et
--------------	----

SOILS OF STEEPLAND TERRAIN

Whangamomona steepland soils	WgS
------------------------------	-----

SOIL TAXONOMIC UNITS ARRANGED PEDOLOGICALLY

YELLOW-BROWN LOAMS

from > 250mm young lapilli showers (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

strongly leached, iron illuvial	Rowan series	Rc
moderately to strongly leached	Riverlea series	Rv
weakly gleyed	Makaka series	Mk

from > 250mm young lapilli showers (Kaupokonui, Maketawa and Manganui tephras) on thick volcanic ash

moderately to strongly leached	Lowgarth series	Lo
--------------------------------	-----------------	----

from < 250mm young lapilli showers (Kaupokonui, Maketawa and Manganui tephras) on volcanic ash overlying laharic debris

moderately leached	Kahui series	Kui
weakly gleyed	Tipoka series	Tk

from < 250mm young lapilli showers (mainly Manganui tephra) on pumiceous lapilli-bearing ash showers (tephras p2, p1 (Druce, 1966) ES and E4) on thick volcanic ash

moderately leached	Stratford series	St
weakly gleyed	Ngaere series	Ng

from pumiceous lapilli-bearing ash showers (tephras p2, p1 (Druce, 1966) ES and E4) on thick volcanic ash

moderately leached	Stratford series, fine topsoil variant	St _v
--------------------	--	-----------------

GLEYSOILS

from > 250mm young lapilli showers (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

Mangawhero series	Mw
-------------------	----

GLEYSOILS

from < 250mm young lapilli showers (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

Awatuna series	At
----------------	----

from recent andesitic sands and gravels

Okato series	Ok
--------------	----

INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS

from recent andesitic sands and gravels

Hangatahua series	Hn
-------------------	----

RECENT SOILS

from thin volcanic ash (Tahurangi Formation) on older volcanic ashes

very strongly leached	Tahurangi series	Tah
-----------------------	------------------	-----

LITHOSOLS AND SKELETAL SOILS

from andesitic rock, scree and tephra

unnamed Subalpine soils	S
unnamed Alpine soils	A1

ORGANIC SOILS

from woody peat with interbedded tephra layers

Eltham series	Et
---------------	----

STEEPLAND SOILS RELATED TO YELLOW-BROWN EARTHS

from silty sandstone

Whangamomona series	WgS
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† Not shown separately on this map.

TABLE 5.1

SOIL MAPPING UNITS ARRANGED PHYSIOGRAPHICALLY

SOIL OF LOWLAND LAHARIC TERRAIN (generally below 350m)

On flat to strongly rolling land between 90-340m elevation

Riverlea-Makaka association	Rv-Mk
Riverlea-Mangawhero association	Rv-Mw
Kahui-Tipoka association	Kui-Tk
Tipoka-Kahui association	Tk-Kui
Makaka-Riverlea association	Mk-Rv
Lowgarth soils	Lo
Lowgarth soils, strongly rolling phase	Lo ₁
Stratford soils	St
Stratford soils, strongly rolling phase	St ₁
Stratford soils, fine topsoil variant	St _v

In low-lying areas or in depressions between 120-340m elevation

Makaka-Mangawhero association	Mk-Mw
Mangawhero-Riverlea association	Mw-Rv
Awatuna-Tipoka association	At-Tk
Awatuna-Kahui association	At-Kui
Ngaere-Stratford association	Ng-St

On strongly rolling, hilly land between 120-290m elevation

Lowgarth hill soils	LoH
Stratford hill soils	StH
Stratford hill-Stratford association	StH-St
Stratford hill-Stratford soils, strongly rolling phase association	StH-St ₁

SOILS OF UPLAND LAHARIC TERRAIN (generally above 300m)

On lahar mounds and flat to rolling land
between 310-760m elevation

Rowan-Makaka association ----- Rc-Mk

Rowan-Mangawhero association ----- Rc-Mw

On lahar mounds between 360-460m elevation

Rowan hill-Mangawhero association ----- RcH-Mw

In low-lying areas or in depressions
between 220-460m elevation

Mangawhero-Makaka association ----- Mw-Mk

On flat to hilly slopes on Mt. Egmont
between 760-1,100m elevation

Tahurangi-Tahurangi hill association ----- Tah-TahH

SOILS OF SUBALPINE AND ALPINE TERRAIN (above 1,100m)

On steep and very steep slopes on the very steeply sloping
terrain, on the southerly flanks of Mt. Egmont between
1,100-2,518m elevation

unnamed Subalpine soils ----- S

unnamed Alpine soils ----- A1

SOILS OF RIVER FLATS AND TERRACES

Hangatahua-Okato association ----- Hn-Ok

Okato-Hangatahua association ----- Ok-Hn

SOILS OF DRAINED SWAMPLAND

Eltham soils ----- E1

SOILS OF STEEPLAND TERRAIN

Whangamomona steepland soils ----- WgS

TABLE 5.2

SOIL TAXONOMIC UNITS ARRANGED PEDOLOGICALLY

YELLOW-BROWN LOAMS

from > 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

strongly leached, iron illuvial	_____ Rowan series	_____	Rc
moderately to strongly leached	_____ Riverlea series	_____	Rv
weakly gleyed	_____ Makaka series	_____	Mk

from > 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on thick volcanic ash

moderately to strongly leached	_____ Lowgarth series	_____	Lo
--------------------------------	-----------------------	-------	----

from < 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on volcanic ash overlying laharic debris

moderately leached	_____ Kahui series	_____	Kui
weakly gleyed	_____ Tipoka series	_____	Tk

from < 250mm *young lapilli showers* (mainly Manganui tephra) on pumiceous lapilli-bearing ash showers (tephras p2, p1 (Druce, 1966) E5 and E4) on thick volcanic ash

moderately leached	_____ Stratford series	_____	St
weakly gleyed	_____ Ngaere series	_____	Ng

from pumiceous lapilli-bearing ash showers (tephras p2, p1 (Druce, 1966) E5 and E4) on thick volcanic ash

moderately leached	_____ Stratford series, fine topsoil variant	_____	St _v
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GLEY SOILS

from > 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

Mangawhero series	_____	Mw
-------------------	-------	----

GLEYSOILS

from < 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris

Awatuna series _____ At

from recent andesitic sands and gravels

Okato series _____ Ok

INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS

from recent andesitic sands and gravels

Hangatahua series _____ Hn

RECENT SOILS

from thin volcanic ash (Tahurangi Formation) on older volcanic ashes

very strongly leached _____ Tahurangi series _____ Tah

LITHOSOLS AND SKELETAL SOILS

from andesitic rock, scree and tephra

unnamed Subalpine soils _____ S

unnamed Alpine soils _____ Al

ORGANIC SOILS

from woody peat with interbedded tephra layers

Eltham series _____ El

STEEPLAND SOILS RELATED TO YELLOW-BROWN EARTHS

from silty sandstone

Whangamomona series _____ Wgs

drainage and relief. In this survey the members of the association are soil series and phases of these and unlike the association itself, can be classified in the pedological legend. Each soil association consists of two or more members. The association is named after the two most extensive members, with the name of the dominant member first. Table 5.3 lists the soil associations shown on the soil map and indicates the position of dominant and subdominant members in relation to their position in the landscape and to their natural drainage.

In some areas the soil is relatively uniform and there are only minor occurrences or inclusions of soils of other taxonomic units. Where the proportion of inclusions is less than about 15%, the mapping unit is named after the dominant taxonomic unit, and the term "soils" as opposed to "series" is applied to distinguish the mapping unit from the taxonomic unit.

Phases of soils, based on slope, are separated as distinct mapping units because they are considered significant for land use. On hilly and steep land, where soil profiles may be varied depending on slope, position on the slope and aspect, complex mapping units termed hill soils and steepland soils are used. These complex mapping units are named after the dominant taxonomic unit to avoid the multiplication of geographic series names (e.g. Stratford hill soils, Whangamomona steepland soils).

In this section, the soil mapping units and soil taxonomic units are discussed separately.

Soil mapping units are described in the same order as they occur in the physiographic legend. Areas of each soil mapping unit, and if necessary members within it, are given as well as the nature of the landscape on which each unit occurs. Characteristics of the component members of the mapping units are given in the extended legend (Appendix IV).

The soil taxonomic units are discussed in relation to their pedological characteristics.

Figure 5.1 shows the relationship between Quaternary geological formations as providers of soil parent materials, topography and the soil series identified in this survey.

The soils are rated in terms of their limitations for pastoral, cropping, horticultural, forestry and urban uses and in terms of their values for food production (Appendix V).

Soil taxonomic unit sheets are provided in Appendix VI.

TABLE 5.3

SOIL MEMBERS WITHIN ASSOCIATIONS AND THEIR RELATION TO TOPOGRAPHICAL SITES

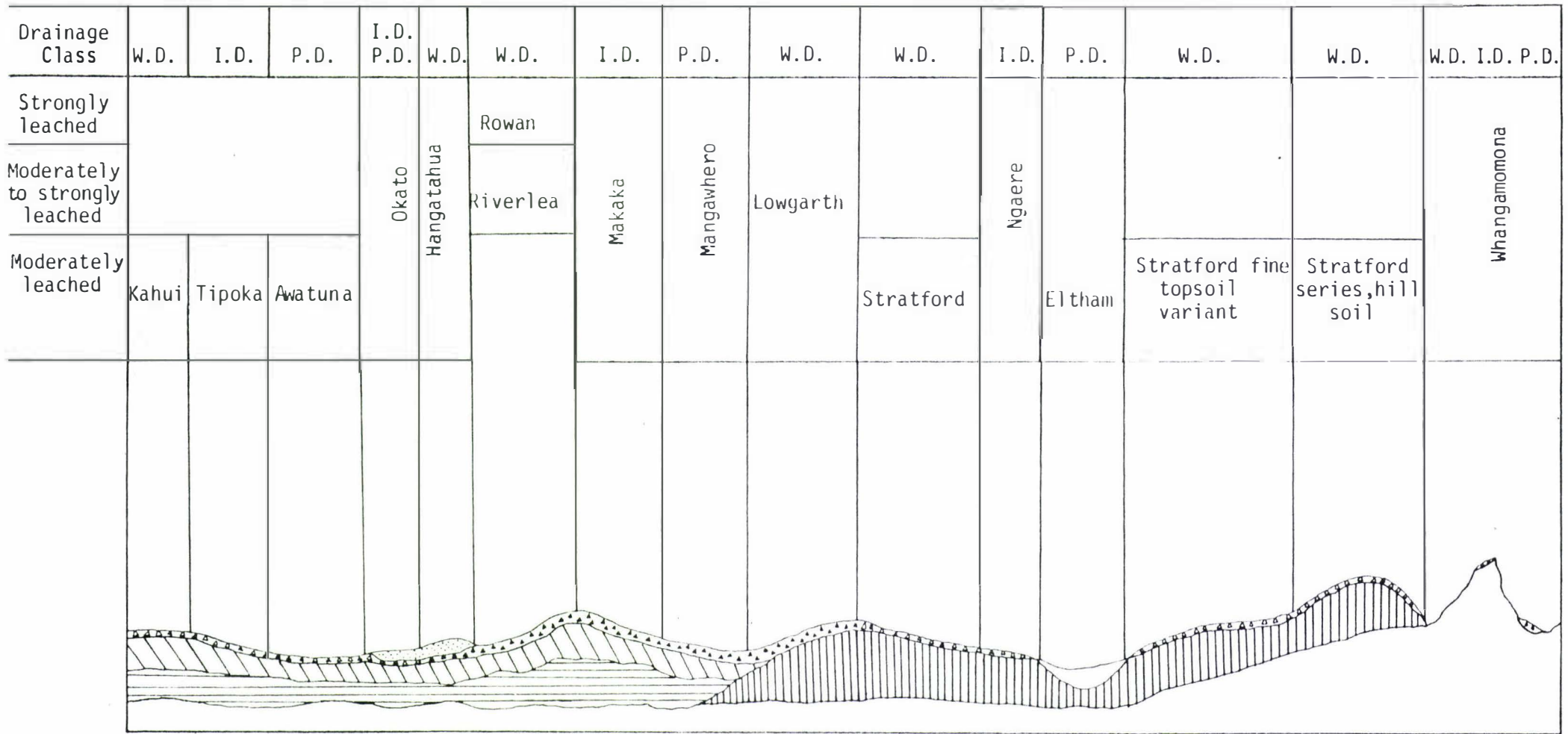
Association	Sides and crests of tephra mantled lahar mounds, and dissected lahar plateaus, hilly land. Well drained.	Strongly rolling land. Well drained.	Level to very gently sloping sites on flat to easy rolling or rolling land. Well drained.	On flat to gently undulating land or in depressions surrounding lahar mounds.	
				Imperfectly drained.	Poorly drained.
Rowan hill - Mangawhero	ROWAN hill soils (>50%)		Rowan soils	Makaka soils	Mangawhero soils
Rowan - Mangawhero			Rowan soils	Makaka soils	Mangawhero soils
Rowan - Makaka			ROWAN SOILS (>50%)	Makaka soils	
Makaka - Mangawhero				MAKAKA SOILS (>50%)	Mangawhero soils
Mangawhero - Makaka				Makaka soils	MANGAWHERO SOILS (>50%)
Mangawhero - Riverlea			Riverlea soils	Makaka soils	MANGAWHERO SOILS (>50%)
Riverlea - Makaka			RIVERLEA SOILS (>50%)	Makaka soils	
Makaka - Riverlea			Riverlea soils	MAKAKA SOILS (>50%)	
Riverlea - Mangawhero			RIVERLEA SOILS (>50%)	Makaka soils	Mangawhero soils
Kahui - Tipoka			KAHUI SOILS (>50%)	Tipoka soils	
Tipoka - Kahui				TIPOKA SOILS (50%)	
Awatuna - Tipoka				TIPOKA SOILS (50%)	AWATUNA SOILS (50%)
Awatuna - Kahui			Kahui soils	Tipoka soils	AWATUNA SOILS (>50%)
Ngaere - Stratford			Stratford soils	NGAERE SOILS (>50%)	
Stratford hill - Stratford	STRATFORD hill soils (>50%)		Stratford soils		
Stratford hill - Stratford soil, strongly rolling phase	STRATFORD hill soils (>50%)	Stratford soil, strongly rolling phase			
Hangatahua - Okato			HANGATAHUA SOILS (>50%)		Okato soils
Okato - Hangatahua			Hangatahua soils		OKATO SOILS (>50%)

Notes:

- Names of dominant or co-dominant members are shown in capitals, subdominant members are shown in lower case.
- Up to 15 of soils other than those listed above may occur in some of the mapping units.

Figure 5.1

Hypothetical cross-section of Eltham County showing soil series in relation to leaching, drainage and parent materials



West



<250mm Kaupokonui, Maketawa and Manganui tephras



Hangatahua Gravels and Sands



Warea and Opua Formations



> 250mm Kaupokonui, Maketawa and Manganui tephras



Opunake and Pungarehu Formations



Stratford Formation



Woody peat with interbedded tephras



Tertiary sedimentary rocks

East

Drainage Class

W.D. - Well drained

I.D. - Imperfectly drained

P.D. - Poorly drained

2. SOIL GROUPS IN SURVEY AREA

Soil groups recognised in this survey comprise yellow-brown loams, an intergrade between yellow-brown loams and recent soils, recent soils, lithosols, skeletal soils, gley soils, organic soils and steepland soils related to yellow-brown earths (Table 5.2). All occur in the Central Region of the soil zones of New Zealand (Leamy and Fieldes, 1976).

YELLOW-BROWN LOAMS

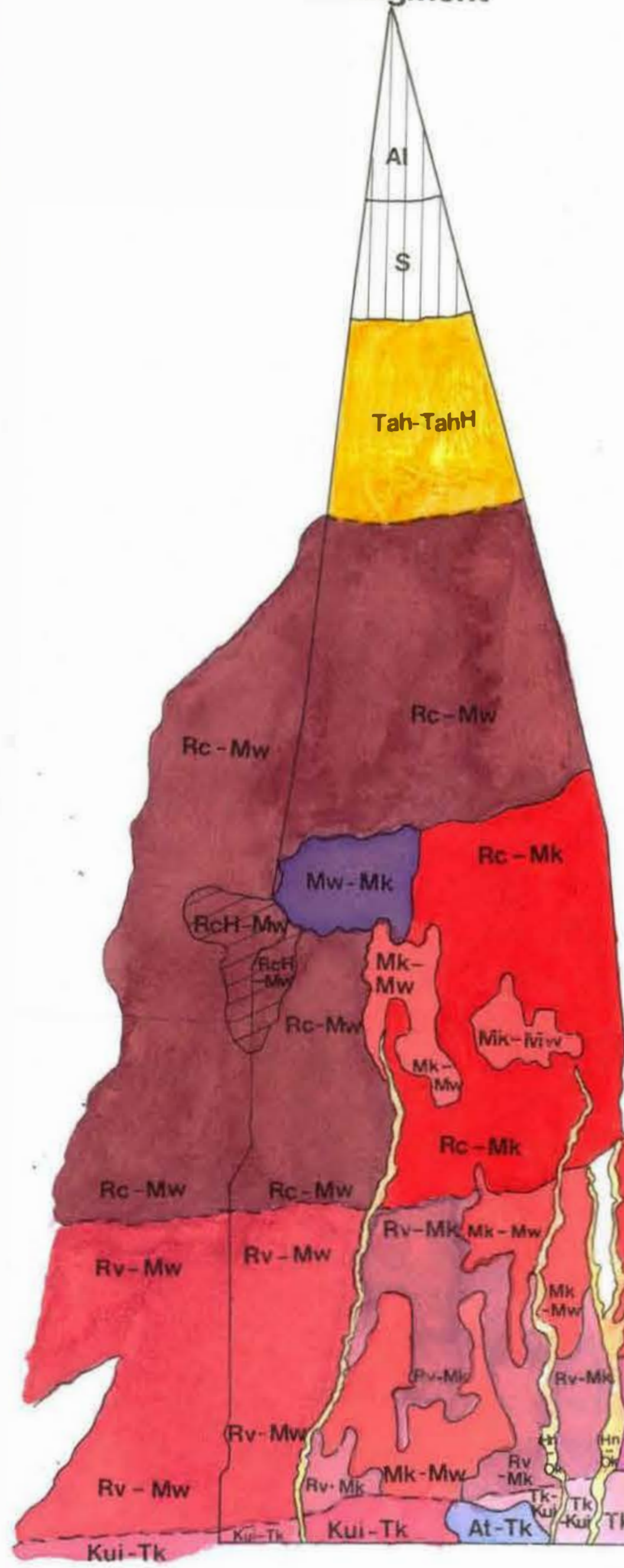
The yellow-brown loams are the most extensive soils in Eltham County and include the Rowan, Riverlea, Makaka, Kahui, Tipoka, Lowgarth, Stratford, Stratford fine topsoil variant and Ngaere soils. They are well drained and are characterised by low bulk densities, friable consistencies and yellowish-brown or brown B horizons. The structure in A horizons is a moderately to strongly developed nut structure and is typically stronger than that of B horizons, which have weakly developed medium or coarse nut or blocky structures breaking to fine crumb.

A feature of the yellow-brown loams of Eltham County is that profiles contain pumiceous and lithic lapilli, which can be scattered or concentrated in bands and which become more strongly weathered with depth. The coarseness of tephra parent materials increases with increasing proximity to Mt. Egmont. Laharic debris may occur at varying depths in soil profiles with the concomitant presence of gravels, stones and boulders.

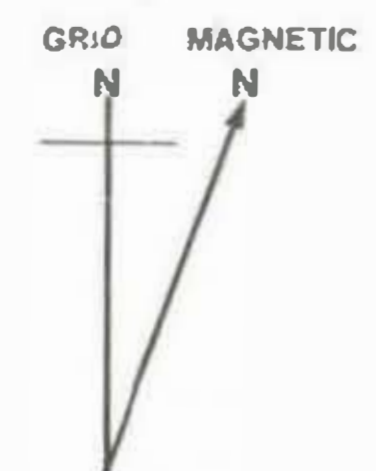
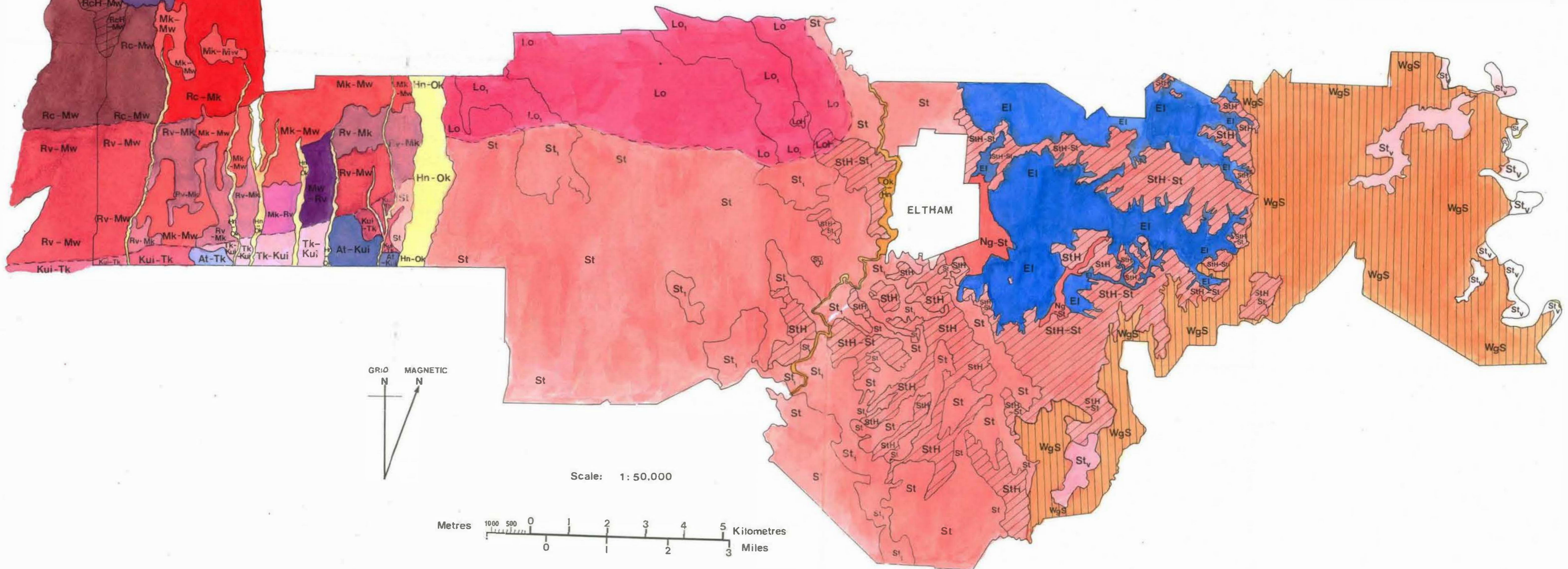
The clay mineralogy is dominated by allophane, which produces a characteristic greasy or smeary feel to the soils and a low resistance to stress and crushing. The allophane content determines the characteristic physical and chemical properties of the yellow-brown loams, as well as the gley soils and to a lesser extent, the most coarsely textured recent soils and their intergrade with yellow-brown loams.

The mean annual rainfall, in the study area, varies from 1330mm, at 90m elevation to above 4000mm at 760m elevation. Below 310m elevation rainfall is less than 2400mm and soils are moderately leached and moderately to strongly leached yellow-brown loams. Above 310m elevation, where the rainfall exceeds 2400mm the soils are strongly leached, with iron illuviation evident in well drained profiles. In the imperfectly drained soils fluctuations in the water-table level cause sub-surface

Mt. Egmont



SOIL SURVEY OF PART ELTHAM COUNTY.



Scale: 1: 50,000



gleying, which tends to mask the effects of rainfall. These soils are recognised as weakly gleyed yellow-brown loams in which gleying affected the lower horizons of profiles, while the upper horizons resemble those of well drained soils.

GLEYSOILS

These include Mangawhero, Awatuna and Okato soils. The soils are poorly drained and have the morphology of a gley soil with gleying up to and sometimes within A horizons. The gleyed B horizons are characterised by pale colours of 10YR hue, varying from brown to light yellowish-brown, with dark reddish-brown to yellowish-red mottles. The mottles increase with depth and can be confined to the irregular surface staining of the lithic and pumiceous lapilli or associated with soil aggregates. Iron oxide concretions may be a feature of the profiles and can be cemented together, to form an indurated, vesicular iron oxide pan at the textural boundary between the overlying tephras and the underlying laharic deposits.

The distinction between yellow-brown loams, weakly gleyed yellow-brown loams and gley soils is based on the depth to which gleying is first encountered in the profile. This follows the procedure adopted in the Egmont County survey, where it was noted that since the three groups form a continuum, any separation must be regarded as arbitrary.

Soils with non-gleyed horizons to a depth of 1m were classed as yellow-brown loams. Soils with gleyed horizons beneath non-gleyed B horizons were classed as weakly gleyed yellow-brown loams. Soils with all horizons gleyed were classed as gleys.

INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS

One soil series, the Hangatahua is recognised as an intergrade between yellow-brown loams and recent soils and is developed from recent andesitic sands and gravels. There is evidence of the development of an incipient Bw horizon but weathering has not proceeded sufficiently for the soil to have fully developed the profile characteristics of a yellow-brown loam.

RECENT SOILS

One soil series, the Tahurangi, is recognised as a recent soil. Recent soils are those soils where profiles show A horizon development but there is little or no horizon differentiation beneath. They are mainly

coarse-texture soils, derived from young deposits of alluvium or volcanic ash.

LITHOSOLS AND SKELETAL SOILS

Unnamed subalpine and alpine soils are found at elevations over 1000m on the steep to precipitous slopes of Mt. Egmont. The slopes are composed of lava flows covered by scree and recent tephra, with a vegetation of subalpine scrub and tussock or absent altogether. The precipitation varies from 4000 to over 8000mm and soils that form show weak profile development and are subject to severe erosion or frequent additions of fresh material.

ORGANIC SOILS

The organic Eltham soil is derived from woody peat, with interbedded andesitic tephra layers. The A horizon has a strongly developed nut structure, contrasting with the subsoil which becomes a structureless peat with depth.

STEEPLAND SOILS RELATED TO YELLOW-BROWN EARTHS

Only one soil series (Whangamomona) belonging to the steepland soil group related to yellow-brown earths is recognised in this survey. However, in the area there is a wide range of soil profile variability dependant on variations of parent material within short distances; slope; and position on slope, and with more detailed work additional series would be recognised and separated out.

Small scale maps showing the broad distribution of soil groups, depth of volcanic ash to laharic debris and rainfall isohyets are given in Appendix VII.

3. SOIL TAXONOMIC UNITS

YELLOW BROWN LOAMS

- from > 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephra) on thin (with minor thick), volcanic ash, overlying laharic debris.

Rowan series

Rowan series was introduced by Aitken et al., (1978) to include moderately to strongly leached soils derived from a lapilli-bearing "unnamed ash" over "Stratford Ash". The series was separated into two soil types, Rowan coarse sandy loam and Rowan gravelly loam.

In this survey Rowan series is defined as a well drained, strongly leached, iron-illuvial yellow-brown loam. The topsoil is formed in the Kaupokonui, Maketawa and Manganui tephra > 250mm thickness, hereafter referred to as the *young lapilli showers* (Plate 5.1). In the subsoil these tephra overlie tephra p2 and p1 (Druce, 1966), which in turn overlie laharic debris of the Warea Formation (12-15,000 years B.P.).

Rowan series occurs on flat to hilly land, in tephra mantled, upland laharic terrain, from 310 to 760m elevation.

Profiles have dark reddish-brown or dark brown sandy loam A horizons. Lithic and pumiceous lapilli are characteristic throughout the profiles, with 5YR or 2.5YR iron-illuvial coatings. The *young lapilli showers* impart a gravelly modification to the topsoil and upper B horizons. The B horizons range from yellowish-brown to dark brown in colour, with weak blocky structures and iron illuvial coatings on ped surfaces and pumiceous and lithic lapilli. The lapilli occur either scattered or concentrated in a band (Plate 5.2).

The underlying laharic debris of the Warea Formation is composed of gravel and breccia and is usually cemented. The thickness of volcanic ash over laharic debris varies from 0.80 to greater than 2m.

Rowan series differs from the Lowgarth and Riverlea series in being found at higher elevations. With rainfall ranging from 2060 to 3860mm, it is more strongly leached than the Lowgarth and Riverlea series, which are moderately to strongly leached.

Rowan series differs from Kahui series in being considerably more leached, with greater than 250mm thickness of *young lapilli showers* present in the profile, which impart a gravelly modification to the upper horizons. Profiles of Rowan series on hill slopes of the lahar mounds may contain a few stones and boulders from the laharic materials beneath the ash cover. These soils occur in a small area, in the vicinity of Upper Auroa Road.

Included within Rowan series is an unnamed variant, characterised by

Plate 5.1

Rowan soil at N119/663521
Upper Mangawhero Road



Kaupokonui
tephra

Maketawa
tephra

Manganui
tephra

young lapilli showers

Traces of p2 tephra

Plate 5.2

Rowan soil, near Upper Mangawhero
Road, at N119/674526 (S.B. 9707).

Note the pumiceous lapilli
(Kaupokonui and Maketawa tephras)
in the topsoil and abundant gravels
(Manganui tephra) concentrated in
the lower part of the Bs horizon.



cms.

0

Ap

30

Bs

51

Bw

75

2C

a placic horizon. Placic horizons have wavy or convolute forms and range from 2mm to 10mm in thickness and are found in profiles above 420m elevation.

Riverlea series

Riverlea series is a well drained, moderately to strongly leached yellow-brown loam, which has been identified for the first time in this survey. It is formed on level to very gently sloping sites, in tephra mantled, lowland laharic terrain, between 220 and 310m elevation. Annual rainfall ranges from 1730 to 2060mm.

Profiles of Riverlea series have very dark greyish-brown to very dark brown loam to sandy loam A horizons, over dark yellowish-brown to yellowish-brown silt loam to sandy loam B horizons. Lithic and pumiceous lapilli are a characteristic feature of Riverlea soils, with the *young lapilli showers* being concentrated in the A and upper B horizons. Older lithic and pumiceous lapilli occur either scattered or concentrated in bands, in the lower B horizons and are more strongly weathered than the *young lapilli showers* (Plate 5.3). The thickness of volcanic ash over laharic debris ranges from 0.70 to 2m. Laharic debris is composed of breccia, gravel and sands and can be cemented.

Riverlea series differs from Lowgarth and Stratford series in being found in shallower, (not greater than 2m), volcanic ash. In addition, in the Stratford series there is less than 250mm thickness of *young lapilli showers* present.

Riverlea series grades into Kahui series, as the *young lapilli showers* become less than 250mm in thickness.

Riverlea series differs from Rowan series in being moderately to strongly leached. The Kaupokonui and Maketawa tephtras are scattered throughout the topsoil in the Riverlea series but are present as a distinct band in the Rowan series.

Makaka series

Makaka series is introduced in this survey for an imperfectly drained, weakly gleyed yellow-brown loam, formed in *young lapilli showers* greater than 250mm in thickness, which overlies tephtras p2 and p1 (Druce, 1966) on laharic debris.

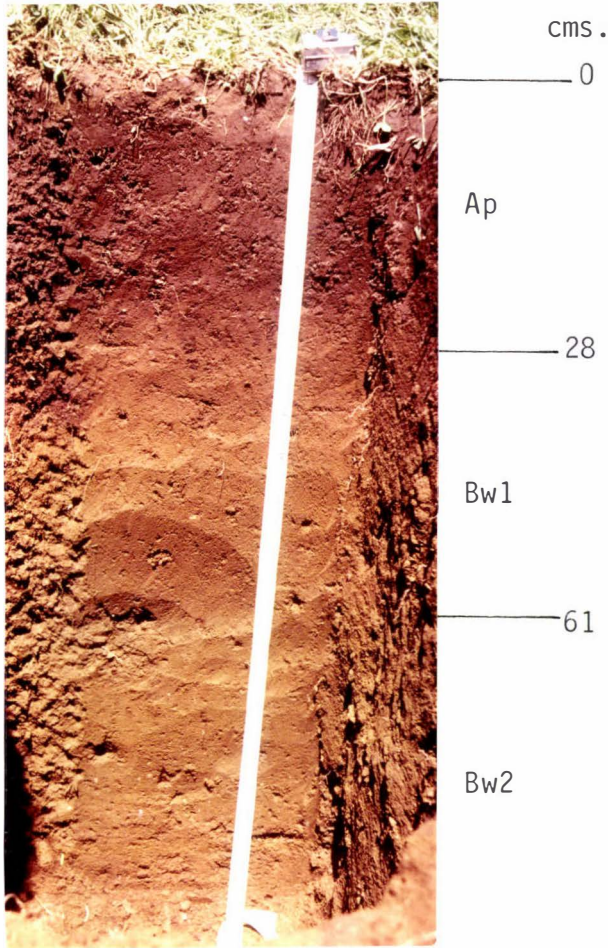


Plate 5.3

Riverlea soil, near Eltham Road at N119/679457.

Note dark brown, well developed topsoil containing Manganui tephra. Pumiceous lapilli occur scattered in the B horizons.

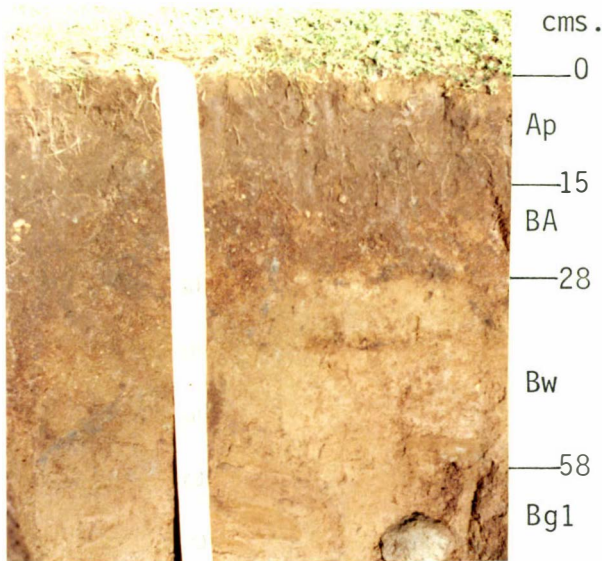


Plate 5.4

Makaka soil at the type section, near Upper Mangawhero Road, at N119/653504. (S.B. 9703).

Note abundant iron-stained gravels, (Manganui tephra) concentrated in the A and BA horizons. Andesite stone in Bg1 horizon derived from laharic debris.

Makaka series occurs in an environment where gleying and leaching processes both operate together. The series is found in strongly leached and moderately to strongly leached environments but gleying tends to be the dominant process in the lower subsoils.

Profiles have a very dark greyish-brown to dark brown A horizon overlying either one or two non-gleyed horizons. The non-gleyed horizons are dark brown or brown in colour and are usually gravelly due to the presence of the Manganui tephra (c. 3,300 years B.P.).

The lower B horizons are gleyed and vary from dark greyish-brown to yellowish-brown in colour, with red to dark reddish-brown mottles, which are usually associated with the moderately to strongly weathered pumiceous lapilli, which are scattered or concentrated in bands (Plate 5.4). Iron concretions may be present and are concentrated within the lapilli bands. An iron pan can occur at the textural break with the laharic debris. The thickness of volcanic ash over laharic debris ranges from 0.60 to 2m.

Makaka series differs from Rowan and Riverlea series in that gleying occurs above a depth of 1m, or above the contact between volcanic ash and laharic deposits, where this contact is shallower. Makaka series differs from Tipoka series in having greater than 250mm thickness of *young lapilli showers*, producing a gravelly modification, in the upper horizons.

— from > 250mm *young lapilli showers*
(Kaupokonui, Maketawa and Manganui tephras)
on thick volcanic ash

Lowgarth series

Lowgarth series was introduced by Aitken et al., (1978) as a moderately leached soil derived from a lapilli-bearing "unnamed ash" over "Stratford Ash". One soil type, Lowgarth sandy loam was recognised.

In this survey, the Lowgarth series is somewhat more closely defined as a well drained, moderately to strongly leached yellow-brown loam, formed in thick, (greater than 2m), volcanic ash. The upper soil horizons are formed from *young lapilli showers* greater than 250mm in thickness. Lowgarth series grades into Stratford series as the *young lapilli showers* become less than 250mm in thickness. Thus the topsoil and upper B horizon

in the Stratford series lack a gravelly modification.

The A horizons vary from very dark greyish-brown to dark brown and have a well developed nut structure over weakly structured, dark yellowish-brown to yellowish-brown B horizons. The topsoil and upper B horizon of Lowgarth soils are characterised by the presence of abundant lithic lapilli of the Manganui tephra, which produces a distinct gravelly and gritty modification to the sandy loam to loam texture.

The lower B horizons are of softer penetration and finer texture, varying from sandy clay loam to loam. Many concentrated, to few scattered, pumiceous lapilli are present and become more strongly weathered with depth (Plate 5.5).

Lowgarth series occurs on level or gently sloping sites, on flat to strongly rolling and hilly land, in tephra mantled lowland laharic terrain, between 230-340m elevation. Lowgarth series differs from Rowan series in that it is found at lower elevations and is not strongly leached. It differs from the Riverlea series in that it is normally formed from *young lapilli showers* overlying thick volcanic ash.

Profiles of Lowgarth series on hill slopes are very similar to Lowgarth series on flatter areas.

Included within Lowgarth series is an unnamed imperfectly drained variant, which is characterised by mottles in the subsoil. The gleying is associated with the presence of pumiceous lapilli, just above one metre depth. This imperfectly drained variant occurs in depressions, on flat to gently undulating land but it is not separated out on the soil map.

Lowgarth series was included in Inglewood, Stratford and Awatuna sets by N.Z. Soil Bureau (1954).

— from < 250mm *young lapilli showers*
(Kaupokonui, Maketawa and Manganui tephras)
on volcanic ash overlying laharic debris

Kahui series

Kahui series was introduced by N.Z. Soil Bureau (1954). The soil unit "Kahui set" included a variety of soils, which were more strongly leached than Egmont or Stratford soils and were derived from "Egmont and

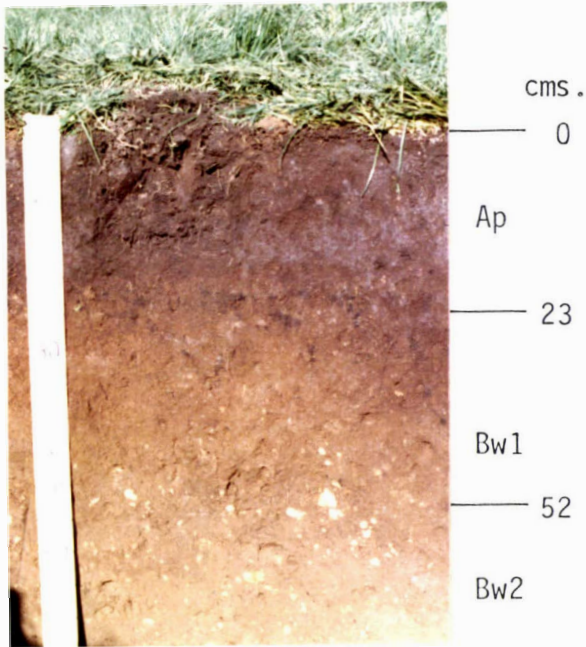


Plate 5.5

Lowgarth soil, at type section, near Lower Hastings Road, at N119/796515. (S.B. 9706).

Note dark brown topsoil with abundant gravels (Manganui tephra) and many, moderately weathered pumiceous lapilli concentrated in the Bw2 horizon.

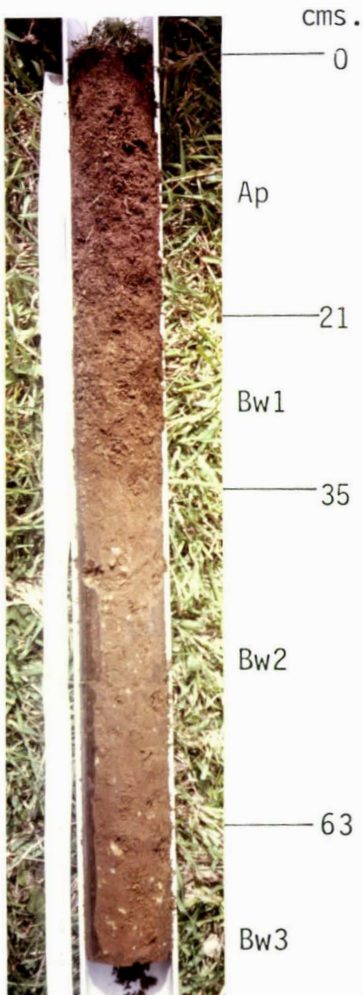


Plate 5.6

Kahui soil core, near Riverlea, at N119/678443.

Note dark coloured topsoil with traces of Manganui tephra over yellowish-brown subsoil containing moderately to strongly weathered pumiceous lapilli.

Stratford Ash" on laharic debris. The area of Kahui series mapped in this survey was previously mapped in Egmont and Glenn sets by N.Z. Soil Bureau (1954).

Kahui series was defined by Palmer *et al.*, (1981), as a moderately to strongly leached, well drained soil, formed from 0.40 to 2m of volcanic ashes on laharic deposits, between 165 and 430m elevation. In Eltham County Kahui series occurs at lower elevations, 210 to 270m.

In Eltham County Kahui series is defined as a moderately leached, well drained soil formed from less than 250mm thickness of *young lapilli showers*, overlying tephras p2 and p1 (Druce, 1966), on fine textured ashes, over laharic debris of the Opuia and Warea Formations. The Opuia Formation is dated at 7320 ± 110 years B.P. (NZ1781C) and Warea Formation deposited between *c.* 12,000 and *c.* 15,000 years B.P. In Egmont County Kahui series differs in that it is largely found above laharic debris of the older Pungarehu Formation, dated at $22,700 \pm 600$ years B.P. (NZ1623B).

Profiles have very dark greyish-brown to dark brown coloured A horizons, with loam to silt loam textures. The B horizons vary from brown to yellowish-brown, with sandy clay loam textures. A thin band of loamy sand may occur above the laharic debris.

There are traces of *young lapilli showers* in the upper part of Kahui series. In the lower B horizons moderately weathered, scattered pumiceous and lithic lapilli occur and are more strongly weathered at depth. In Eltham County a band of strongly weathered pumiceous lapilli, probably tephras E5 and E4, are concentrated just above one metre and form a characteristic feature of Kahui soils (Plate 5.6).

The Kahui series differs from Stratford series in being found where laharic debris occurs at less than 2m depth.

Kahui series differs from Rowan and Riverlea series in having less than 250mm thickness of *young lapilli showers*, in the profile.

Kahui series grades into Egmont series, where traces of the *young lapilli showers* become unrecognisable.

Tipoka series

Tipoka series was introduced by Palmer *et al.*, (1981) as a moderately well drained and imperfectly drained, weakly gleyed soil, derived from 0.6-2m of volcanic ash, overlying laharic material.

In Eltham County Tipoka series is more closely defined as an imperfectly drained, weakly gleyed soil derived from less than 250mm thickness of *young lapilli showers*, overlying tephras p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris of the Opua and Warea Formations. The series is found in a moderately leached environment but gleying tends to be the dominant process in the lower subsoils.

Tipoka series occurs in depressions in flat to gently undulating land, in volcanic ash mantled, lowland laharic terrain, between 210 and 270m elevation.

Profiles have a very dark greyish-brown to dark brown A horizon, overlying either one or two brown or dark brown non-gleyed B horizons. These horizons contain a few scattered pumiceous and lithic lapilli of the *young lapilli showers*. The lower B horizons are gleyed and have brown to light yellowish-brown colours, with red to yellowish-red mottles. The mottles are associated with the strongly weathered pumiceous lapilli, which are scattered or concentrated in the lower part of the profile (Plate 5.7). Concretions may be present and increase in abundance with depth.

The thickness of volcanic ash over laharic debris ranges from 0.50 to 2m.

Tipoka series differs from Kahui series in that gleying occurs above a depth of 1m or above the contact between volcanic ash and laharic debris, where this contact is shallower.

Tipoka series has similar drainage to Makaka series but differs in having less than 250mm thickness of *young lapilli showers* in the profile.

Tipoka series was included in Glenn and Egmont sets by N.Z. Soil Bureau (1954).

— from <250mm *young lapilli showers*
 (mainly Manganui tephra) on pumiceous
 lapilli-bearing ash showers (tephras p2, p1
 (Druce, 1966) E5 and E4) on thick volcanic ash.

Stratford series

Stratford series was introduced by Grange and Taylor (1933) for soils derived from the Stratford Shower. The series was divided into two soil



Plate 5.7
 Tipoka soil, near Auroa Road, at N118/643445.
 The dark brown topsoil has a moderately developed nut structure and overlies an unmottled B horizon.
 The mottles present in the Bg1 horizon are associated with strongly weathered pumiceous lapilli.

cms.
 0
 Ap
 16
 Bw
 38
 Bg1

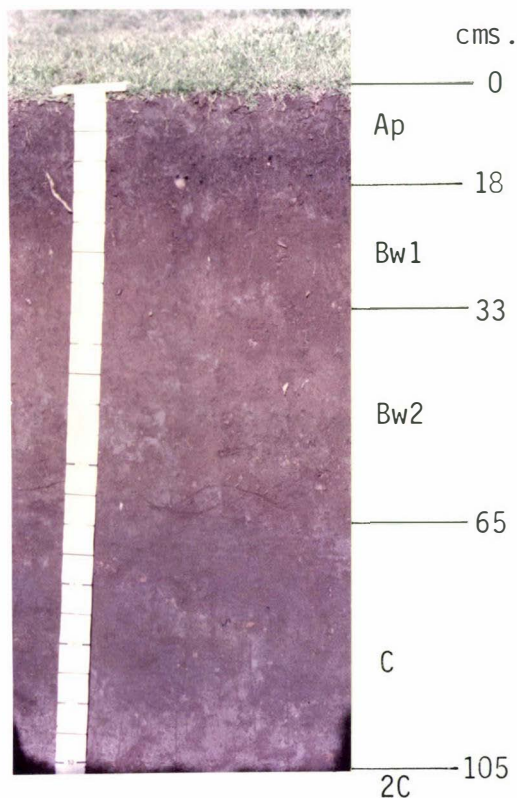


Plate 5.8
 Hangatahua soil, near Manaia Road, 2.5 km south of Kaponga at N119/718445 (S.B. 9702).
 Note very dark brown topsoil containing a few moderately weathered pumiceous lapilli.
 A very dark greyish-brown fine sand horizon occurs at 65 cm., with scattered, strongly weathered pumiceous lapilli.

cms.
 0
 Ap
 18
 Bw1
 33
 Bw2
 65
 C
 105
 2C

types, Stratford sandy loam and Stratford sand. The Stratford sandy loam occurred where the Stratford Shower was 225mm or less in thickness. Stratford sandy loam occurs in a 1125-1750mm rainfall zone and Stratford sand in a 1500-2500mm rainfall zone.

In N.Z. Soil Bureau (1954) Stratford sandy loam, hill soil and Stratford sand, hill soil were introduced.

Aitken et al., (1978), in Stratford County, redefined Stratford series to include well drained, moderately leached soils formed from "Stratford Ash" overlying the older deposits of Egmont Ash and bouldery lahar detritus. Three units were redefined, Stratford coarse sandy loam, Stratford fine sandy loam and Stratford hill soils.

In Eltham County the parent material of Stratford series is more closely defined as consisting of moderately weathered tephra comprised of Manganui tephra, less than 250mm in thickness, the tephra p2 and p1 (Druce, 1966) as distinct bands of pumiceous lapilli, with E5 and E4 present, less than 1m from the surface, either on thick ash or sedimentary rocks. Stratford series differs from Egmont series in that it is formed in younger tephra, contains pumiceous lapilli throughout the soil profile and has a coarser texture. Stratford series also forms under a somewhat higher (1330-1810mm) mean annual rainfall range, compared with Egmont series (1100-1600mm).

Profiles have A horizons varying in colour from very dark greyish-brown to very dark brown and in texture from loam to silt loam. B horizons are yellowish-brown and vary in texture from silt loam to sandy loam. The subsoil in Stratford soils is characterised by containing pumiceous lapilli, which are usually concentrated in distinct bands but may be scattered throughout the profile. The lapilli are weakly to moderately weathered in the upper B horizons but are more strongly weathered at depth (Plate 5.9).

Stratford series differs from Stratford series, fine topsoil variant, in having (i) traces of Manganui tephra (ii) the tephra p2 and p1 (Druce, 1966) present as distinct bands of pumiceous lapilli and (iii) the tephra E5 and E4 present less than 1m from the surface.

Stratford soils on hilly slopes have similar profiles but the pumiceous lapilli tend to be more strongly weathered with depth. Abundant mafic crystals produce a speckled appearance, in the lower B horizons. In some profiles, fragments of the underlying Tertiary sedimentary rocks, such as silty sandstone, may be admixed with volcanic ash in the subsoil.

Ngaere series

Ngaere series was introduced in this survey for imperfectly drained, weakly gleyed yellow-brown loams, derived largely from pumiceous lapilli that include traces of the *young lapilli showers*, tephras p2 and p1 (Druce, 1966) and E5 and E4, on thick volcanic ash.

Ngaere series occurs on level or near level sites and in depressions on flat to gently undulating land, in volcanic ash mantled lowland laharc terrain, between 150 and 240m elevation.

Profiles are similar to those of Stratford series but Ngaere series in contrast shows evidence of gleying.

Ngaere series profiles have very dark brown to dark brown loam A horizons, with a few scattered lithic lapilli. There may be one or two non-gleyed horizons, above the gleyed lower B horizons. Included within Ngaere series is a poorly drained variant, in which all the B horizons are gleyed.

The upper B horizons vary from dark reddish-brown to brown, weathered, sandy loam to loam. The lower B horizons range from strong brown to reddish-brown to yellowish-brown colour, with dark reddish-brown to yellowish-red mottles. Mottles tend to be associated with the moderately to strongly weathered pumiceous lapilli present, which are scattered or concentrated in a band. A feature of the Ngaere series are few to many iron concretions, usually adjacent to pumiceous lapilli.

Ngaere series was included in Stratford set by N.Z. Soil Bureau (1954).

— from pumiceous lapilli-bearing ash showers
(tephras p2, p1 (Druce, 1966) E5 and E4)
on thick volcanic ash.

Stratford series, fine topsoil variant

It was found necessary to introduce one new named soil variant, in the survey, here referred to as Stratford series, fine topsoil variant. The variant is closely related to Stratford series but is too distinctive to be regarded as a taxadjunct and too extensive to be considered a mapping inclusion.

Profiles are well drained and moderately leached. They are

characterised by very dark brown coloured A horizons of silt loam texture and moderately well developed crumb structure. The upper B horizon, in a Stratford series, fine topsoil variant is typified by scattered, strongly weathered pumiceous lapilli, which average less than 10mm in diameter. The lower B horizons are yellowish-brown in colour, with a speckled appearance due to the presence of mafic crystals and a loam to sandy clay loam texture (Plate 5.10).

Stratford series, fine topsoil variant differs from Stratford series in having (i) no Manganui tephra present, (ii) the tephras p2 and p1 (Druce, 1966), together with E5 and E4 scattered throughout the subsoil. On average these tephra are less than 10mm in diameter.

Stratford series, fine topsoil variant, differs from Egmont series in having been formed under a higher mean annual rainfall range, 1500-1900mm.

The areas of this soil mapped in Eltham County were previously mapped in New Plymouth and Egmont sets by N.Z. Soil Bureau (1954).

GLEYSOILS

- from > 250mm *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephras) on thin (with minor thick) volcanic ash, overlying laharic debris.

Mangawhero series

Mangawhero series is identified for the first time in this survey. It is a gley soil and its closest correlation is with Awatuna series. However, it differs in having greater than 250mm of *young lapilli showers*, which impart a gravelly modification to the upper horizons.

It forms in depressions, on flat to gently undulating land, in tephra mantled upland and lowland laharic terrain, between 220 and 760m elevation.

Profiles have A horizons varying from very dark greyish-brown to very dark brown in colour and from loam to silt loam in texture.

The B horizons are all gleyed and have colours varying from yellowish-brown to pale brown, with dark reddish-brown to red mottles, which are few and faint, near the surface, but increase to many, distinct mottles, with depth. The concretions are reddish-brown and can be cemented together to form an indurated, vesicular iron oxide pan, at the textural boundary between tephra and laharic deposits beneath (Plate 2.9). The mottles and concretions tend to be found in association with lithic and pumiceous lapilli, which may be concentrated in distinct bands or scattered.

The Manganui tephra is usually concentrated in the upper gleyed horizons. The upper part of the tephra consists of iron stained lithic lapilli and the lower part is a heavily iron stained, discontinuous lithic tuff.

The thickness of volcanic ash over laharic debris varies from 0.50 to 2m.

Included within Mangawhero series is a peaty topsoil variant.

— from < 250mm *young lapilli showers*
(Kaupokonui, Maketawa and Manganui tephrae)
on thin (with minor thick) volcanic ash,
overlying laharic debris.

Awatuna series

Awatuna series was introduced by Grange and Taylor (1933) to include poorly drained soils, related to Glenn series, derived mainly from volcanic debris deposited by streams, covered with about 25mm of Stratford Shower in places.

It was included in Awatuna set by N.Z. Soil Bureau (1954) and defined as a gley soil of moderate natural drainage, derived from "Egmont and Stratford Ash". Awatuna set still remained related to Glenn set but occurred under higher rainfall. The area mapped as Awatuna series in this survey was previously mapped in the Glenn set by N.Z. Soil Bureau (1954).

In Waimate West County, Campbell and Wilde (1970) described Awatuna sandy loam as a poorly drained to imperfectly drained soil, formed on flood plains from alluvium of volcanic origin. The parent material was mainly coarse textured, with a thin coating of "Stratford Ash" in places.

However, in Egmont County the Awatuna series was redefined by Palmer *et al.*, (1981). It is still regarded as a gley soil but is no longer considered simply a higher rainfall equivalent of Glenn series. Awatuna series is derived from between 0.60 and 1.50m of volcanic ash on laharic debris.

In Eltham County the above definition is followed but is further qualified as having less than 250mm thickness of *young lapilli showers*, overlying tephras p2 and p1 (Druce, 1966), on fine textured ashes over laharic debris.

Profiles of the Awatuna series have very dark greyish-brown to dark grey A horizons over gleyed B horizons.

A few pumiceous and lithic lapilli may be found in the A and upper B horizons. Plant roots are usually iron stained. Dark reddish-brown to yellowish-red mottles increase from being few, faint to many, distinct mottles with depth. Concretions may be a feature of the profile and similarly increase with depth. The mottles and concretions tend to be associated with the presence of lithic and pumiceous lapilli that are either concentrated in distinct bands or scattered throughout the profile. The concretions can be cemented together to form an indurated, vesicular iron oxide pan, at the textural boundary between the tephra and underlying laharic debris. The water-table in Awatuna series is often less than one metre from the surface.

Awatuna series is found in similar parent materials as Tipoka series but differs in having gleying throughout all the B horizons.

Awatuna series differs from Mangawhero series in having less than 250mm thickness of *young lapilli showers* in the upper horizons.

— from recent andesitic sands and gravels

Okato series

Okato series is a gley soil introduced by Palmer *et al.*, (1981) to include imperfectly and poorly drained soils, in Egmont County, derived mainly from recent andesitic alluvium. The deposits vary in texture from loamy sand to coarse sand and may be stony, gravelly or bouldery in nature. There is no volcanic ash cover. The same definition has been

followed in Eltham County.

A horizons vary from dark reddish-brown to dark brown silt loam to loamy sand. In imperfectly drained profiles a non-gleyed B horizon, similar to those of well drained soils, forms below the A horizon. In poorly drained profiles the A horizon rests directly on gleyed B horizons. The gleyed B horizons vary from very dark greyish-brown to dark brown, with dark red mottles. Textures vary from loam to loamy sands. The B horizons have a weakly developed structure or are single grained.

The C horizons are gleyed, with many mottles and vary in texture from silt to coarse sand. There can be A/C profiles, with B horizons absent.

Okato series differs from Hangatahua series, in having gleyed horizons, within one metre of the surface.

Okato series was included in Esk set by N.Z. Soil Bureau (1954) and in earlier work by Grange and Taylor (1933) was included with Hangatahua series.

INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS

— from recent andesitic sands and gravels

Hangatahua series

Hangatahua series was introduced by Grange and Taylor (1933) to include all Taranaki soils formed from volcanic material resorted by streams. The series was subdivided into loam, bouldery loam, sand and gravelly sand soil types. In N.Z. Soil Bureau (1954) Hangatahua series was included in Esk set. In the soil survey of Waimate West County, Campbell and Wilde (1970), described Hangatahua soils as well drained and well drained to somewhat excessively drained soils, derived from volcanic alluvium on flat land. Hangatahua silt loam was mapped on well drained terraces and broad levées, derived from old alluvial deposits, while Hangatahua sandy loam was mapped in the valleys of streams, on lower terraces than the silt loam. Hangatahua sandy loam was also mapped by Aitken et al., (1978) in Stratford County, as a well drained soil derived from alluvium that was free from flooding. It was considered to show

enough profile development to be classified as a weakly weathered yellow-brown loam. In Egmont County Palmer et al., (1981) defined the Hangatahua series as a well drained, weakly weathered intergrade between yellow-brown loams and recent soils, developed on non-accumulating alluvium and debris flow deposits of Hangatahua Gravels and Maero Debris Flows.

In Eltham County Hangatahua series is similarly defined as a well drained, non-accumulating intergrade between yellow-brown loams and recent soils developed from andesitic alluvium.

It should be noted that the Hangatahua series has undergone several changes in concept and classification having been regarded in turn as a recent soil, a yellow-brown loam and now an intergrade between yellow-brown and recent soil. The classification and definition of the Hangatahua series has now been stabilised.

Profiles are characterised by black to dark brown A horizons. Textures are variable and range from silt loam to fine loamy sand. The B horizons have dark greyish-brown to yellowish-brown colours and show either weakly developed structures or single grains. The C horizons are very dark to dark greyish-brown, fine to coarse sands, which may be loose or firm (Plate 5.8). Gravel and stones are usually present and increase in concentration with depth. Boulders may be present in areas close to the rivers.

RECENT SOILS

— from thin volcanic ash (Tahurangi Formation)
on older volcanic ashes

Tahurangi series

Tahurangi series was introduced by Tonkin (1970) in a small survey of the south-eastern slopes of Mt. Egmont. Tahurangi fine sandy loam and Tahurangi hill soils were classed as very strongly leached, yellow-brown pumice soils, from andesite tephra.

Aitken et al., (1978) mapped Tahurangi fine sandy loam and Tahurangi hill soils in Stratford County. Tahurangi soils were classified as

recent soils from tephra of the Tahurangi Formation over the Burrell Formation. They occur on the upper slopes of Mt. Egmont between 760-1,100m elevation and their natural drainage is imperfect.

In Egmont County Tahurangi series is a very strongly leached, iron illuvial, recent soil from shallow volcanic ash of the Tahurangi Formation, on older volcanic ashes and debris flow deposits (Palmer *et al.*, 1981). The lower limit of Tahurangi series follows the 50mm isopach of the Tahurangi Formation, taken from Druce (1966). The Formation reaches up to 100mm in thickness where Tahurangi series occurs.

In Eltham County the above definition of Tahurangi series is followed. Tahurangi series occurs on flat to hilly slopes of Mt. Egmont, between 760 and 1,100m elevation.

Profiles of Tahurangi series are characterised by thin, dark greyish-brown sandy loam A horizons of weak, fine crumb structure, overlying a dark brown, loamy coarse sand subsoil, containing iron-coated pumiceous and lithic lapilli (Burrell Formation and Puniho Lapilli I), lying on a layer of gravel and sand, with dark reddish-brown coatings of iron oxide. N.Z. Soil Bureau (1954) mapped Tahurangi soils as "Mountain soils".

LITHOSOLS AND SKELETAL SOILS

— from andesitic rock, scree and tephra

Unnamed subalpine and alpine soils

Unnamed subalpine and alpine soils were introduced by Aitken *et al.*, (1978) in Stratford County for soils derived from andesitic volcanic ash and rock at high elevations, on Mt. Egmont.

Unnamed subalpine and alpine soils were mapped in Egmont County, above the level of continuous forest cover, but were not examined in detail.

In Eltham County unnamed subalpine soils occur in the area of subalpine scrub and tussock, between 1,100 and 1525m elevation, under rainfalls varying from about 4000 to 6000mm per annum.

Unnamed alpine soils occur above 1525m elevation, where vegetation is largely absent and rainfalls vary as high as 8000mm annually.

Neither of these soils were examined in detail in this survey.

ORGANIC SOILS

— from woody peat with interbedded tephra layers

Eltham series

Eltham series was first introduced by Grange and Taylor (1933) as Eltham peaty loam, derived from a mixture of peat and volcanic ash.

The N.Z. Soil Bureau (1954) included Eltham series within Piako set, despite the higher rainfall and the woody nature of the peat in Taranaki.

Aitken et al., (1978) redefined Eltham series, as a moderately developed organic soil, derived from a lowmoor, woody peat, with interbedded thin andesitic tephra layers. This definition is followed in Eltham County.

Eltham series occurs on flat land, on the edge of the volcanic ring plain, between 210-220m elevation and under mean annual rainfalls, ranging between 1620 and 1890mm.

Profiles of Eltham series have dark reddish-brown to dark brown A horizons, with silt loam to peaty loam texture and strongly developed nut structure. The roots are usually concentrated in the topsoil and are often iron stained. The subsoil tends to be very dark brown to black, becoming a dark reddish-brown, structureless peat with depth. The distribution of pumiceous and lithic lapilli is irregular and can be concentrated in bands or pockets. Pumiceous lapilli vary in diameter, from less than 1mm to greater than 20mm and become strongly weathered with depth. The distinctive lithic-rich Manganui tephra (c. 3,300 years B.P.) has been identified at a depth of approximately 0.60 to 0.70m and results in a gravelly horizon.

Partly decomposed fragments of wood, twigs and fibres are a feature throughout the profile and are concentrated at approximately 0.90m depth. The water-table usually occurs between 0.60 and 1.50m.

STEEPLAND SOILS RELATED TO YELLOW-BROWN EARTHS

— from moderately consolidated silty sandstone

Whangamomona series

Whangamomona series was introduced by N.Z. Soil Bureau (1954) for soils derived from sandy mudstone and sandstone, (Whangamomona silt loam) and mudstone and sandstone, Stratford and Egmont ash (Whangamomona complex), in eastern Taranaki. The area mapped in this survey was previously mapped in Whangamomona and Moumahaki sets.

In N.Z. Soil Bureau (1968) Whangamomona soils were described as being derived from sandstone and were mapped in association with Mangamahu soils, from sandstone and mudstone.

Whangamomona soils were more closely defined as being formed from moderately consolidated silty sandstone by Aitken *et al.*, (1978). These authors accepted that due to parent material differences a considerable variety of soils were included within the mapping unit, Whangamomona soils. In Eltham County, Whangamomona series is similarly reserved for those soils derived from silty sandstone. However, parent rock composition within the mapping unit can range from hard sandstone to silty mudstone, with varying amounts of volcanic ash present in the profiles. Occasional outcrops of shelly limestone also occur. In a more detailed survey these variations would be separated out as a different soil series.

Whangamomona series occurs on steep and very steep slopes, in dissected Tertiary age sedimentary rock terrain, between 120 and 490m elevation, under mean annual rainfalls between 1500 and 1900mm.

In this survey, a catena-like pattern of soils on valley sides (Campbell, 1973) is recognised, with four distinct soil units occurring on 1) ridge top 2) intermediate steep slope 3) eroded slope and 4) accumulation slope. The series on the intermediate steep slope is taken as the principal, name-giving component of the catena, while the remaining soils are accommodated as, ridge, eroded slope and accumulation slope phases.

Profiles on the intermediate steep slope have dark greyish-brown to brown A horizons, overlying thin, light yellowish-brown to brownish-yellow subsoils. Mottles can be a feature of the subsoil and increase

with depth. Fragments of silty sandstone may be present throughout the profile and there is often a sharp, distinct boundary to the moderately consolidated silty sandstone.

Whangamomona ridge phase differs from the intermediate steep slope by having a more strongly developed fine nut structure, in the A horizon and more weathered B horizons, with a BA horizon often present. The depth to parent rock is usually greater and the transition to parent rock is more gradual.

Whangamomona eroded slope phase differs from the intermediate steep slope by having a weakly structured shallower topsoil. Lateral seepage is a common feature, with mottles and concretions being a characteristic of the profile. The depth to parent rock is shallower than in the intermediate steep slope.

Whangamomona accumulation slope phase differs from the intermediate steep slope by having more silty sandstone fragments, especially in the lower horizons and a greater depth to the parent rock.

4. SOIL MAPPING UNITS

The following brief descriptions give details of the soil mapping units recognised in this survey. The members of each soil association (one of mapping units used) shown on the soil map are listed in Table 5.3 in relation to topography and drainage. Individual members of the mapping units (soil associations) are described in more detail in the extended legend (Appendix IV).

SOILS OF LOWLAND LAHARIC TERRAIN

1. On flat to strongly rolling land between 90-340m elevation

Riverlea-Makaka association (Rv-Mk) :

Mapped over a total area of 770ha west of Kaponga and east of Upper Rowan Road, between the Mangawheroiti Stream and the Otakeho Stream. Riverlea series is the dominant member and occurs on well

drained sites while Makaka series occupies the imperfectly drained, lower-lying sites. Inclusions of Kahui series occur near the boundary between Riverlea series and Kahui series. This boundary is gradational and is based on the 250mm isopach for the *young lapilli showers*. Inclusions of Rowan series occur in the north of the mapping unit.

Riverlea-Mangawhero association (Rv-Mw) :

Mapped over a total area of 620ha in two localities. The first is in the extreme west of Eltham County, in an area between the Otakeho Stream and east of the Oeo Stream. The second is an area in the vicinity of Kaponga, between Dunns Stream and immediately east of Upper Rowan Road. Riverlea series occurs on the well drained, flat to gently undulating land and occupies more than 50% of the mapping unit. Mangawhero series occurs in the low-lying, poorly drained depressions. The imperfectly drained Makaka series is also present.

Kahui-Tipoka association (Kui-Tk) :

Mapped over a total area of 180ha in two localities. The first is an area south-west of Kaponga, in the vicinity of Dunns Stream and the second is a strip adjacent to the Waimate West County Boundary, in the extreme west of Eltham County. Kahui series occupies 50% or more of the mapping unit on the well drained, flat to gently undulating sites while Tipoka series occurs on imperfectly drained, lower-lying sites.

Tipoka-Kahui association (Tk-Kui) :

Mapped in a single area of 220ha, in the south-west of Eltham County, adjacent to the Waimate West County Boundary between Rowan and Mangawhero Roads. Tipoka and Kahui series occupy about equal portions of this mapping unit. Inclusions of Awatuna series occur in low-lying, poorly drained sites.

Makaka-Riverlea association (Mk-Rv) :

Mapped in a single small area of 100ha, near Riverlea, below Opunake Road, between Mangawheroiti Stream and one of its tributaries

to the east. Makaka series occupies 50% or more of the mapping unit in imperfectly drained sites. Riverlea series occurs in the well drained sites, with inclusions of Mangawhero series in the poorly drained sites.

Lowgarth soils (Lo) :

Mapped over 1960ha of flat to rolling land between Kaponga, in the west and Stuart Road, in the east and to the north of Eltham Road. Consists predominantly of Lowgarth series, with inclusions of Stratford series, near the boundary between Lowgarth and Stratford series. This boundary is gradational and is based on the 250mm isopach for the *young lapilli showers*.

Lowgarth soils, strongly rolling phase (Lo₁) :

Mapped over a total area of 970ha between Upper Stuart Road and Lower Hastings and Hunter Roads, to the west of Upper Palmer Road and between Inaha Stream and Upper Palmer Road. Consists predominantly of Lowgarth soils, strongly rolling phase, with inclusions of Stratford soils, strongly rolling phase, due to the gradational nature of the boundary, based on the 250mm isopach for the *young lapilli showers*.

Stratford soils (St) :

Mapped over 7890ha of flat to rolling land east of Kaponga. The mapping unit consists predominantly of Stratford series with inclusions of Ngaere series, where drainage is imperfect.

Stratford soils, strongly rolling phase (St₁):

Mapped on strongly rolling land west and south-west of Eltham Borough. The mapping unit consists predominantly of Stratford soils, strongly rolling phase and has a total area of 1640ha.

Stratford soils, fine topsoil variant (St_v) :

Mapped over a total area of 1,250ha. It occurs in several areas, specifically in the east of Eltham County. There is an area in the vicinity of Tirimoana Road, several small areas above the Patea River and an area in the vicinity of Mangamingi Road. Consists predominantly of Stratford soils, fine topsoil variant, with inclusions of Stratford series.

2. In low-lying areas or in depressions between 120-340m elevation

Makaka-Mangawhero association (Mk-Mw):

Mapped over a total area of 1330ha in several areas west of Kaponga. Makaka series is the dominant member of this association and occurs on the imperfectly drained, level or near level sites, while Mangawhero series occupies the poorly drained, low-lying sites and old stream channels.

Mangawhero-Riverlea association (Mw-Rv) :

Mapped on a single area of 160ha, west of Kaponga, in the vicinity of Rowan and Opunake cross-roads. Mangawhero series is the dominant member of the association and lies in the lower, poorly drained parts. Riverlea series occurs on the well drained sites, with Makaka series occurring in intermediate positions where the drainage is imperfect.

Awatuna-Tipoka association (At-Tk) :

Mapped in a single area of 43ha, in the south-west of Eltham County, between the Mangawhero Stream and just west of Lower Mangawhero Road. Awatuna and Tipoka series occupy about equal portions of this mapping unit.

Awatuna-Kahui association (At-Kui) :

Mapped on a single area of 170ha in the south-west of Eltham County, between the Kaipokonui Stream and just east of Lower Rowan Road. Awatuna series lies in the poorly drained depressions, with Tipoka series occurring where drainage is imperfect. Kahui series occurs on higher, well drained sites. The Awatuna series is the dominant member.

Ngaere-Stratford association (Ng-St) :

Mapped over a total area of 210ha, near Eltham Borough, adjacent to the Eltham Swamp. Ngaere series is the dominant member of the association. Stratford series, the subdominant member, occurs on the well drained sites.

3. On strongly rolling, hilly and steep land between 120-290m elevation

Lowgarth hill soils (LoH) :

Mapped in two small areas, west of Upper Stuart Road, of total area 17ha.

Stratford hill soils (StH) :

Mapped over a total area of 1850ha, surrounding Eltham Borough and to the east and south-east in Eltham County, where there are highly dissected remnants of Eltham lahar surfaces.

Stratford hill-Stratford association (StH-St) :

Mapped over a total area of 1690ha, east and south-east of Eltham Borough, where there are remnants of the Eltham lahar surfaces. The most highly dissected areas produce a distinctive landscape, with Stratford hill soils on the hilly slopes and Stratford soils on the flatter areas.

Stratford hill-Stratford soils, strongly rolling phase (StH-St₁) :

Mapped over a total area of 250ha, which includes a small area west of Lower Stuart Road, an area to the west of Eltham Borough, between the Waingongoro River and Upper and Lower Stuart Roads, and an area in the vicinity of Lake Rotokare, between Sangster and Rotokare Roads.

Stratford series, hill soil occurs on the hilly land and occupies more than 50% of the mapping unit while the Stratford series, strongly rolling phase occurs on the strongly rolling terrain.

SOILS OF UPLAND LAHARIC TERRAIN

1. On lahar mounds and flat to rolling land between 310-760m elevation

Rowan-Makaka association (Rc-Mk) :

Mapped over a total area of 890ha. Consists predominantly of Rowan series on well drained sites. Makaka series occurs on

imperfectly drained sites, while smaller areas of Mangawhero series occupy poorly drained sites.

Rowan-Mangawhero association (Rc-Mw) :

Mapped over a total area of 940ha, mainly within Egmont National Park, up to an elevation of about 760m and an area west of the Otakeho Stream, above 300m elevation. Rowan series occurs on the well drained sites, with Makaka series occupying imperfectly drained sites and Mangawhero series on the poorly drained sites. No one member dominates the others.

2. On lahar mounds between 360-460m elevation

Rowan hill-Mangawhero association (RcH-Mw) :

Mapped on a single small area of 40ha, in the vicinity of Upper Auroa Road. The mapping unit covers a landscape of laharic mounds, where Rowan series, hill soil occurs on the sides and crests of lahar mounds and Mangawhero series lies in the most poorly drained parts of intervening depressions. Makaka series occurs in intermediate positions.

3. In low-lying areas or in depressions between 220-460m elevation

Mangawhero-Makaka association (Mw-Mk) :

Mapped on a single area of 160ha to the east of Upper Auroa Road, below 450m elevation. Mangawhero series is the dominant member and occurs in low depressions and old stream channels, while Makaka series occurs on raised areas, where drainage is slightly better than in Mangawhero series.

4. On flat to hilly slopes on Mt. Egmont between 760-1,100m

Tahurangi soils and hill soils (Tah-TahH) :

Tahurangi series occurs on flat to rolling topography and Tahurangi series, hill soil occurs on hilly slopes, which include

gully sides and stream channels. These soils occur within the one mapping unit, which covers the upper slopes of Mt. Egmont between 760 and 1,100m elevation over a total area of 460ha.

SOILS OF SUBALPINE AND ALPINE TERRAIN

On steep and very steep slopes on the very steeply sloping terrain on the southerly flanks of Mt. Egmont

— between 1,100 and 1,525m elevation

Unnamed subalpine soils (S) :

Mapped above the level of continuous forest cover on subalpine steeplands of Mt. Egmont over an area of 210ha.

— between 1,525 and 2,518m elevation

Unnamed alpine soils (A1) :

Mapped above the level of continuous plant cover on the upper most slopes of Mt. Egmont over a total area of about 200ha.

SOILS OF RIVER FLATS AND TERRACES

— between 120 and 460m elevation

Hangatahua-Okato association (Hn-Ok) :

Mapped over a total area of 490ha adjacent to many stream channels in Eltham County, in such catchments as the Otakeho, Mangawhero, Mangawheroiti and Kapuni Streams, with an extensive area along the Kaupokonui Stream.

The association is mapped on alluvial fans, levées and river terraces. Hangatahua series occupies 50% or more of the area and occurs on well drained sites. Okato series, the subdominant member, occurs in sites of imperfect or poor drainage.

Okato-Hangatahua association (Ok-Hn) :

Mapped over a total area of 200ha adjacent to several stream channels and extensive in catchments of Dunns, Waingongoro and Mangawhero Streams. The association is mapped on alluvial fans, levées and river terraces. Okato series occupies 50% or more of the area and occurs on imperfect or poorly drained sites. Hangatahua series, the subdominant member, occurs on well drained sites.

SOILS OF DRAINED SWAMPLAND

Eltham soils (E1) :

Mapped on the drained swamps east of Eltham Borough.

The Eltham Swamp and the Ngaere Swamp occur at two different levels, 210m and 220m, respectively.

The mapping unit consists predominantly of Eltham series and occupies a total area of 2670ha. The land is typically flat, with the swamps bordered to the east by steep hills and to the west by the volcanic ring plain.

SOILS OF STEEPLAND TERRAIN

Whangamomona soils (WgS) :

Mapped over an extensive area of 6000ha east of Eltham Borough, on steep and very steep land, in the dissected Tertiary sedimentary rock terrain. The series on the intermediate steep slope is taken as the principal name-giving component of the mapping unit, while the remaining soils are accommodated as ridge, eroded slope and accumulation slope phases. The phases can gradually merge into one another and separation can be difficult.

Overall the soils fall within the imperfectly drained class.

There are inclusions of Moumahaki, Tirangi and Tahora steep land soils. Moumahaki steep land soils occur where the parent material is strongly consolidated sandstone, Tirangi steep land soils where the

parent material is sandy siltstone and Tahora steep-land soils occur where the parent material is sandy mudstone. The map unit also includes small areas of Stratford soils, fine topsoil variant on volcanic ash mantled terraces.

5. DISTINGUISHING STRATFORD SOILS FROM EGMONT SOILS

Stratford and Egmont soils are the two most widespread soil series in central Taranaki. Of the well drained yellow-brown loams in Eltham County Stratford soils are the most common and are derived from moderately weathered andesitic volcanic ash and pumiceous lapilli. Further south Egmont soils are recognised, and become extensive in south Taranaki.

In the past, mapping of the Stratford series has relied upon rather vague concepts of the distinction between Stratford and Egmont Ash Showers. The terms Stratford Shower and Egmont Shower have implied largely pumiceous and largely non-pumiceous deposits respectively. This has resulted in difficulty recognising soils in the boundary areas where both soil series approach one another in a gradational fashion. Part of this research study was to investigate and to accurately locate the position of the boundary and to elucidate criteria necessary for distinguishing Stratford from Egmont soils.

History and Distribution

Egmont Soils

Egmont soils were first named by Grange and Taylor (1933) for soils derived from volcanic ash belonging to the "Egmont Shower". Egmont series was divided into two soil types based mainly on the colour of the topsoil. In the south, between Manaia and Mokoia and in the north, between Onaero and Okato, (areas which were formerly covered with fern and scrub in pre-European times), the topsoil is dark grey to black and the soil was mapped as Egmont black loam. Inland where the pre-European vegetation was all forest, the topsoil is notably browner and was mapped as Egmont brown loam (Figure 5.2).

The distribution of Egmont black and brown loams was remapped by N.Z. Soil Bureau (1954) using the concept of the soil set. The redefined distribution is shown in Figure 5.3. The soil set was a New Zealand mapping unit for grouping soils with like profiles or like assemblages of profiles. It was employed as a convenient mapping unit for the general survey of the soils of the North Island. The constituent soils in a set are not necessarily geographically associated. Egmont brown loam, Egmont brown loam, hill soil and Egmont black loam (including Warea black loam) were all soil sets belonging to the Egmont Suite (N.Z. Soil Bureau, 1954).

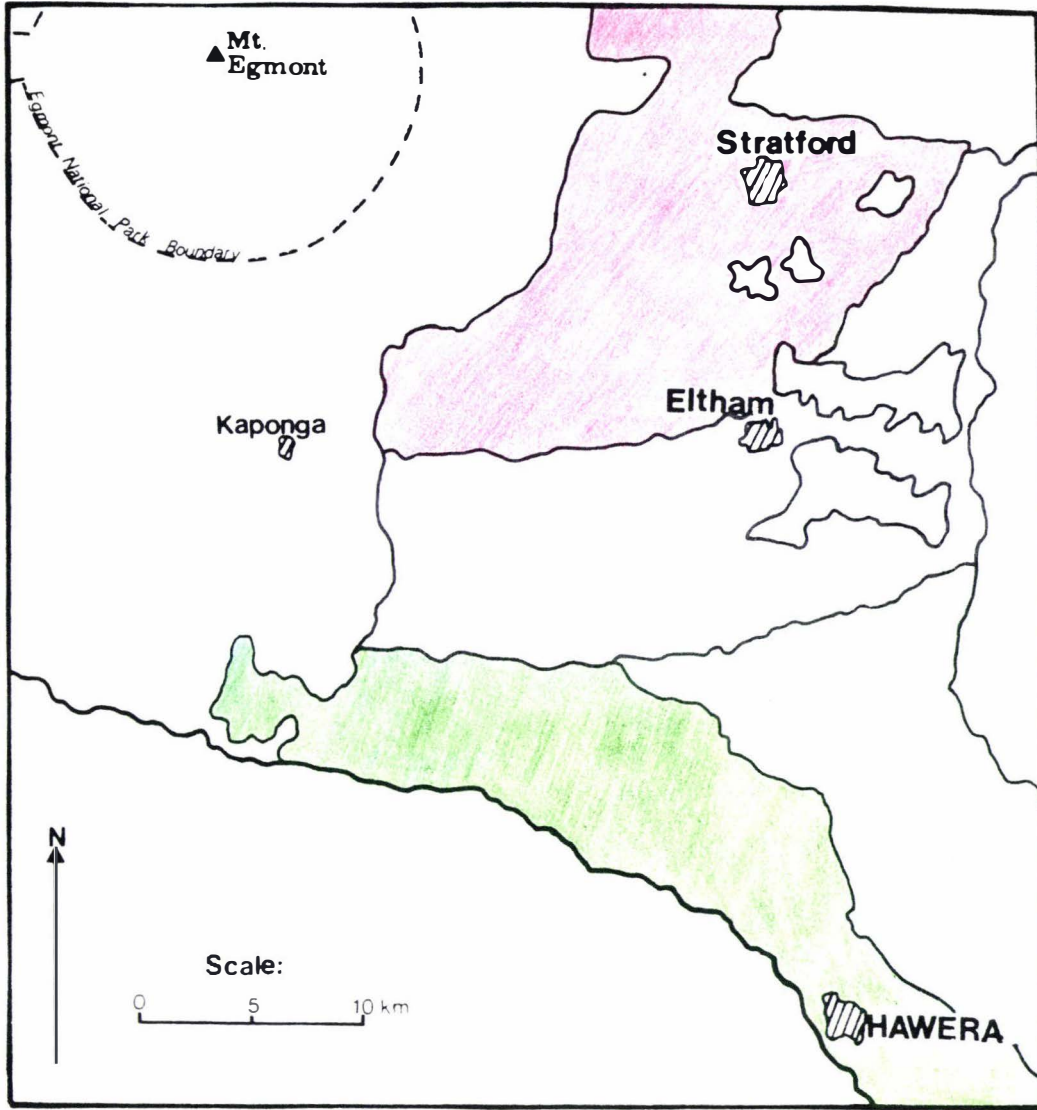







Figure 5.2 Grange and Taylor's reconnaissance soil map of western Taranaki modified to show distribution of Egmont and Stratford soil series in vicinity of study area

Soil mapping units

- | | | | |
|---|------------------------|---|-----------------|
|  | - Stratford sand | } | Stratford soils |
|  | - Stratford sandy loam | | |
|  | - Egmont brown loam | } | Egmont soils |
|  | - Egmont black loam | | |
|  | - Other soils | | |

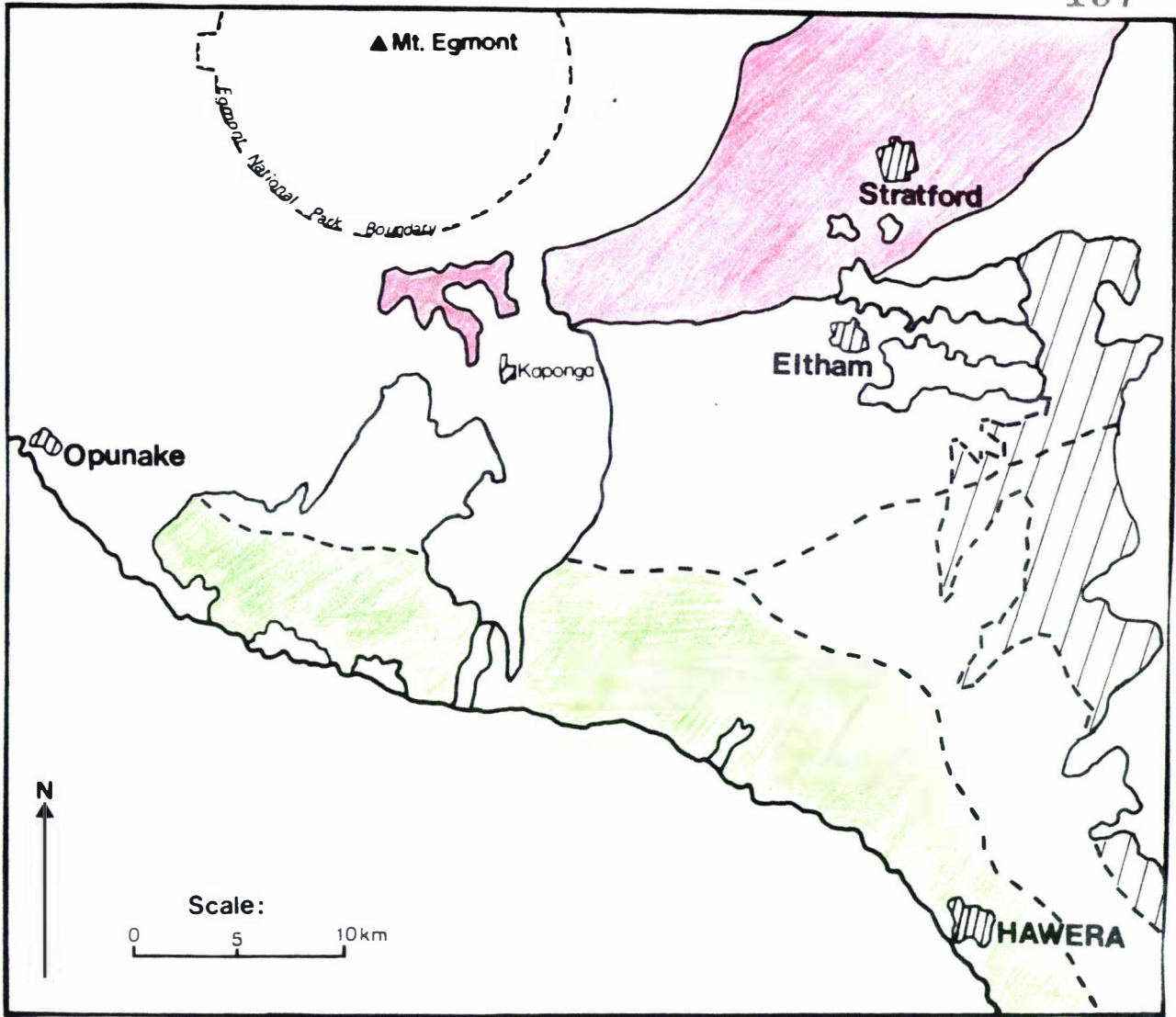









Figure 5.3 Modified soil map of part of Taranaki in vicinity of study area by N.Z. Soil Bureau, 1954

Soil mapping units

- | | |
|---|--|
|  - Stratford sand |  - Egmont brown loam |
|  - Stratford sandy loam |  - Egmont brown loam, hill soil |
|  - Stratford sandy loam, hill soil |  - Egmont black loam |
|  - Other soil series | |

The Egmont soils were formed from approximately 0.6 to 0.9m thickness of Grange and Taylor's Egmont Shower.

The distinction between Egmont black and brown loams was continued by Campbell and Wilde (1970) in their survey of Waimate West County. They mapped the boundary between the two Egmont loams at approximately 67m elevation and 3.2 km inland from the coast. It was recognised that Egmont Ash directly overlay gravel and lahar deposits of the Opunake Formation in places. In such circumstances the ash was commonly greater than 1m thick. However, in other areas the ash was as thick as 5m, where it overlay the Stratford Formation. A moderately deep phase of the Egmont brown loam was mapped where Egmont Ash is only 0.6 to 0.9 m thick and overlies compact deposits of sand or gravel. Neall (1972) later recognised two distinct tephras within the Egmont Shower, namely the Oakura (upper) and Okato (lower) Tephras, as being widespread in western and northern Taranaki.

A detailed investigation into the parent material stratigraphy of a representative Egmont black loam, near Hawera, was conducted by Stewart *et al.*, (1977). It showed that the soil parent material to the east consisted of tephra, over tephric loess, which overlies aeolian sands. In that study two lithological units within the "Egmont Ash" were recognised. The Ap, Bw1 and Bw2 horizons of the Egmont soil are recognised as having developed within an upper tephra unit whilst the 2Cu1 and 2Cu2 horizons are developed in a lower tephric loess unit. Lapilli are rare within the lower unit, except for a band preserved at the base resting on 2m of "speckled ash" nearer to Mt. Egmont. Palmer *et al.*, (1981) described Egmont soils from Egmont County developed on moderately weathered andesitic volcanic ashes, comprised of Oakura and Okato Tephras, on laharic and fluvial sandstone and conglomerate of the Opunake Formation. Here the Egmont soils show more than 1.5m thickness of volcanic ash or volcanic ash over tephric loess. In the Egmont County survey Egmont soils were mapped as a series, with no subdivision based on colour of the topsoil. The Egmont series was restricted to the south-west of the County, in the vicinity of Oeo and Pihama, and extending north towards Awatuna. In the 1933 and 1954 maps Egmont soils were also mapped along the western coast, near Cape Egmont, but are now regarded as belonging to the Warea series (Palmer *et al.*, 1981).

Stratford Soils

Stratford soils were first named by Grange and Taylor (1933) for soils derived from volcanic ash and lapilli belonging to the "Stratford Shower". The Stratford Shower overlies the Egmont Shower and was deposited by westerly winds spreading tephra eastwards from Mt. Egmont. No type localities were ever designated but 0.3m of Stratford Shower was described as resting on the considerably older Egmont Shower at the Demonstration Farm, Stratford. In an internal unpublished report of their survey Grange and Taylor describe several localities and sections showing the Stratford Shower, which are now known to comprise at least three different aged pumiceous tephra.

Grange and Taylor divided Stratford series into two types, the Stratford sandy loam, where rainfall varies from 1125-1750mm per annum and the Stratford sand, with a rainfall of 1500-2500mm per annum. The Stratford sandy loam was recognised where the Stratford Shower was 0.22m (9 in.) or less in thickness and was mapped bordering the Stratford sand in two belts, one to the north, in a 6.4 km wide zone, and the other, to the south, in a 9.6 km wide zone. The Stratford sand was mapped in a strip from Eltham, in the south, to Lepperton, in the north. Stratford sand, hill soils and Stratford sandy loam, hill soils were introduced by N.Z. Soil Bureau in 1954.

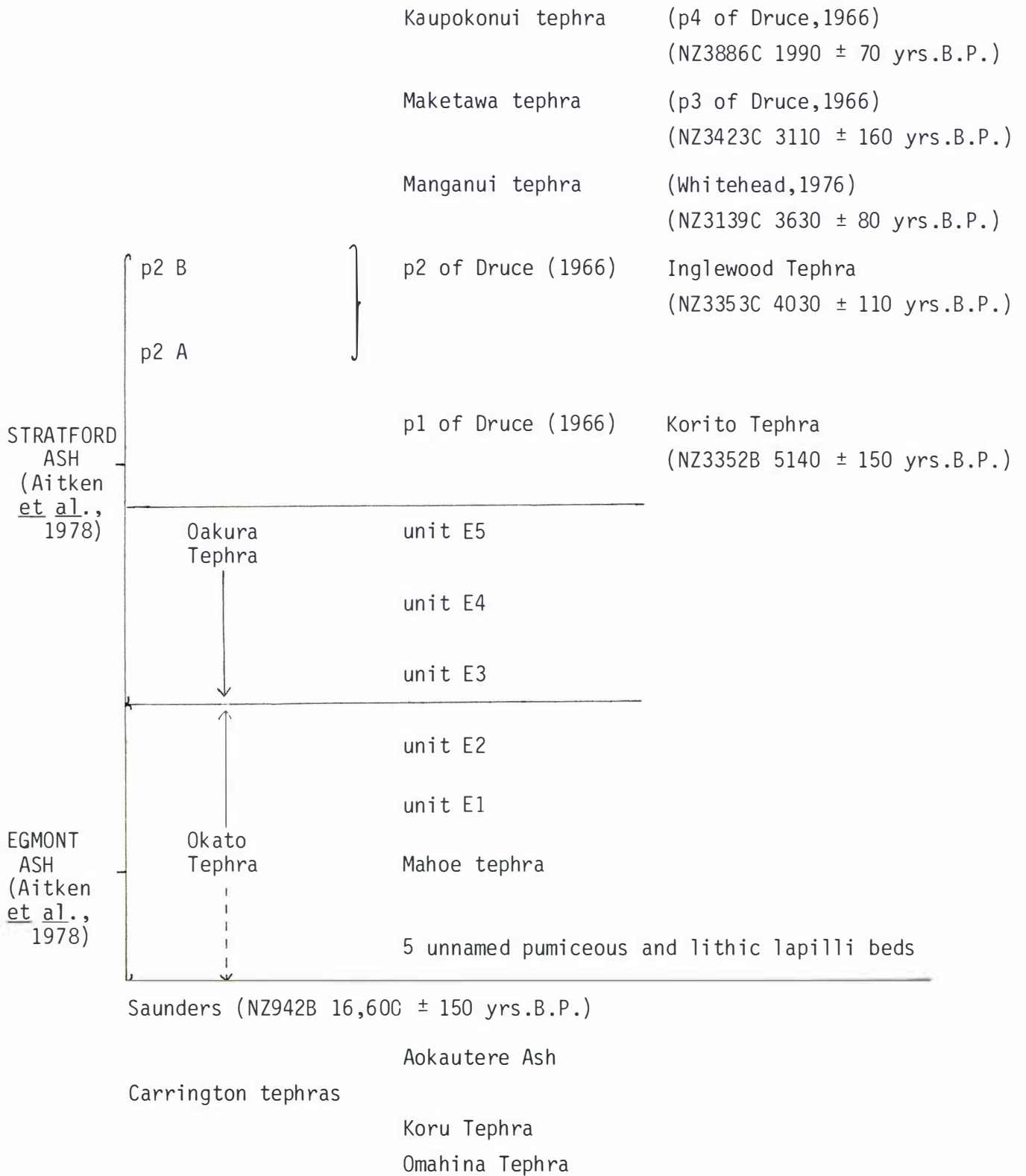
In Waimate West County Campbell and Wilde (1970) recognised that "soils derived from thin deposits of the younger andesitic ash of the Stratford Ash Formation occur in small areas, in the northern part of the county". However, the Stratford soils were considered not extensive enough to be mapped as a separate mapping unit.

It was not until the Stratford County Survey (Aitken et al., 1978) that attempts were made to subdivide the Stratford Shower. In Stratford County, Rowan and Lowgarth soils were separated from Stratford series because they were derived from an unnamed lithic lapilli deposit, younger than the "Stratford Ash". This deposit was subsequently informally referred to as the Manganui tephra by Whitehead (1976). Earlier workers had included the Manganui tephra in the Stratford Ash.

The pumiceous deposits that are now recognised within the originally defined Stratford Shower, range from the Kaupokonui tephra, which is youngest to E3, the oldest (Table, 5.4). In the sense of Aitken et al., (1978), the "Stratford Ash" shower would only have included units p2B

Table 5.4

TEPHRAS CURRENTLY RECOGNISED IN ELTHAM COUNTY



(youngest) to E3 (oldest). Units below E3 were grouped into the Egmont Shower, on the basis of their orange and more weathered appearance, compared to the creamy coloured lapilli of the "Stratford Ash". Stratford soils were redefined by Aitken et al., (1978) to include soils formed from "Stratford Ash" overlying the older deposits of Egmont Ash and bouldery lahar detritus. The soils mapped were subdivided into Stratford coarse sandy loam close to Mt. Egmont, where Stratford Ash is both deeper and coarser-textured, and Stratford fine sandy loam and Stratford hill soils, east of Stratford.

In this survey, soils belonging to the Stratford series have been more closely defined. They are well drained, moderately leached soils, formed in volcanic ash, greater than two metres thick, containing pumiceous lapilli-bearing ash showers. In the topsoil there is no more than 250mm thickness of Manganui tephra. In the subsoil the tephra p2 and p1 (Druce, 1966) are present as a distinct band of pumiceous lapilli, overlying E5 and E4, less than one metre from the surface. An extensive area of Stratford soils is mapped east of Kaponga.

A Stratford fine topsoil variant was introduced in this survey for soils in which the Manganui tephra is absent from the topsoil, and the strongly weathered tephra p2 and p1 (Druce, 1966), and E5 and E4 are scattered and average less than 10mm in diameter, becoming a speckled ash in the subsoil. Stratford series, fine topsoil variant is mapped in the east of the County, in the vicinity of Tirimoana and Mangamingi Roads and adjacent to the Patea River. This variant has also been mapped in Waimate West County to update Campbell and Wildes (1970) map and occurs between the Kapokonui and Kapuni rivers, north of Manaia (Figure 5.4).

The above definitions of the Stratford series and Stratford series, fine topsoil variant, with the limits of tephra identification and thickness of ash, are based on detailed soil morphological and tephrochronological study. This tephrochronological approach allows the soil series to be defined on precise tephra and lithological characteristics, which not only provide a chronostratigraphic basis but also dictate the physical, chemical and mineralogical properties of each soil series.

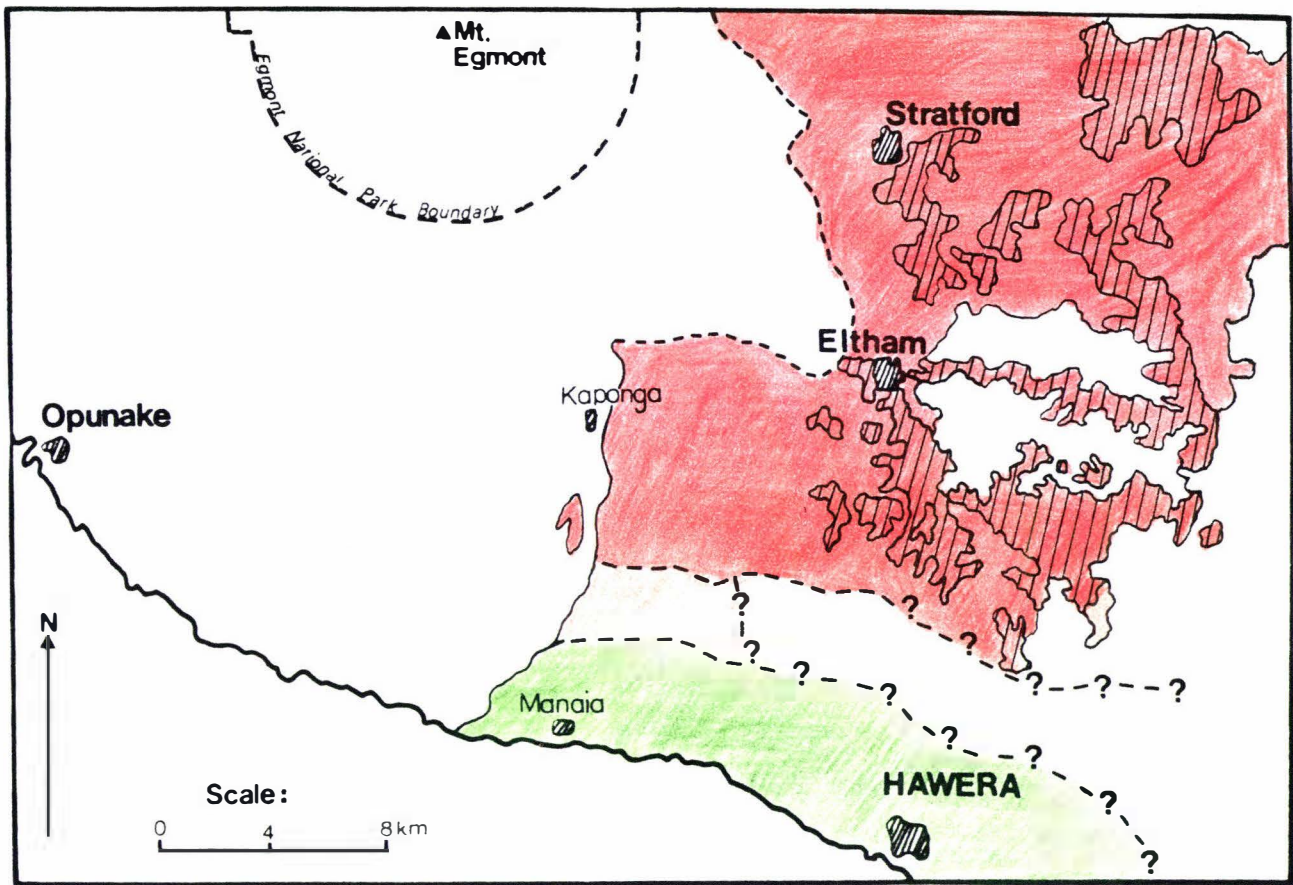







Figure 5.4 Map to show present known distribution of Stratford and Egmont soils in vicinity of study area

Soil mapping units

-  - Stratford series
-  - Stratford series, hill soil
-  - Stratford series, fine topsoil variant
-  - Egmont series
-  - Other soil series

Morphological Properties

The elevation and rainfall ranges, landform and mean annual air temperature under which Stratford, Stratford fine topsoil variant and Egmont soils are found are shown in Table 5.5.

Each soil unit is a deep, well drained, moderately leached yellow-brown loam having similarities of yellowish-brown subsoil colour, friable consistence and light to medium texture, varying from sandy loam to silt loam. Although the morphology of the three soils initially appears uniform, distinct differences can be recognised. The presence of less than 250mm thickness of the gravelly Manganui tephra in the topsoil and pumiceous lapilli, averaging 20mm in diameter and usually concentrated in bands in the subsoil, are a distinguishing feature of the Stratford series. The pumiceous lapilli in the Stratford series are weakly to moderately weathered in the upper B horizons and become more strongly weathered with depth. The Stratford series, fine topsoil variant contains no visible Manganui lapilli. The variant is distinguished by the presence of the strongly weathered tephras p2 and p1 (Druce, 1966), and E5 and E4 (averaging less than 10mm in diameter) scattered in the upper B horizons. In the Egmont soil, the absence of Manganui tephra, and the rare presence of strongly weathered pumiceous lapilli, scattered throughout the subsoil are distinguishing features. Here the pumiceous lapilli average less than 20mm in diameter and become reduced to a speckled ash with depth.

Typical profile descriptions of Stratford, Stratford fine topsoil variant and Egmont soil series are given below.

The range of general morphological features observed is summarised in Table 5.6.

Table 5.5

RANGE OF ELEVATION AND RAINFALL, LANDFORM
AND MEAN ANNUAL AIR TEMPERATURE UNDER WHICH
STRATFORD, STRATFORD FINE TOPSOIL VARIANT
AND EGMONT SOILS ARE FOUND

Soil	Elevation Range	Landform	Rainfall Range and Soil Moisture Class (Soil Survey Staff, 1975)	Mean Annual Air Temperature and Temperature Regime (Soil Survey Staff, 1975)
Stratford	120-290m	Volcanic ash mantled lowland laharic terrain	1330-2790mm (Udic)*	11.6 ⁰ C (Mesic) [†]
Stratford fine topsoil variant	90-240m	Volcanic ash mantled terraces and lowland laharic terrain	1400-1900mm (Udic)	11.9 ⁰ C (Mesic)
Egmont	S.L.-230m	Volcanic ash mantled marine plain and lowland laharic terrain	1100-1600mm (Udic)	12.7 ⁰ C (Mesic)

* The udic moisture regime implies that in most years the soil moisture control section is not dry in any part for as long as 90 days (cumulative).

† The mesic temperature regime implies that the mean annual soil temperature is 8⁰C or higher but lower than 15⁰C and the difference between mean summer and mean winter soil temperature is more than 5⁰C at a depth of 50cm.

STRATFORD SOIL

- Location : Lower Hastings Road, 1.5km from Matapu.
Farm 230, second paddock along from haybarn.
N119/797423
- Elevation : 175m
- Slope : 0°
- Rainfall : 1330-2790mm
- Vegetation : Ryegrass and clover
- Parent material : Moderately weathered andesitic volcanic ash, comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2 and p1 (Druce, 1966) and E5 and E4, on thick volcanic ash.
- Profile : Ap very dark brown (10YR2/2) loam with Manganui gravels confined to top 0.25m; moderately weathered pumiceous lapilli < 20mm in diameter; very friable; slightly plastic; slightly sticky; gritty feel; moderately developed coarse blocky structure breaking to fine crumb; firm penetration; abundant very fine roots; distinct wavy boundary.
- Bw1 dark brown (10YR3/3) sandy loam with abundant 35-65cm moderately weathered pumiceous lapilli, averaging 20 - 10mm in diameter, occasional lithic lapilli; friable; non plastic; non sticky; weak, medium blocky structure breaking to fine crumb; firm penetration; common roots; indistinct wavy boundary.
- Bw2 yellowish-brown (10YR5/4) loam, with scattered 65-100cm strongly weathered pumiceous lapilli; friable; slightly sticky; slightly plastic; gritty feel; weakly developed, medium blocky structure; firm penetration; few roots.

STRATFORD FINE TOPSOIL VARIANT

Location : Hicks Road. Dairy number 259.
N129/723359

Elevation : 110m

Slope : 0°

Rainfall : 1400-1900mm

Vegetation : Ryegrass and clover

Parent material : Moderately weathered andesitic volcanic ash, comprised of strongly weathered tephras, p2 and p1 (Druce, 1966) and E5 and E4, on thick volcanic ash.

Profile: Ap very dark brown (10YR2/2) silt loam with moderately weathered, scattered pumiceous lapilli, averaging less than 20mm in diameter; friable; moderately developed fine nut structure; abundant roots; distinct wavy boundary.

0-25cm

Bw1 dark brown (10YR3/3) loam with moderately weathered pumiceous lapilli, greater than 20mm in diameter; friable; gritty feel; weakly developed fine nut structure; many roots; distinct wavy boundary.

25-52cm

Bw2 dark yellowish-brown (10YR4/4) sandy clay loam; occasional strongly weathered pumiceous lapilli; firm; massive; few roots.

52-100cm

EGMONT SOIL

Location :	Normanby Road, 1km east of junction with Manaia Road. Richardson's property. Dairy number 339. N129/719343
Elevation :	90m
Slope :	1°
Rainfall :	1100-1600mm
Vegetation :	Ryegrass and clover
Parent material :	Moderately weathered andesitic volcanic ashes, comprised of Oakura and Okato Tephra on the Stratford Formation.
Profile :	
Ap	black (10YR2/1) loam with rare pumiceous lapilli, averaging less than 20mm in diameter; very friable; slightly plastic; slightly sticky; moderately developed fine nut structure; abundant very fine roots; distinct, wavy boundary.
0-17cm	
BA	very dark greyish-brown (10YR3/2) loam; friable; non plastic; non sticky; gritty feel; moderate to weakly developed fine nut and crumb structure; many fine roots; distinct, irregular boundary.
17-27cm	
Bw1	brown (10YR4/3) loam with scattered strongly weathered pumiceous lapilli, averaging less than 20mm in diameter; friable; slightly plastic; slightly sticky; weakly developed medium blocky structure; few roots; indistinct boundary.
27-55cm	
Bw2	yellowish-brown (10YR5/4) sandy clay loam; massive.
55-100cm	

Table 5.6

RANGE OF GENERAL MORPHOLOGICAL PROFILE FEATURES

STRATFORD	top soil	10YR2/2 (very dark brown), 10YR3/2 (very dark greyish-brown) silt loam, loam; Manganui tephra < 250mm in thickness; very friable, friable; moderately to weakly developed fine to very fine crumb structure.
	sub soil	10YR3/3 (dark brown), 10YR4/3 (dark brown-brown), 10YR4/4 (dark yellowish-brown), 10YR5/4 (yellowish-brown) silt loam, loam, sandy loam; weakly to moderately weathered pumiceous lapilli, averaging 20mm in diameter, can be concentrated in a band or scattered and strongly weathered with depth; friable to firm; weak, coarse to very coarse blocky structure.
STRATFORD FINE TOPSOIL VARIANT	top soil	10YR2/2 (very dark brown), 10YR3/2 (very dark greyish-brown) silt loam, loam; may contain a few scattered pumiceous lapilli < 10mm in diameter; very friable, friable; moderately developed very fine, fine nut structure.
	sub soil	10YR3/3 (dark brown), 10YR4/4 (dark yellowish-brown), 10YR5/4 (yellowish-brown), 10YR5/6 (yellowish-brown) loam, sandy clay loam, sandy loam; may have a gritty modification and speckled appearance due to concentration of mafic crystals; friable; weak, fine, coarse, medium, nut, blocky or massive.
EGMONT	top soil	10YR2/1 (black), 10YR2/2 (very dark brown), 10YR3/1 (very dark grey) silt loam, loam; rare pumiceous lapilli < 20mm in diameter; very friable, friable; moderately developed fine nut structure.
	sub soil	10YR3/6 (dark yellowish-brown), 10YR4/3 (dark brown-brown), 10YR4/6 (dark yellowish-brown), 10YR5/4 (yellowish-brown) silt loam, loam, sandy clay loam; scattered strongly weathered pumiceous lapilli, < 20mm in diameter. Speckled appearance with depth; friable to firm; weak, medium nut, blocky or massive.

See Plates 5.9 - 5.11.

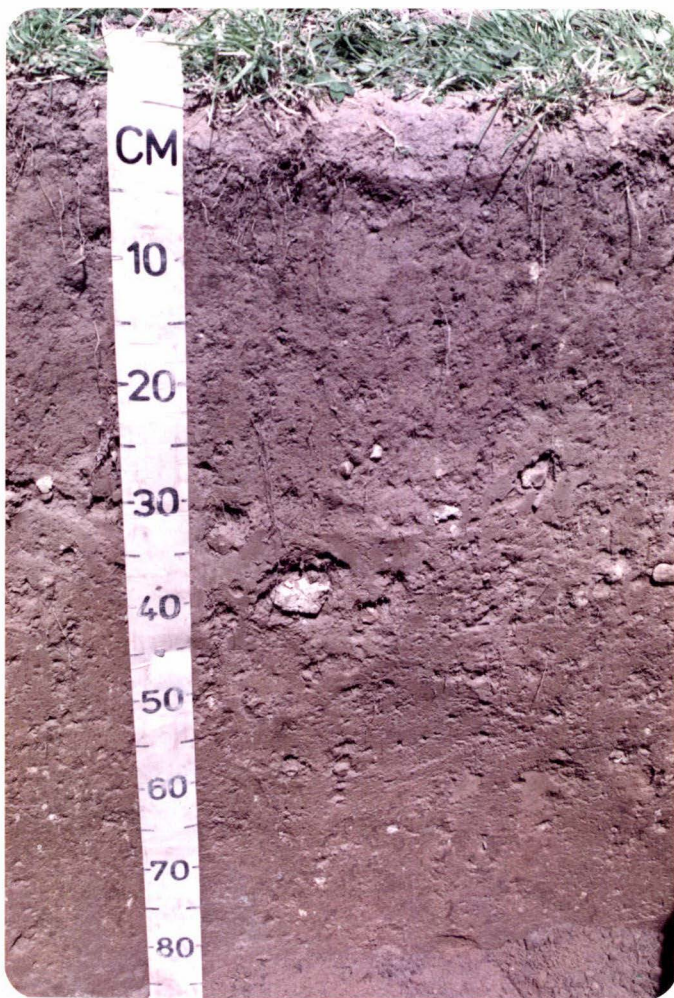


Plate 5.9

Stratford soil. Lower Hastings Road, 1.5km north of Matapu. Paddock adjacent to hay barn, at N119/797423.

Note the moderately and strongly weathered pumiceous lapilli present throughout the profile.



Plate 5.10

Stratford fine topsoil variant, Hicks Road, 3km north of Manaia, at N119/717359.

Note the occasional strongly weathered pumiceous lapilli.

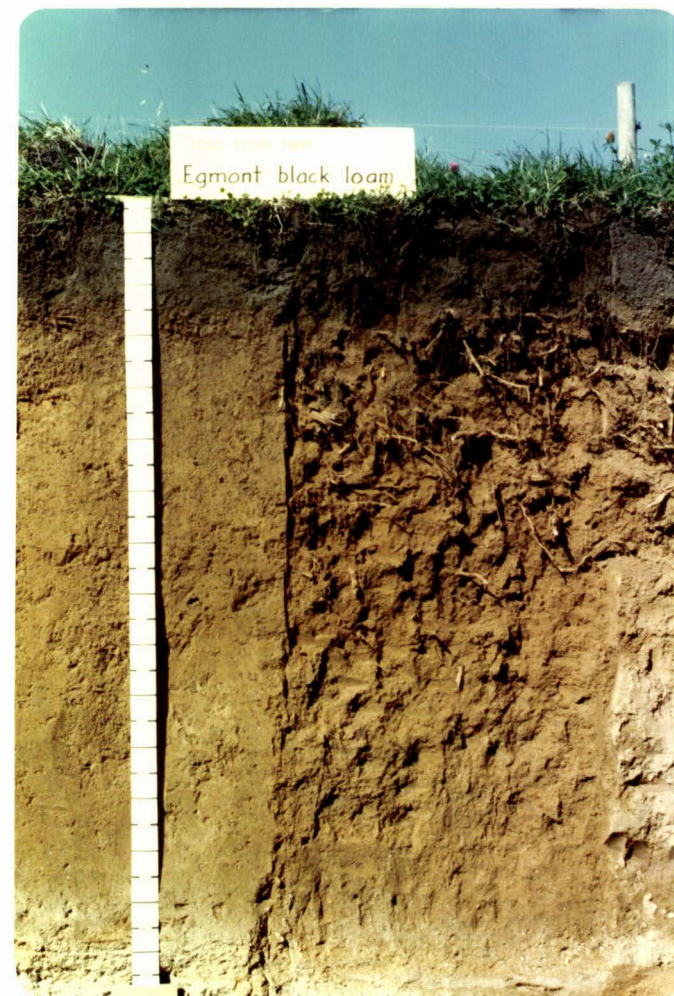


Plate 5.11

Egmont soil. 1km west of Mokoia, along main Wanganui-Hawera highway. Paddock north side of road, at N129/931238.

Note the black topsoil.

Selected Laboratory Analyses

Selected chemical and physical analyses were conducted to investigate relationships in soil properties of four Stratford soil profiles, one Stratford fine topsoil variant and three Egmont soil profiles. In addition a Burrell soil, on younger pumiceous material and a Patua soil, close to Mt. Egmont were included for comparative purposes. All soils are from well drained sites, located in Figure 5.5

The properties selected, namely: pH, pH_{NaF} , phosphate retention, moisture retention at 15-bars and KCl-extractable aluminium were those likely to reflect differences in the parent material, elevation and rainfall between each soil unit.

METHODS

pH measurements:-

The pH measurements were carried out in both water and 1 M KCl, standing and stirred. The ratio of soil to water was 1 : 2.5.

When KCl is used, extensive ion exchange takes place, including the release of aluminium. Hydronium ions and other proton donors are brought into solution, influencing the glass electrode and lowering the measured pH (Black, 1968). The pH values obtained with the KCl will not necessarily represent those of soil solutions but Black has suggested that they may approach the pH values in the ion atmospheres of the original soil.

pH_{NaF} :-

The Fieldes and Perrott (1966) field test for the presence of allophane involves a saturated (approximately 1M) solution of sodium fluoride reacting with a soil to produce a high pH value. It is based on the aluminium-bonded hydroxyl ion being readily displaced by the fluoride ion. The reaction may not always be specific for allophane and aluminium because 1) organic matter may block the reaction and 2) non-crystalline hydrous oxides of aluminium can also produce high pH values in sodium fluoride solutions (Wada, 1977 in Parfitt 1980).

In this study, pH_{NaF} values were taken at intervals of 2 minutes, 5 minutes and 60 minutes to monitor the dynamics of the NaF reaction. In addition pH_{NaF} values were taken at similar intervals with 10ml of a

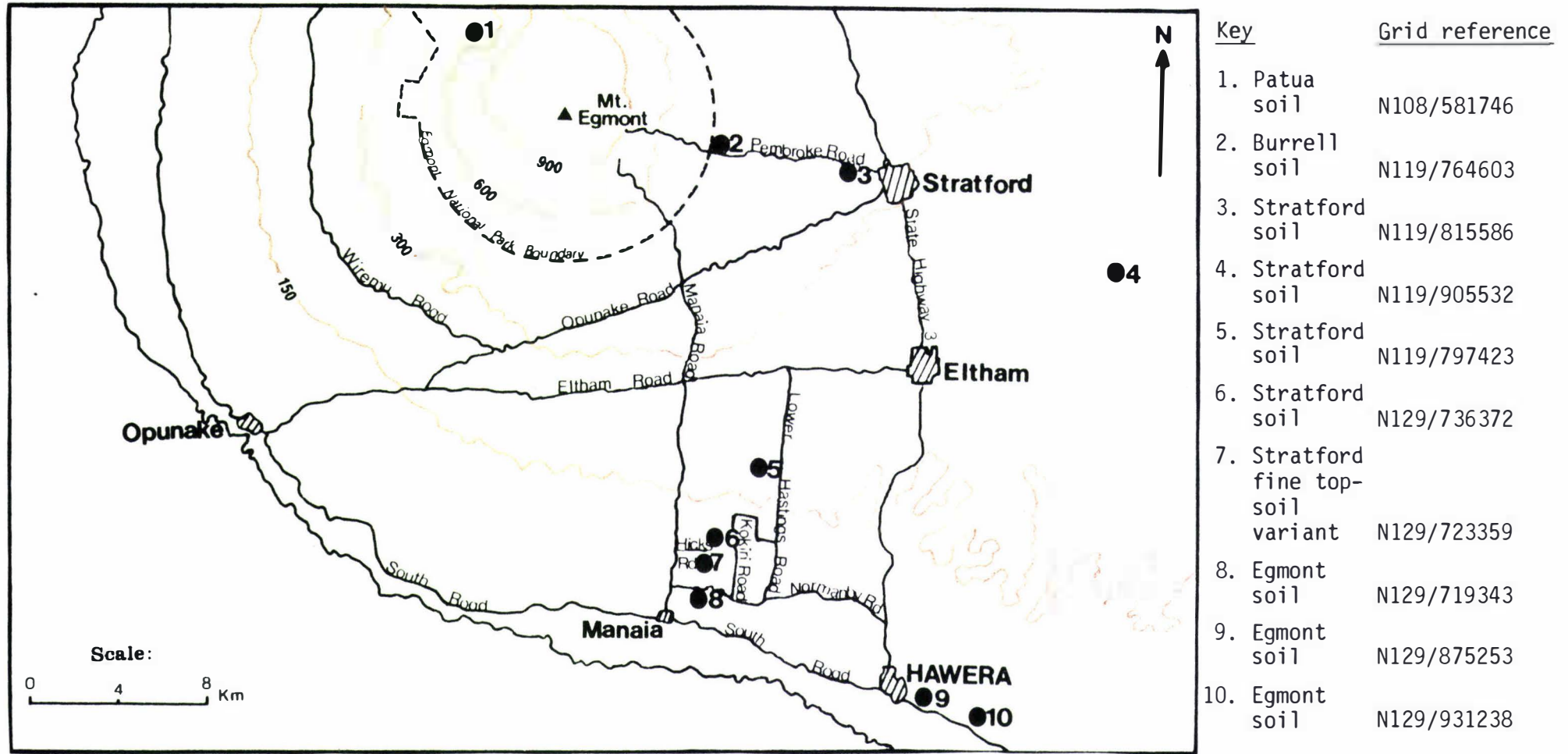


Figure 5.5 Sampling sites of a Patua soil, Burrell soil, four Stratford soils, a Stratford fine topsoil variant and three Egmont soils

ferrhydrite suspension added to the soil. Ferrhydrite ($\text{Fe}_5(\text{O}_4\text{H}_3)_3$) is a rusty, voluminous precipitate with high specific area ($200\text{-}350\text{m}^2/\text{g}$) and is rich in absorbed water, inorganic ions and organic matter (Schwertmann and Taylor, 1977). Allophane, imogolite, polymeric hydroxy-aluminosilicates (Wada, 1980) and ferrhydrite are all short range or poorly ordered minerals, which occur as the first weathering products of coarse grained volcaniclastic deposits. The ferrhydrite was added to discover whether there was an elevation in value due to the active FeOH groups.

Phosphate retention:-

Phosphate retention is a measure of the ability of a soil to rapidly remove phosphate from solution and is attributed to the presence of amorphous compounds of aluminium and iron (Saunders, 1965; White, 1980).

The method used measures percentage of added phosphate taken up in 24 hours by 5g of soil, shaken at 20°C with 25ml of NaOAc-HOAc buffer solution, at pH 4.6, with an initial phosphate concentration of $0.032\text{MKH}_2\text{PO}_4$.

Moisture retention at 15-bars:-

A pressure plate apparatus was used to determine the moisture held at a tension of 15-bars on saturated samples. Two samples from each soil horizon were collected, one kept moist and the other air-dried to remove moisture retained beyond tensions of 15-bars before re-wetting. An irreversible drying effect on 15-bar water retentions is a distinctive property of allophanic soils, the degree to which it occurs depending on degree of weathering.

KCl-extractable aluminium:-

KCl-extractable aluminium, which is also referred to as "exchangeable" aluminium was measured by leaching 5g of soil with 50ml of 1M KCl and determining the amount of aluminium in the extract by atomic absorption spectrometry.

RESULTS

Each soil sample analysed shows characteristic properties associated with the presence of allophane in the clay fraction of yellow-brown loams. All the results show high pH_{NaF} values and irreversible effects on moisture retention of air-dry soils (Tables 5.7 - 5.12).

pH measurements:

The standing and stirred potassium chloride values were identical but standing and stirred water values tended to vary slightly (Table 5.7).

The pH values for samples in both water and potassium chloride increased steadily with profile depth. Most A horizons are moderately acid, with the topsoil of the Egmont marginally strongly acid and the Burrell strongly acid. Most subsoil horizons were slightly acid or near neutral but the Burrell subsoil and highest elevation Stratford site are moderately acid.

A trend towards greater acidity at $\frac{1}{2}$ m and 1m depth was evident, with increased elevation and rainfall, consistent with increased soil leaching (Figure 5.6).

The pH_{H_2O} values were subtracted from pH_{KCl} values and negative ΔpH values were obtained for nearly all horizons. There is a tendency for the negative ΔpH values to approach zero with depth, as the organic matter content decreases. Only in the Bw3 horizon in the Stratford soil is there no ΔpH , indicating this horizon is at its natural point of zero charge (pH 6.3).

 pH_{NaF} :

The Andisol proposal (Leamy *et al.*, 1980) has adopted the criteria $pH > 9.4$ in 1M NaF as an indication of the dominant presence of allophane for inclusion in the Andisol order.

The values obtained (Table 5.8) were all above 9.4 after two minutes, confirming that reactive surfaces were present; Table 5.8 shows that there was no elevation in value when ferrihydrite was added. In fact, addition of ferrihydrite resulted in an overall decrease in values of pH in NaF.

There was an increase in value with length of time, which is probably a measure of the amounts of crystalline material present.

Phosphate retention:

The phosphate retention values are shown in Table 5.9. The values were high to very high, ranging from 84-99% and tend to increase with depth down the profile. The influence of organic matter is indicated by the slightly lower values for the A horizons.

Table 5.7 pH_{KCl} AND pH_{H_2O} RESULTS

$$\Delta pH = (pH_{KCl} - pH_{H_2O})$$

SOIL	HORIZON	DEPTH (cm)	KCl standing	KCl stirred	deionized		ΔpH standing	ΔpH stirred
					H ₂ O standing	H ₂ O stirred		
1. Patua	Ah	0- 14	4.4	n.d.	5.3	n.d.	- 0.9	n.d.
	AB	14- 29	4.6		5.5		- 0.9	
	Bwg1	29- 54	5.1		5.6		- 0.5	
	Bws	54- 87	5.4		5.5		- 0.1	
	Bwg2	87-100	5.5		5.4		0.1	
2. Burrell	A	0- 17	4.4	4.4	4.7	4.6	- 0.3	- 0.2
	Bw1	17- 37	5.1	5.1	5.6	5.6	- 0.5	- 0.5
	Bw2	37- 56	5.6	5.6	5.8	5.8	- 0.2	- 0.2
	Bw3	56- 87	5.7	5.7	6.0	6.0	- 0.3	- 0.3
	Bw4	87-100	5.5	5.5	5.9	5.9	- 0.4	- 0.4
3. Stratford	Ap	0- 21	4.7	4.8	5.7	5.6	- 1.0	- 0.8
	Bw1	21- 38	4.9	4.9	5.2	5.1	- 0.3	- 0.2
	Bw2	38- 60	5.3	5.3	5.7	5.7	- 0.4	- 0.4
	Bw3	60-100	5.8	5.8	6.0	6.0	- 0.2	- 0.2
4. Stratford	Ap	0- 20	4.4	4.4	5.7	5.6	- 1.3	- 1.2
	Bw1	20- 47	5.4	5.4	5.8	5.9	- 0.3	- 0.5
	Bw2	47- 68	5.5	5.5	5.9	6.0	- 0.4	- 0.5
	Bw3	68-100	5.9	5.9	6.3	6.2	- 0.4	- 0.3
5. Stratford	Ap	0- 25	4.7	n.d.	5.7	n.d.	- 1.0	n.d.
	Ap	25- 35	5.3		6.3		- 1.0	
	Bw1	35- 65	5.6		6.5		- 0.9	
	Bw2	65-100	5.8		6.6		- 0.8	
6. Stratford	Ap	0- 18	5.0	5.0	5.8	5.6	- 0.8	- 0.6
	Bw1	18- 38	5.9	5.9	6.3	6.5	- 0.4	- 0.6
	Bw2	38- 62	6.2	6.2	6.4	6.6	- 0.2	- 0.4
	Bw3	62-100	6.3	6.3	6.3	6.6	0	- 0.3
7. Stratford fine topsoil variant	Ap	0- 25	5.0	5.0	5.6	5.9	- 0.6	- 0.9
	Bw1	25- 52	5.8	5.9	6.6	6.7	- 0.8	- 0.8
	Bw2	52-100	6.3	6.3	6.7	6.8	- 0.4	- 0.5
8. Egmont	Ap	0- 17	4.3	4.3	5.2	5.1	- 0.9	- 0.8
	BA	17- 27	4.5	4.5	5.1	5.1	- 0.6	- 0.6
	Bw1	27- 55	5.8	5.8	6.3	6.4	- 0.5	- 0.6
	Bw2	55-100	6.5	6.5	6.9	7.0	- 0.4	- 0.5
9. Egmont	Ap	0- 8	4.9	n.d.	5.7	n.d.	- 0.8	n.d.
	Ap	8- 15	5.0		6.2		- 1.2	
	Bw	20- 35	5.3		6.3		- 1.0	
	BC	45- 55	5.7		6.4		- 0.7	
	C	73- 88	5.7		6.4		- 0.7	
10. Egmont	Ap	0- 21	5.9	n.d.	6.6	n.d.	- 0.7	n.d.
	Bw1	21- 38	6.3		6.9		- 0.6	
	Bw1	38- 55	6.1		6.7		- 0.6	
	Bw2	55- 89	5.9		6.6		- 0.7	
	2Bw3	89-115	5.7		6.7		- 1.0	
	2C	115-145	5.5		6.5		- 1.0	

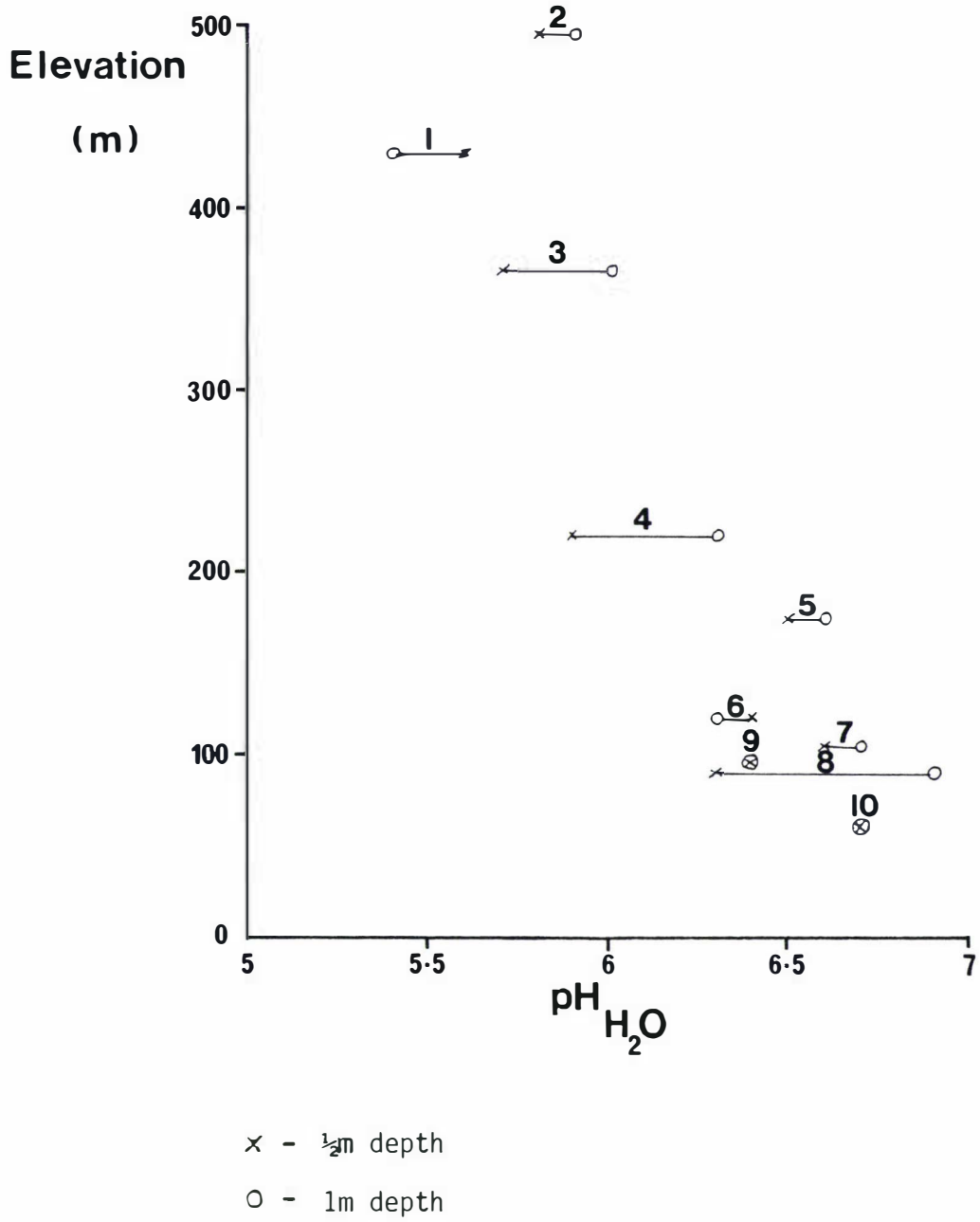


Figure 5.6 Elevation versus pH_{H2O} at 1/2m and 1m depth

Key

- | | |
|-------------------|-----------------------------------|
| 1. Patua soil | 6. Stratford soil |
| 2. Burrell soil | 7. Stratford fine topsoil variant |
| 3. Stratford soil | 8. Egmont soil |
| 4. Stratford soil | 9. Egmont soil |
| 5. Stratford soil | 10. Egmont soil |

Table 5.8 pH_{NaF} RESULTS

SOIL	HORIZON	DEPTH (cm)	pH_{NaF} of soil alone			pH_{NaF} of soil + added ferrihydrite		
			2 mins	5 mins	60 mins	2 mins	5 mins	60 mins
1. Patua	Ah	0- 14	11.3	n.d.	n.d.	n.d.	n.d.	n.d.
	AB	14- 29	11.6					
	Bwg1	29- 54	11.5					
	Bws	54- 87	11.3					
	Bwg2	87-100	11.0					
2. Burrell	A	0- 17	10.6	10.8	11.0	9.2	9.5	10.4
	Bw1	17- 37	11.2	11.3	11.5	9.3	9.6	10.4
	Bw2	37- 56	11.1	11.4	11.6	9.4	9.7	10.6
	Bw3	56- 87	11.0	11.2	11.5	9.6	9.8	10.6
	Bw4	87-100	11.0	11.2	11.5	9.4	9.5	10.4
3. Stratford	Ap	0- 21	10.0	11.1	11.3	9.5	9.8	10.5
	Bw1	21- 38	11.1	11.3	11.5	9.3	9.5	10.2
	Bw2	38- 60	10.1	11.2	11.5	9.3	9.6	10.5
	Bw3	60-100	10.9	11.1	11.5	9.4	9.7	10.2
4. Stratford	Ap	0- 20	10.7	11.0	11.3	9.5	9.7	10.2
	Bw1	20- 47	11.0	11.3	11.6	9.4	9.7	10.3
	Bw2	47- 68	11.0	11.2	11.6	9.2	9.4	10.3
	Bw3	68-100	10.8	11.1	11.5	9.3	9.6	10.3
5. Stratford	Ap	0- 25	10.7	n.d.	n.d.	n.d.	n.d.	n.d.
	Ap	25- 35	11.0					
	Bw1	35- 65	11.0					
	Bw2	65-100	10.8					
6. Stratford	Ap	0- 18	10.1	10.4	11.1	9.2	9.4	9.9
	Bw1	18- 38	10.5	10.9	11.4	9.2	9.5	10.4
	Bw2	38- 62	10.5	10.9	11.4	9.0	9.4	10.1
	Bw3	62-100	10.5	10.8	11.4	9.0	9.2	9.9
7. Stratford fine topsoil variant	Ap	0- 25	10.4	10.7	11.3	9.1	9.5	10.2
	Bw1	25- 52	10.5	10.8	11.3	9.4	9.5	10.0
	Bw2	52-100	10.3	10.7	11.3	9.1	9.4	10.1
8. Egmont	Ap	0- 17	10.4	10.7	11.2	9.1	9.4	10.1
	BA	17- 27	10.7	11.0	11.3	9.1	9.4	10.1
	Bw1	27- 55	10.6	10.9	11.3	9.1	9.5	10.3
	Bw2	55-100	10.6	10.9	11.3	9.1	9.4	10.1
9. Egmont	Ap	0- 21	10.7	n.d.	n.d.	n.d.	n.d.	n.d.
	Bw1	21- 38	11.0					
	Bw1	38- 55	10.8					
	Bw2	55- 89	10.9					
	2Bw3	89-115	10.7					
	2C	115-145	10.5					

Table 5.9 PHOSPHATE RETENTION RESULTS

SOIL	HORIZON	DEPTH (cm)	% PHOSPHATE RETAINED	WEIGHTED AVERAGES (25cm - 1m depth)
1. Patua	Ah	0- 14	91	99%
	AB	14- 29	97	
	Bwg1	29- 54	99	
	Bws	54- 87	99	
	Bwg2	87-100	99	
2. Burrell	A	0- 17	96	99%
	Bw1	17- 37	99	
	Bw2	37- 56	99	
	Bw3	56- 87	98	
	Bw4	87-100	98	
3. Stratford	Ap	0- 21	92	99%
	Bw1	21- 38	99	
	Bw2	38- 60	99	
	Bw3	60-100	99	
4. Stratford	Ap	0- 20	92	99%
	Bw1	20- 47	99	
	Bw2	47- 68	99	
	Bw3	68-100	99	
5. Stratford	Ap	0- 25	84	93%
	Ap	25- 35	90	
	Bw1	35- 65	93	
	Bw2	65-100	93	
6. Stratford	Ap	0- 18	97	96%
	Bw1	18- 38	94	
	Bw2	38- 62	95	
	Bw3	62-100	97	
7. Stratford fine topsoil variant	Ap	0- 25	97	98%
	Bw1	25- 52	97	
	Bw2	52-100	98	
8. Egmont	Ap	0- 17	94	98%
	BA	17- 27	96	
	Bw1	27- 55	97	
	Bw2	55-100	98	
9. Egmont	Ap	0- 8	89	97%
	Ap	8- 15	92	
	Bw	20- 35	96	
	BC	45- 55	98	
	C	73- 88	97	
10. Egmont	Ap	0- 21	88	98%
	Bw1	21- 38	98	
	Bw1	38- 55	99	
	Bw2	55- 89	99	
	2Bw3	89-115	96	
	2C	115-145	91	

The values for the weighted averages of all horizons between 25cm and 1m (control section) were very high for all the soils. A slight trend is evident, with 99% for the Patua, Burrell and Stratford (3 and 4) soils while the Stratford (5 and 6), Stratford variant and two Egmont soils have values ranging from 93-98%.

Moisture retention at 15-bars:

The results of moisture retention at 15-bars are shown in Tables 5.10 and 5.11. Bands of pumiceous lapilli present in the profiles contribute to the variability of values obtained because water can be trapped in the voids of pumice (Maeda et al., 1970).

The differences between the 15-bar moisture contents of previously dried and undried soil samples is not only related to the allophane content but to the amount of drying that the soil experiences in natural circumstances in the field.

The moderately high 15-bar values of the moist samples demonstrate the capacity of these soils to retain moisture at high tensions and that this capacity decreases markedly on drying. The percentage decreases in 15-bar moisture values, as a result of air-drying are very high and are thought to be due to the loss of very fine microscopic pores and intra-colloidal cavities during the air-drying process. The percentage decreases are lowest in A horizons and increase in the subsoils to values as high as 74% in the Patua soil. The percentage loss on drying seems to be a function of the environment, as it is greatest in those soils that in nature are kept perennially moist, like the Patua, Burrell and Stratford (3) soils.

The 15-bar water of the air-dry samples seems to be a function of the amount of allophane. In the Patua, Stratford (4), Stratford fine topsoil variant and Egmont soils, the wilting points in the subsoils exceed those of the upper horizons, consistent with higher subsoil allophane contents. The available water capacities of the A horizons will depend not only on allophane but also on organic matter content (Bonfils and Moinereau, 1971; Maeda et al., 1976) so the higher air-dry values in the topsoils are not attributed entirely to the allophane content.

In the unpublished proposals by Dr. G. Smith (1978) for the re-classification of Andepts, there is an attempt to define the family names "ashy" and "medial" in terms of measurable water retentive properties.

Table 5.10 % DECREASE OF 15-BAR WATER RESULTS

Soil	Horizon	Depth	15-bar Field Moist	15-bar Air Dry	Δ	% Decrease of 15-bar
1. Patua	Ah	0- 14	58	25	33	57
	AB	14- 29	55	20	35	64
	Bwg1	29- 54	63	19	44	70
	Bws	54- 87	67	19	48	72
	Bwg2	87-100	69	18	51	74
2. Burrell	Ap	0- 17	35	26	9	26
	Bw1	17- 37	65	21	44	68
	Bw2	37- 56	62	19	43	69
	Bw3	56- 87	48	18	30	63
	Bw4	87-100	45	16	29	64
3. Stratford	Ap	0- 21	36	27	9	25
	Bw1	21- 38	60	22	38	63
	Bw2	38- 60	60	21	39	65
	Bw3	60-100	63	20	43	68
4. Stratford	Ap	0- 20	37	31	6	16
	Bw1	20- 47	53	21	32	60
	Bw2	47- 68	55	21	34	62
	Bw3	68-100	51	19	32	63
5. Stratford	Ap	0- 25	25	19	6	24
	Ap	25- 35	27	15	12	44
	Bw1	35- 65	28	13	15	54
	Bw2	65-100	27	11	16	59
6. Stratford	Ap	0- 18	39	35	4	10
	Bw1	18- 38	32	16	16	50
	Bw2	38- 62	36	16	20	56
	Bw3	62-100	39	16	23	59
7. Stratford Fine Top- Soil Variant	Ap	0- 25	31	28	3	10
	Bw1	25- 52	36	21	15	42
	Bw2	52-100	43	20	23	54
8. Egmont	Ap	0- 17	38	32	6	16
	BA	17- 27	39	24	15	38
	Bw1	27- 55	39	20	19	49
	Bw2	55-100	44	20	24	55
10. Egmont	Ap	0- 21	30	23	7	23
	Bw1	21- 38	36	18	18	50
	Bw1	38- 55	39	16	23	59
	Bw2	55- 89	42	17	25	60
	2Bw3	89-100	31	15	16	52

Table 5.11 WEIGHTED AVERAGE 15-bar MOISTURE
RETENTION-FIELD MOIST AND AIR DRY

Soil	(25cm-1m)			(0-1m)		
	Field Moist	Air Dry	% Decrease of Weighted Average	Field Moist	Air Dry	% Decrease of Weighted Average
1. Patua	65.4	18.8	71.3	63.2	19.9	68.5
2. Burrell	53.7	18.1	66.3	51.4	19.7	61.7
3. Stratford	61.6	20.6	66.6	87.1	22.0	74.7
4. Stratford	52.7	20.1	61.9	49.6	22.4	54.8
5. Stratford	27.5	12.3	55.3	26.9	14.0	48.0
6. Stratford	36.8	16.0	56.5	36.8	19.4	47.3
7. Stratford Fine Top- Soil Variant	40.5	20.4	49.6	38.1	22.3	41.5
8. Egmont	42.0	20.1	52.1	41.1	22.4	45.5
10. Egmont	38.8	16.3	58.0	36.8	21.2	42.4

For example, medial is defined as having a water retention at 15-bars of 12% or more on previously dried samples or between 30% and 100% on undried samples.

The results (Table 5.11) show that, apart from the Stratford soil (5), which is close to being ashy, all the other soils are classed as medial.

A figure of 15% water retention at 15-bars of previously dried samples and of 30% on undried samples, as a weighted average of all horizons between 25cm and 1m (control section) is used as the boundary between the great groups of Vitrudands and Hapludands in the proposed Andisol Order. Thus, with the exception of Stratford (5), all the soils in this sequence are classed as Hapludands.

KCl-extractable Aluminium

KCl-extractable aluminium ranged in value from 2.1me% to 0 (Table 5.12).

The highest values obtained were in the Patua and Burrell soils, indicating a greater release of active aluminium under the low pH conditions in these soils.

Conclusions

The Stratford, Stratford series, fine topsoil variant and Egmont series are all yellow-brown loams, with chemical and physical properties dominated by the presence of allophane.

The fundamental difference between Stratford and Egmont soils is the parent material. Egmont series is recognised as having formed from Oakura and Okato Tephra, overlying the Opunake Formation. Although it is now evident that a non-pumiceous ash, a distal equivalent of the Stratford Ash, wedges into the upper horizons. Stratford series is formed in the younger tephra, p2 and p1 (Druce, 1966) overlying E5 and E4, less than one metre from the surface. The 250mm Manganui tephra isopach acts as a marker bed for the boundary between Stratford series and Lowgarth series, the latter soils having a distinctive gravelly modification to the topsoil.

Table 5.12

KC1-EXTRACTABLE ALUMINIUM RESULTS

Soil	Horizon	Depth	Al me. %
1. Patua	Ah	0- 14	2.1
	AB	14- 29	1.2
	Bwg1	29- 54	0.22
	Bws	54- 87	0.14
	Bwg2	87-100	0.13
2. Burrell	Ap	0- 17	0.5
	Bw1	17- 37	0.1
	Bw2	37- 56	-
	Bw3	56- 87	-
	Bw4	87-100	0.2
3. Stratford	Ap	0- 21	0.1
	Bw1	21- 38	0.1
	Bw2	38- 60	-
	Bw3	60-100	-
4. Stratford	Ap	0- 20	0.1
	Bw1	20- 47	-
	Bw2	47- 68	-
	Bw3	68-100	-
5. Stratford	Ap	0- 25	0.34
	Ap	25- 35	0.06
	Bw1	35- 65	0.03
	Bw2	65-100	0.02
7. Stratford Fine Topsoil Variant	Ap	0- 25	0.2
	Bw1	25- 52	-
	Bw2	52-100	-
8. Egmont	Ap	0- 17	0.2
	BA	17- 27	-
	Bw1	27- 55	-
	Bw2	55-100	-
10. Egmont	Ap	0- 21	0.26
	Bw1	21- 38	0.15
	Bw1	38- 55	0.15
	Bw2	55- 89	0.14
	2Bw3	89-115	0.12
	2C	115-145	0.11

The age of parent material cannot be used as an absolute criteria since in boundary areas other factors, such as rainfall may become critical. In addition, correlation problems still exist with increasing distance from source. Attempts to locate and establish an exact boundary between Stratford and Egmont soils, based on identification of distal tephras, can only be tentative. It is more realistic to concentrate on measureable soil properties, as well as profile features, that would characterise and separate the soil series in a meaningful way.

The laboratory analyses failed to distinguish the three soils in this study. The 15-bar water contents are all classed as medial, although the Stratford soil (5) comes close to being ashy. The differences in elevation and rainfall were reflected in a slight decrease in pH with increase in leaching. However, the trend was not distinct enough to separate the Stratford, Stratford fine topsoil variant and Egmont soils. In addition all the soils have the same temperature regime and soil moisture class (Table 5.5).

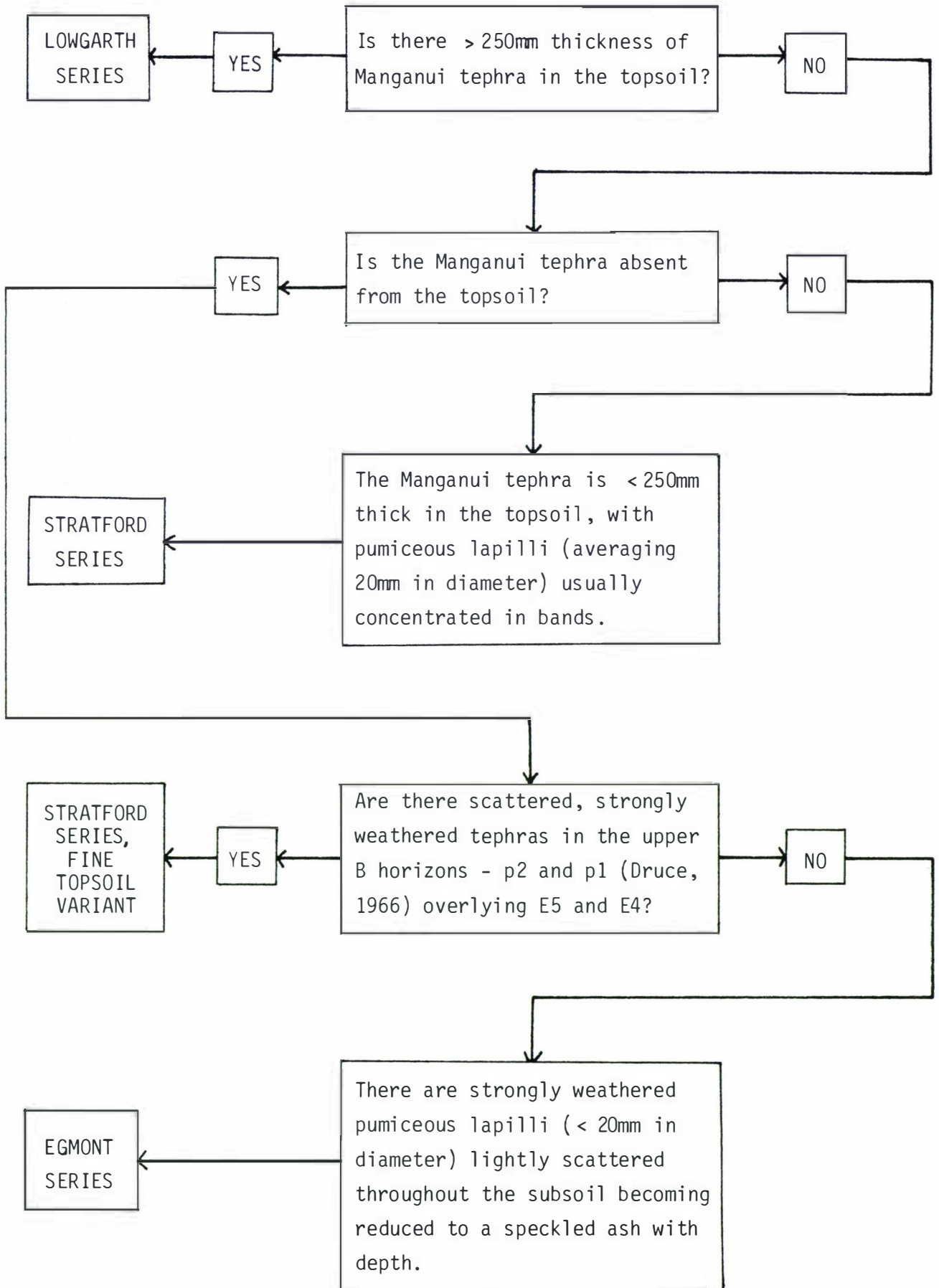
The range of profile features (Table 5.6) indicates that a "transitional area" exists so that any boundary between Stratford and Egmont soil, as such is gradational.

The introduction of the Stratford series, fine topsoil variant overcomes the problem of a sharp boundary between Stratford and Egmont soils.

The Stratford series, fine topsoil variant is sufficiently different to not be regarded as a taxadjunct and it is too extensive, 1250ha. to be correlated as mapping inclusions. In introducing the Stratford series, fine topsoil variant criteria are more readily established for defining the nature of a gradational contact between Stratford and Egmont soils into an intermediate category. Thus, the newly established unit can be conveniently defined and specific criteria can be listed to differentiate the unit from the Stratford and Egmont series to the north and south (Figure 5.7).

Figure 5.7

FLOW DIAGRAM TO AID FIELD IDENTIFICATION
OF STRATFORD SERIES, STRATFORD SERIES,
FINE TOPSOIL VARIANT AND EGMONT SERIES



6. AN INSIGHT INTO THE VARIABILITY OF THE STEEPLAND SOILS

Introduction

Two steepland soil subcatchments were investigated in detail at Mangamingi, east of Eltham Borough, to provide an insight into the soil pattern of the steepland terrain in the east of Eltham County (Figure 5.8). These detailed studies might then be used to extrapolate and apply soils information to elsewhere in the steepland terrain. Several widespread reconnaissance observations were initially carried out before final study areas were selected.

There are several methods of approaching variability in steepland soils and studies carried out in the last 15 years have noticeably centred around approaches by:-

- 1) Campbell (1973, 1975)
 - 2) Ives and Cutler (1972)
- and 3) Dalrymple, Blong and Conacher (1968); Conacher and Dalrymple (1977).

Previous work in steepland catchments near Wanganui indicates that besides differences in aspect and parent material, the pattern of steepland soil variation, between ridge crest and valley bottom is largely related to slope and geomorphic differences (Campbell, 1973). In Campbell's 1973 study a catena-like pattern of soils on valley sides was recognised and four distinct soil units were described occurring on four distinct geomorphic units:- 1) ridge top 2) intermediate steep slope 3) eroded slope and 4) accumulation slope. The soil series on the intermediate steep slope is taken as the principal name giving component of the catena, while the remaining three components ridge, eroded slope and accumulation slope are considered "variants".

On steep hillsides of large areas, as in the Mowbray Catchment, South Canterbury, the variation pattern has been studied as a toposequence because it occurs on a single parent rock. The soils are on a much larger landform compared with the Wanganui region so that the individual mapping units were extensive enough to be mapped as separate series (Ives and Cutler, 1972).

Dalrymple *et al.*, (1968) proposed a hypothetical nine unit landscape model to describe and interpret landsurfaces at a general level. The

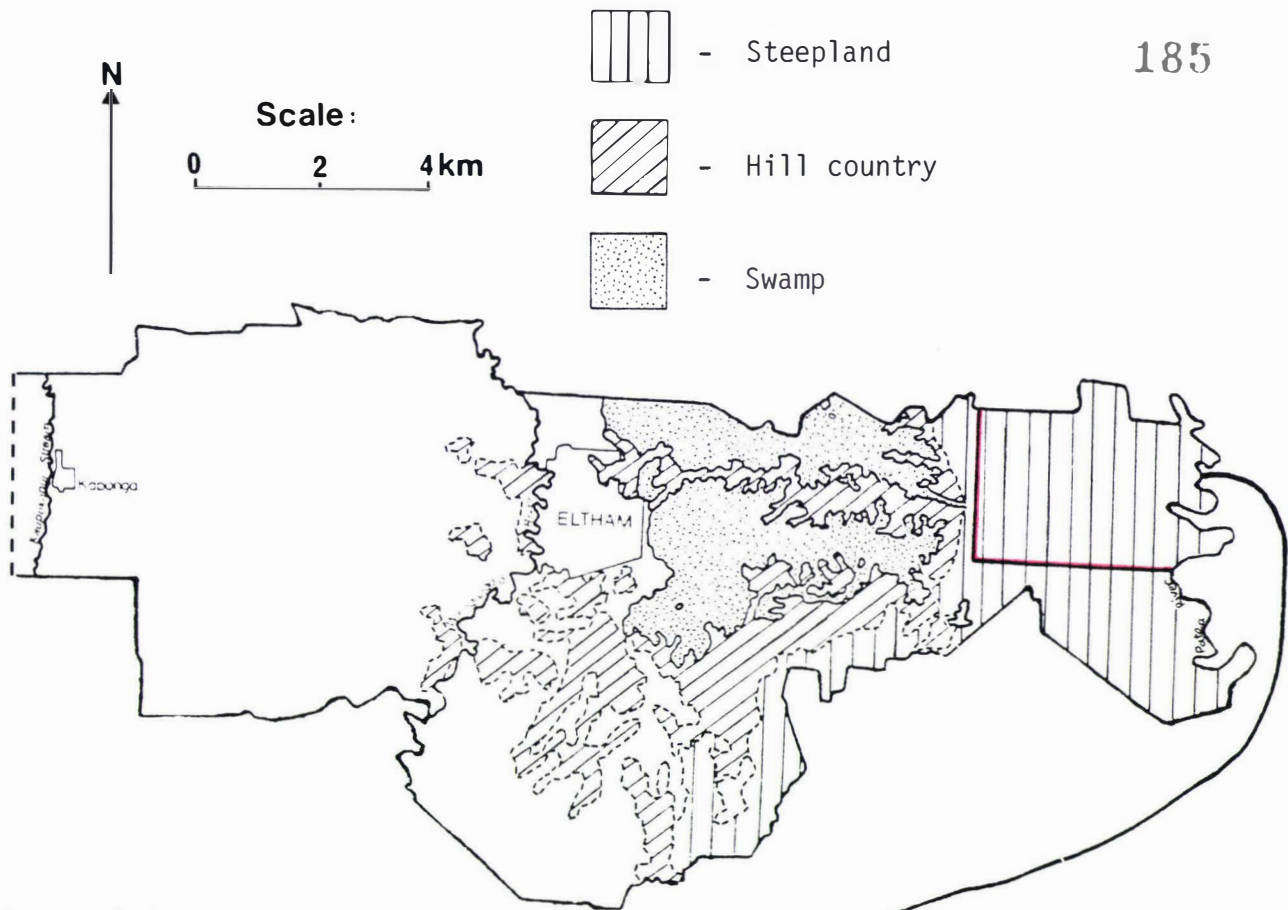


Figure 5.8

Location of steepland area in central Eltham County

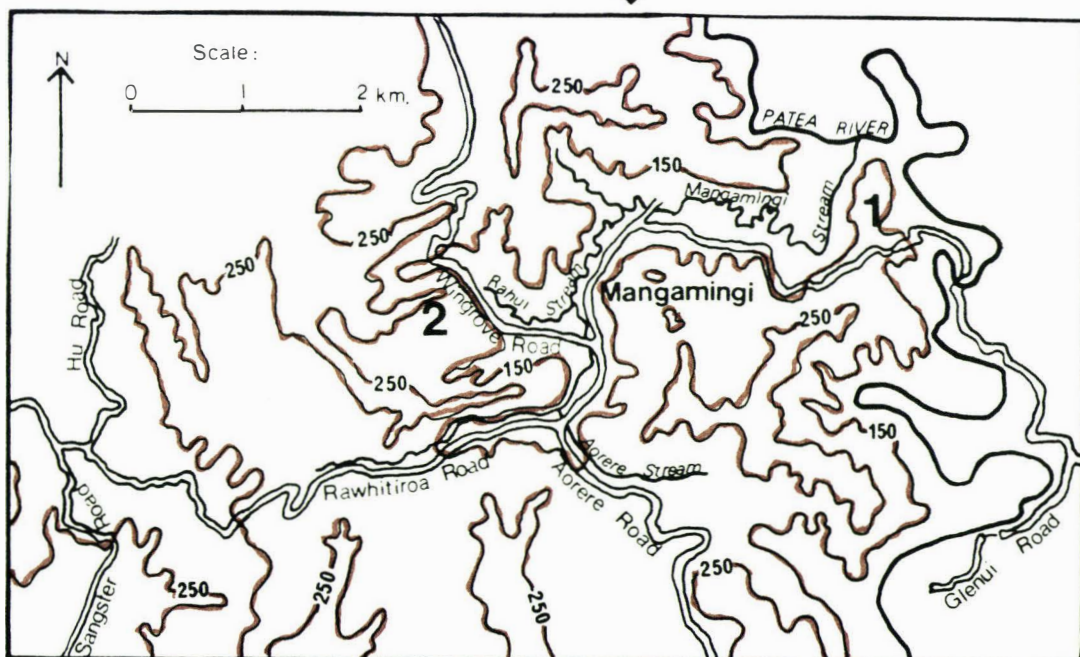


Figure 5.9

Location of steepland study areas

Contours in metres.

model is regarded as a three-dimensional complex extending from the drainage divide to the centre of the channel bed and from the ground surface to the uppermost boundary of unweathered rock. Hillslopes are divided into nine subsystems or units, with each unit defined in terms of form and the dominant geomorphic and pedological processes acting on it at the present time. The landsurface units may be repeated down or across a slope and it is rare to find all nine units occurring on any single landsurface catena.

A similar type of approach to Campbell's study (1973, 1975) has been adopted in this study because his technique is easy to apply visually in steepland terrain. The term "variant" has, however, been abandoned since it is inaccurate and misleading. Instead the soil series on the intermediate steep slope is taken as the modal soil, being the most extensive, while the ridge, eroded slope and accumulation slope are regarded as phases.

Campbell found that the four soil units can be characterised by their morphological properties. However, they do gradually merge into one another making separation difficult. It was the location within each geomorphic unit that Campbell found to be most important in determining profile morphology differences rather than the actual angle of slope.

In the study area, the distribution pattern of the soil phases varies with such factors as parent rock characteristics, degree of dissection, length and maturity of slope and different geomorphic processes operating, such as soil creep, surface wash and lateral sub-surface soil-water movement.

The steepland soils studied by Campbell (1973) were in comparatively simple lithologic and topographic situations on relatively uniform parent materials, with land surfaces having undergone only one erosion cycle. In this study area the lithologic pattern is complex and the land surfaces have undergone more than one erosion cycle. The effect of periodicity in landform development is to increase the complexity and variation of the soil patterns usually extending the range of properties for each slope unit (Campbell, 1975).

Two study areas were chosen on two different parent materials, silty sandstone (Area 1) and mudstone (Area 2). Study Area 1 was located 0.5km west of the Patea River, on the property of R. Hardwick-Smith. Study Area 2 was located west of Wingrove Road, 1km from the junction with Rawhitiroa Road, on the property of C.J. and J.F. Hainsworth (Figure 5.9).

Soils were examined at four typical sites in each of the study areas:-

- 1) Ridge crest
- 2) Intermediate steep slope
- 3) Eroded slope
- 4) Accumulation slope

(Plates 5.12 - 5.13).

The complex and variable nature of the parent material in each of the two study areas was explored using the above sites as a sampling framework. Phosphate retention was investigated together with the Fieldes and Perrott (1966) allophane test to provide an indication of the presence of volcanic ash or its absence due to erosion.

ENVIRONMENTAL FACTORS

Physiography

The stepland terrain in this study is thought to comprise eroded remnants of Kaiatea aged, uplifted marine benches and their respective cover beds, that have been extensively dissected. These overlie the Tangahoe Formation and the Matemateonga Formation both of Pliocene age. The Tangahoe Formation is comprised of massive sandy mudstone with scattered concretions. The Matemateonga Formation is a massive sandstone, containing shell-beds and conglomerate bands, interbedded with mudstone and siltstone in the lower part.

This highly dissected Kaiatea terrain is composed of steep and very steep land, with most slopes between 26° and 35° and many slopes over 35° .

Study Area 1 lies at 150-210m elevation and Study Area 2 at 150-280m. Overall the highly dissected Kaiatea terrain finds itself within elevation limits of 120-485m.

Parent material

The nature of the parent material is of fundamental importance for a detailed knowledge of stepland soils. The ability to predict and extrapolate the distribution of detailed soil mapping units elsewhere depends very much on the uniformity of parent material as well as other features, such as landform and vegetation, which are more easily mapped.

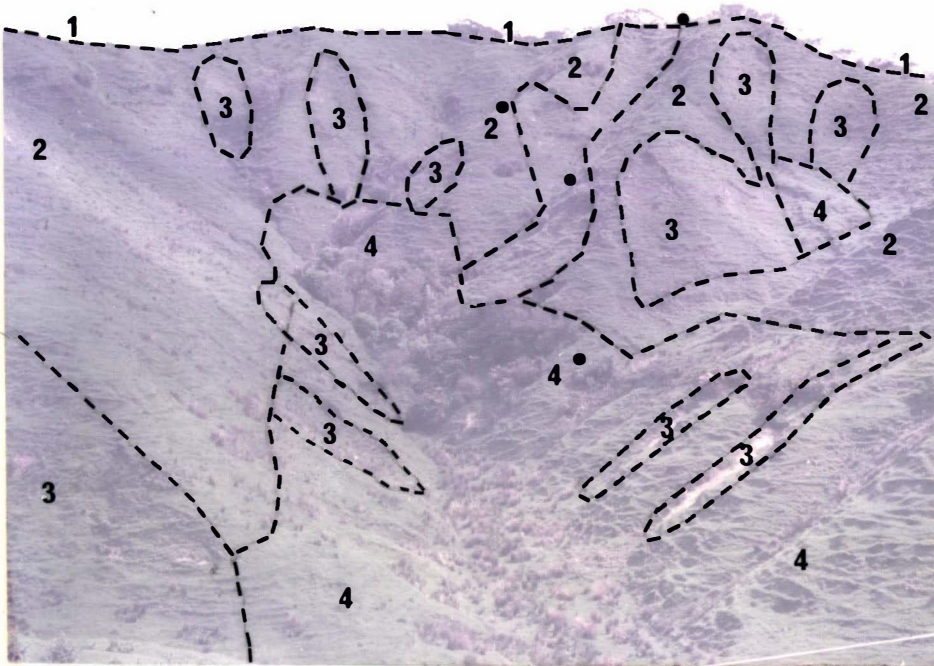


Plate 5.12

Study Area 1.

1. Ridge phase
2. Intermediate steep slope
3. Eroded slope phase
4. Accumulation slope phase.

The locations of the profiles examined are marked by circles.

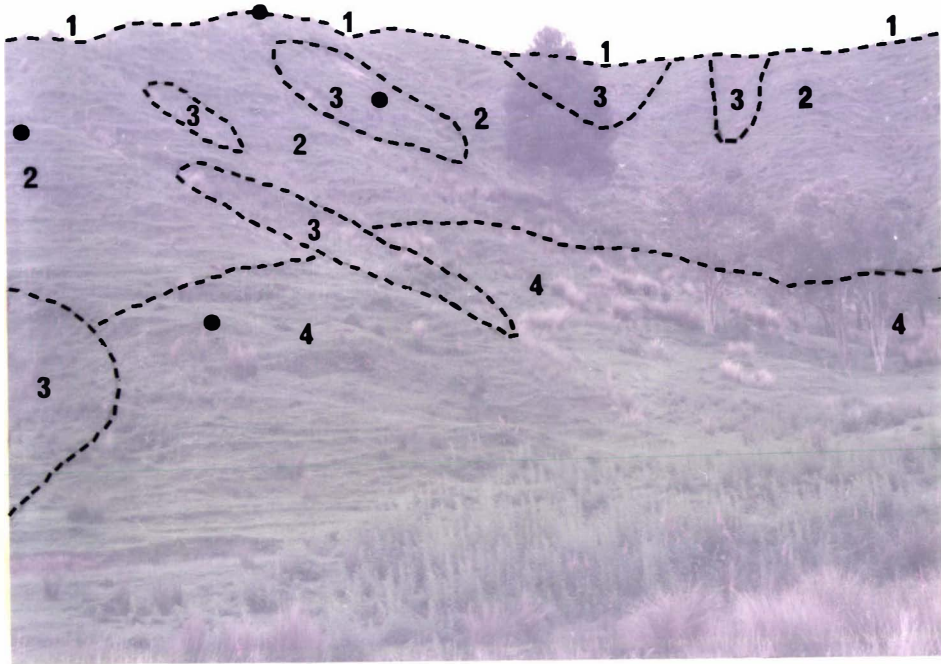


Plate 5.13

Steepland Study Area 2.

1. Ridge phase
2. Intermediate steep slope
3. Eroded slope phase
4. Accumulation slope phase

The locations of the profiles examined are marked by circles.

The occurrence of heterogeneous parent materials in the steepland terrain of Eltham County has meant that large variations in soil profile morphology can be found over short distances, due to distinct parent material differences.

The parent rock is most commonly quartzo-feldspathic moderately consolidated silty sandstone (Plate 5.14) but weakly consolidated fine sandstone, indurated sandstone, mudstone or weakly consolidated sandy siltstone can also occur together with occasional outcrops of shelly limestone. In addition, the area has been periodically covered by volcanic ash from Mt. Egmont (Plate 2.2). However, subsequent erosion has removed the ash from the steeper slopes. This has led to the ash being found as an admixture within the upper horizons of soil profiles in valleys and on terraces or restricted to the ridge crests, where it may occur as a discrete layer. The actual depth of ash is so variable that it is difficult to make any conclusive statements regarding an average thickness.

The parent material in Area 1 was predominantly moderately consolidated silty sandstone and in Area 2, mudstone. Volcanic ash was present in both of the study areas.

Vegetation and erosion history

The area was once clothed in podocarp-hardwood-beech forest. Tawa (Beilschmiedia tawa), rimu (Dacrydium cupressinum), kamahi (Weinmannia racemosa), miro (Podocarpus ferrugineus) and beech (Nothofagus spp.) predominated. Kahikatea (Dacrycarpus dacrydioides) was dominant in lowlying areas. The name of the district Mangamingi is derived from "valley of mingi-mingi bushes" (Cyathodes fasciculata).

The areas studied in detail were cleared and converted into pastoral farmland, in the 1880's. The practice of clearing the land by burning vast areas of forest and sowing pasture grasses was not a success and has, in places, accelerated the "natural" incidence of mass movements. A preference for sheep farming meant diminished control of regrowth, encouraging ferns and bush to crowd out pasture grasses so that large areas have reverted to secondary growth. However, the introduction of aerial topdressing, in the 1950's brought about an improvement in pastoral farming. Areas of land that had reverted to hard fern (Paesia scaberula) and scrub have been subsequently cleared again.

Plate 5.14



Exposure of moderately consolidated silty sandstone belonging to the Matemateonga Formation at Mangamingi Saddle, N119/967466.



Plate 5.15

View from Study Area 1 looking south-east.

Sharp ridges and narrow spurs are well defined. Exposures of silty sandstone bedrock and terracettes are evident in the foreground.

Today pasture is the main vegetation cover of the area, with some secondary growth of bush. The species tend to vary according to fertilizer usage and management. The species browntop (Agrostis tenuis), danthonia (Danthonia spp.) and ratstail (Sporobolus capensis) were found to prevail in the study areas, with weeds such as ragwort (Senecio jacobea), rush (Juncus spp.) and thistle (Cirsium spp.) common.

There appears to be little information on the occurrence of erosion under original forest cover. However, the general effect of devegetation on mass movement rate and occurrence is well documented (e.g. Pain, 1969; Eyles, 1971; O'Loughlin, 1974).

The general protective effect of vegetation has been long established but the specific effect of tree cover upon slope stability is still being investigated. O'Loughlin and Pearce (1976) found that after forest removal denudation rates were increased 40 times in parts of North Westland underlain by massive Tertiary sandstone and siltstone. Their study showed that the supporting effect of tree roots on saturated soils was very high.

There is a lack of detailed information regarding forms of soil erosion occurring in the steepland study area. The only published study of erosion in the area is that undertaken by the National Water and Soil Conservation Organisation, as part of the National Land Resource Inventory Survey. This survey does not take account of past erosion, recording only present and potential erosion. The National Water and Soil Conservation Organisation (1979) states that the steep slopes are presently undergoing slight to moderate earth slip erosion. Potential erosion is considered moderate to severe involving earth slip, sheet and slump erosion.

Erosion is closely associated with variability of rainfall. Protracted dry spells followed by abnormally heavy rains often initiate mass movements in this type of country. An examination of historical records of high rainfall in Taranaki (Taranaki Catchment Commission, 1982) lists several storm events between 1867 - 1980, where high rainfall and flooding resulted in erosion in the steepland area.

The complex pattern of volcanic ash and various types of sedimentary rocks form a combination of stable and potentially unstable slopes. The presence of allophane in steepland soils decreases their shear strength and increases their susceptibility to downslope movement. Hydration of the allophane causes expansion, which may produce a lateral pressure within the soil. Wells and Furkert (1972) refer to this shearing tendency

of allophane under increased pressure.

Terracettes are evident in both study areas and are orientated parallel to the ridges (Plate 5.15). The occurrence of terracettes has been suggested as being a form of soil creep but this has been discounted as they generally do not occur in areas where stock are absent.

Mosley (1977) and Schumm (1977) consider that significant fluctuations in erosion rates are natural so that erosion in the steepland areas may not necessarily be accelerated by any one factor or combination of factors but rather may be part of a cyclical process. However, both these authorities were working in a North American environment. There can be little doubt that the massive deforestation of steepland terrain in the study areas has resulted in manifest accelerated erosion with parent rock exposed in many places.

Land use

Land use in Mangamingi is largely conditioned by the steepness of the terrain. For the most part farming activities are restricted to the production of wool, store-sheep and beef cattle. In more favoured areas in valley bottoms some fat lamb production is possible.

Area 1 is concerned with intensive sheep farming with beef cattle secondary, while Area 2 is devoted to beef cattle and sheep.

Climate

The rainfall station at Omoana (213m), east of the Patea River operated from 1953 up until 1977 but the data obtained is not considered reliable. The nearest representative meteorological station is at Te Wera State Forest. Here temperature data is available for 25 years of observations (1955-1980), (Table 5.13). This data indicates a comparative absence of extreme values, the mean annual air temperature being 11.9°C. Over the 25 year time period the maximum monthly temperature recorded was 31°C and the minimum monthly temperature -7°C. The mean monthly relative humidity at 9.00 a.m. ranges from 77% to 79% for the months December and January to 90% to 91% for the months of June and July with a monthly average over the whole year of 84%.

The same table indicates that at Te Wera the mean annual rainfall is 1837mm with the highest precipitation falling from May to August (\bar{x} 175mm) and the lowest from January to March (\bar{x} 125mm). These figures

C94262 TE WERA FOREST		GRID REFS	NZMS 1, NZMS 260.	1 63360 1 50000	N1 10149718 Q20481185	LAT 39 14S			LONG 174 36E			HT. 180 M			
		PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
RAINFALL MILLIMETRES															
HIGHEST MONTHLY/ANNUAL TOTAL	1955-1980	363	254	221	370	351	360	413	356	452	327	305	482	2576	
90 PERCENTILE VALUE	1955-1980	242	198	210	251	313	305	295	246	289	257	285	251	2270	
MEAN	1955-1980	137	114	123	140	189	166	179	167	158	152	160	152	1837	
10 PERCENTILE VALUE	1955-1980	48	36	44	65	85	72	60	75	70	68	69	68	1481	
LOWEST MONTHLY/ANNUAL TOTAL	1955-1980	18	3	39	30	74	25	54	45	31	25	54	24	1417	
AVERAGE RAIN DAYS, 1.0MM OR MORE	1955-1980	9	8	9	11	13	13	14	15	13	14	13	11	143	
MAXIMUM 1-DAY RAINFALL	1955-1980	91	190	109	129	110	113	69	107	84	81	74	128	190	
MAXIMUM 2-DAY RAINFALL	1955-1980	117	228	110	146	118	120	136	146	147	91	131	135	228	
TEMPERATURE OF THE AIR, DEGREES CELSIUS															
HIGHEST RECORDED	1955-1980	31.3	28.9	28.2	24.6	21.7	19.4	16.4	18.3	21.7	23.3	25.7	28.5	31.3	
AVERAGE MONTHLY/ANNUAL MAXIMUM	1955-1980	27.0	27.0	25.8	22.1	18.9	16.4	14.9	16.5	18.4	20.6	22.3	24.8	27.9	
AVERAGE DAILY MAXIMUM	1955-1980	22.1	22.5	21.1	18.2	14.8	12.5	11.8	12.9	14.4	16.4	18.1	20.3	17.1	
MEAN	1955-1980	16.5	16.6	15.3	12.5	9.7	7.5	6.9	8.1	9.6	11.6	13.0	15.0	11.9	
AVERAGE DAILY RANGE	1955-1980	11.4	11.9	11.6	11.3	10.2	10.1	10.0	9.6	9.6	9.6	10.3	10.6	10.5	
AVERAGE DAILY MINIMUM	1955-1980	10.7	10.6	9.5	6.9	4.6	2.4	1.8	3.3	4.8	6.8	7.8	9.7	6.6	
AVERAGE MONTHLY/ANNUAL MINIMUM	1955-1980	3.9	3.6	1.7	-0.8	-3.0	-4.8	-4.8	-3.9	-2.1	0.0	0.7	2.6	-5.9	
LOWEST RECORDED	1955-1980	0.3	0.0	-2.5	-4.2	-6.4	-6.7	-7.0	-6.6	-5.3	-2.7	-1.2	0.0	-7.0	
TEMPERATURE OF THE GROUND, DEGREES CELSIUS															
LOWEST GRASS MINIMUM RECORDED	1955-1980	-3.7	-4.7	-6.6	-7.7	-9.2	-11.2	-9.4	-12.5	-9.7	-7.7	6.3	-5.2	-12.5	
AVERAGE GRASS MINIMUM	1955-1980	7.9	7.9	7.0	4.6	2.3	0.2	-0.6	0.9	2.1	3.9	5.2	6.9	4.0	
FROST															
AVERAGE DAYS OF GROUND FROST	1955-1980	0.8	0.8	1.3	4.2	9.0	13.4	15.3	11.2	8.2	5.7	3.2	1.0	74.1	
AVERAGE DAYS OF AIR FROST	1955-1980			0.3	1.9	5.6	10.6	11.8	7.6	3.8	1.4	0.5		43.5	
RELATIVE HUMIDITY, (%)															
AVERAGE AT 9 A.M	1955-1980	79	83	85	89	89	91	90	88	84	79	78	77	84	
VAPOUR PRESSURE, MILLIBARS															
AVERAGE AT 9 A.M	1971-1980	15.5	15.6	14.9	12.8	10.3	8.8	8.1	9.1	10.3	11.3	12.8	13.9	12.0	
SPECIAL PHENOMENA, AVERAGE DAYS OF															
SNOW	1955-1980						0.1							0.1	
HAIL	1955-1980			0.2		0.4	0.1	0.1	0.2	0.1	0.1	0.1	0.2	1.5	
THUNDER	1955-1980	0.2		0.3	0.2	0.5	0.3	0.2	0.3	0.3	0.2	0.4	0.3	3.2	
GALE	1955-1980		0.1		0.2				0.1	0.1	0.1	0.1		0.7	
FOG	1955-1980	0.9	2.8	3.2	4.0	4.0	2.4	2.2	2.0	1.6	0.8	0.6	0.9	25.4	

Table 5.13

N.Z. Meteorological Service Summaries of Climatological
Observations to 1980 for Te Wera Forest

express a winter maximum and summer minimum in the rainfall distribution. The isohyet map (Figure 2.1) indicates that for the two study catchments the rainfall ranges from 1500 to 1900mm so that the Te Wera data may be taken as reasonably representative of the two study areas. However, it may be assumed that the study areas will differ from the Te Wera State Forest as regards evapotranspiration and insolation due to differences in vegetation cover.

Frost in the grassed stepland terrain is localised, varying markedly in frequency and intensity depending on topographic position.

Significance of soil-forming factors

Any interpretation of stepland soil processes requires a detailed knowledge of past vegetational changes, climate variation and parent material variability that have operated in the area. Also changes due to Man's actions, in clearing stepland for agricultural purposes, have had a major impact on soil-forming processes in the study area. Accelerated erosion has led to soil loss and often the exposure of parent rock.

The physiographic factor, involving steep and very steep land, results in both horizontal and vertical slope processes taking place, with the mobilisation, translocation and redeposition of soil materials. In the study areas, although certain sites were well drained most of the sites examined were imperfectly or poorly drained due to seepage and impeded internal drainage. The iron stained roots, mottles and concretions are all features associated with gleying processes and gleying can be described as incipient. An increase in both mottles and concretions with depth was observed due to the presence of parent rock influencing profile drainage.

A knowledge of landform evolution is important since the differences between soils formed can be directly related to the land surface differences (Campbell, 1975). Campbell found that on three land surfaces, in the Wanganui area, the nature, rate and intensity of rejuvenation occurring at each intermediate steep slope site was different. Rejuvenation processes involve removal or accumulation and mixing consequent on downslope processes, and may be periodic or continuous. Such rejuvenation processes are clearly operative in the study areas. In the past, intermittent volcanic ash deposition resulted in soil rejuvenation

throughout the steepland area. In stable physiographic positions, such as ridge crests such rejuvenation had a permanent effect on soil properties. On steep slopes much of the airfall volcanic ash was eroded away. There appears to be little evidence for any gradual rejuvenation by downslope movement of volcanic ash affected soil under the influence of soil creep.

Soil correlation

The steepland area was previously mapped at 1:253,440 scale by the N.Z. Soil Bureau (1954) in four soil sets Whangamomona silt loam set was derived from sandy mudstone and sandstone, with Whangamomona complex set being derived from sandstone, mudstone, Stratford ash and Egmont ash. Moumahaki sandy loam set was derived from sandstone and conglomerate while Moumahaki silt loam set was derived from sandstone and Tongariro or Egmont ash.

Aitken et al., (1978) in the Stratford County Soil survey, more closely defined Whangamomona steepland soils as soils with sandy loam textures formed from moderately consolidated silty sandstone. The sandstone fragments in general increase in abundance with increasing soil depth but profiles pass abruptly into parent rock. Moumahaki steepland soils are sandier than Whangamomona soils and have weaker structures. The soil parent material is strongly consolidated sandstone. Tahora steepland soils were reserved for soils derived from sandy mudstone and have a clay loam texture, strongly developed structure, fragments of mudstone throughout the profile and a gradual rather than a sharp transition into rubbly parent rock. Soils with silt loam textures derived from consolidated siltstone were separated out and re-named Tirangi steepland soils. They are formed from slightly coarser textured and more massive sedimentary rocks than Tahora steepland soils and their profiles contain fewer fragments and pass more abruptly into parent rock. It was accepted that mainly due to parent material differences, a considerable variety of soils were included within the Whangamomona mapping unit.

Aitken et al., (1978) mapped soils derived from volcanic ash over sedimentary rocks, as New Plymouth soils and New Plymouth hill soils. However, these soils were typically mapped in northern Taranaki, where they have a thermic soil temperature regime. In Eltham County the soil temperature regime is mesic and under these circumstances the soils have

been mapped as Stratford, fine topsoil variant and Stratford hill soils. These soils are otherwise morphologically very similar to New Plymouth soils and New Plymouth hill soils.

Classification

New Zealand Genetic Classification -- Steepland soils
related to yellow-brown earths.

There is no single precise definition of steepland soils and the present concept of steepland soils, as a separate soil group, in the New Zealand genetic system (Taylor and Cox, 1956) has tended to be used inconsistently.

In the early classifications (N.Z. Soil Bureau, 1948; N.Z. Soil Bureau, 1954) steepland soils were called skeletal soils, and were regarded as soils that were relatively unstable, generally shallow and periodically rejuvenated by erosion.

In the New Zealand genetic classification steepland soils for many years were defined as soils on steep slopes, above 28° , having little or no profile development, with features closely related to the parent rock. Slope has in fact always been an integral part of the definition and the emphasis on a definite slope criteria has meant that until recently all soils developed on slopes above 28° are classified as steepland soils, irrespective of profile morphology. The limit of 28° has recently (1982) been lowered to 26° to conform with the limit adapted for Land Use Capability Surveys of Water and Soil Division of the Ministry of Works and Development. In reality, however, the actual slope angle is not the determining factor but site position. For example, soils on the ridges are often characterised by deep, well developed profile morphology in contrast with those of the eroded slopes where profiles are much more variable as to depth and soil properties. In some cases, areas within the steepland terrain have been stable for a great length of time and the soils have the profile morphology of the associated zonal group (Cutler, 1962).

The mapping unit "steepland soils" was introduced by Gibbs in 1954, by analogy with the "hill soils" and included not only the soils on the steep slopes but also the related soils on the ridges and less steep slopes that occur within the soil mapping unit. The steepland soil

mapping unit, has come to be widely applied in soil mapping in New Zealand and in the process has been used as a classification unit term, with resultant inevitable confusion.

Cowie (1981) has pointed out that this has led to the anomaly whereby the term can be used either to indicate a complex mapping unit formed on a steep-land landscape, which includes a range of taxonomic units, or as a classification term for a specific taxonomic unit, within the mapping unit. Cowie suggests that "steep-land soils" should be retained as a mapping unit term but abandoned as a classification term. He argues for the re-introduction of skeletal soils as a taxonomic unit at the soil group level. The steep-land mapping units would include a range of taxonomic units, including skeletal soils as originally conceived, as well as the appropriate zonal or intrazonal soils where these occur.

Soil Taxonomy (Soil Survey Staff USDA, 1975) - Typic (Andic, Aquic) Dystrachrepts.

It is assumed that there are no horizons with a base saturation greater than 60%, so that according to Soil Taxonomy the steep-land soils examined belong to the Great group Dystrachrepts. Certain pedons in the study areas will meet criteria for the Aquic subgroup due to the presence of low chroma mottles, while the presence of volcanic ash, 18cm or more thick is sufficient for defining an Andic subgroup. At the family level the pedons can be described as having a mesic soil temperature regime. Particle size and mineralogical classes are variable and for the specific classification of individual pedons, in terms of Soil Taxonomy, the profile descriptions should be consulted.

DETAILED DESCRIPTION OF SOIL PROFILES

STUDY AREA 1 (Plate 5.12)

Whangamomona steepland soil (on ridge top) (Plate 5.16).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.

US Soil Taxonomy:- Typic Dystrochrept, clayey, mesic.

Location: Mangamingi. 0.5km west of Patea River.
R. Hardwick-Smith's property.

Profile located on narrow ridge.

N119/032494

Elevation: 210m

Slope: 1°

Rainfall: 1500-1900mm

Vegetation: Improved pasture

Parent material: Quartzo-feldspathic, moderately consolidated silty sandstone.

Profile:

A	0-22cm	dark greyish-brown (10YR 4/2) loam; friable; strongly developed, fine blocky structure; firm; many roots; few strong brown (7.5YR 5/8) iron coatings associated with roots; diffuse interfingering boundary.
Bw1	22-44cm	yellowish-brown (10YR 5/4) sandy clay loam; friable; strongly to moderately developed medium blocky structure; firm; few roots; few brownish-yellow (10YR 6/6) discolourations; distinct wavy boundary.
Bg1	44-68cm	light yellowish-brown (10YR 6/4) clay loam; massive; firm; few light brownish-grey (10YR 6/2) and yellow (10YR 7/8) mottles; indistinct boundary.
Bg2	68 - 1m +	brownish-yellow to yellow (10YR 6/6 - 10YR 7/6) silty-clay; massive; firm; few mottles.



Plate 5.16

Ridge profile Area 1.

Note dark greyish-brown, strongly developed A horizon, with diffuse interfingering boundary to yellowish-brown subsoil.

Whangamomona Steepland soil (on intermediate steep slope) (Plate 5.17).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.
US Soil Taxonomy:- Andic Dystrachrept, fine-loamy mixed, mesic, shallow.

Location: Mangamingi. 0.5km west of Patea River.
R. Hardwick-Smith's property.
Profile located on moderately steep site of spur
N119/031493

Elevation: 200m

Slope: 20°

Rainfall: 1500-1900mm

Vegetation: Improved pasture

Parent material: Quartzo-feldspathic, moderately consolidated silty sandstone

Profile:

A 0-24cm brown (10YR 5/3) fine sandy loam with many silty sandstone fragments, averaging 10cm; friable; strong to moderately developed fine nut structure; soft; many roots; distinct irregular boundary.

Bw 24-41cm light yellowish-brown to brownish-yellow (10YR 6/4 - 6/6) sandy loam; friable; weakly developed fine nut structure; soft; few yellowish-red (5YR 5/8) discolourations along root channels; common roots; distinct wavy boundary.

on

C/B light yellowish-brown (2.5YR 6/4) with strong brown (7.5YR 5/8) distinct coarse mottles; moderately consolidated silty sandstone.



Plate 5.17
Intermediate steep slope profile, Area 1, showing fragments of silty sandstone.

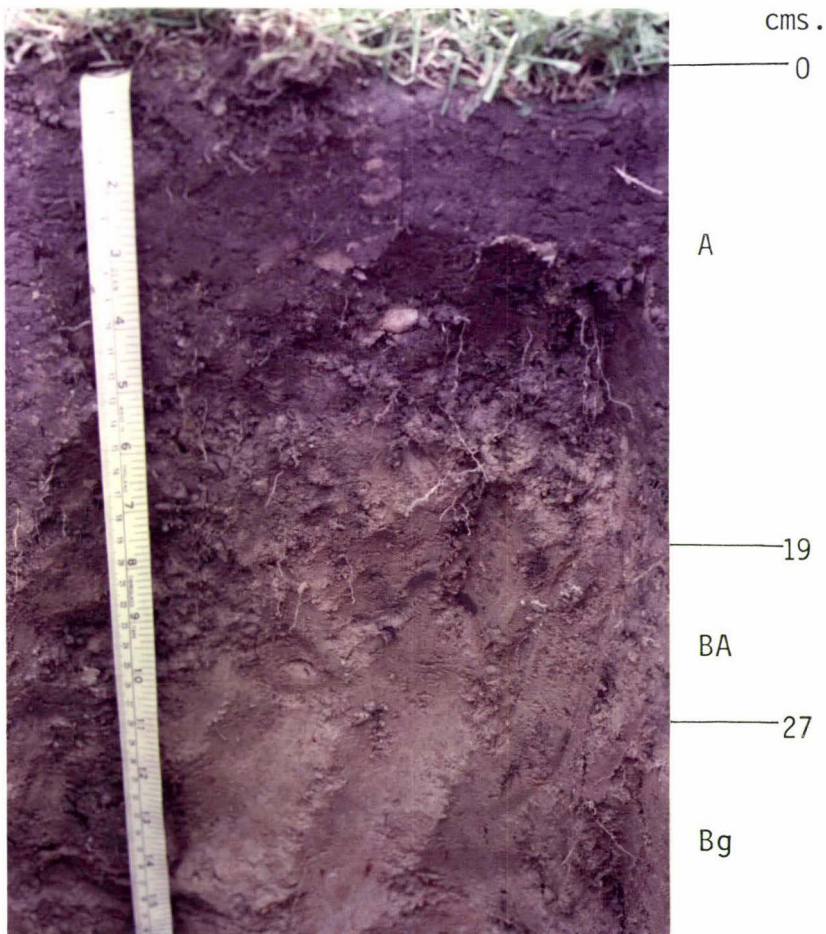


Plate 5.18
Intermediate steep slope profile, Area 2.
Note the dark coloured A horizon containing few, scattered mudstone fragments, overlying a mottled subsoil.

Whangamomona Steepland soil (on eroded slope). (Plates 5.19 and 5.20).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth

US Soil Taxonomy:- Aquic Dystrachrept, clayey, mesic.

Location: Mangamingi. 0.5km west of Patea River.
R. Hardwick-Smith's property.

Profile located on eroded slope facing south-west.
N119/032493

Elevation: 200m

Slope: 19°

Rainfall: 1500-1900mm

Vegetation: Juncus spp.

Parent material: Quartzo-feldspathic, moderately consolidated silty sandstone.

Profile:

- | | | |
|-----------|---------|---|
| A | 0-6cm | olive grey (5YR 5/2) silt loam; friable; weakly developed fine nut and crumb structure; very soft; few strong brown (7.5YR 5/6) soft concretions; many roots; distinct wavy boundary. |
| Bg1 | 6-20cm | pale brown (10YR 6/3) sandy clay; friable; weakly developed fine nut structure; soft; many distinct medium light brownish-grey to light grey (2.5Y 6/2 - 7/2) mottles; many reddish-yellow (5YR 6/8) concretions; few roots; distinct irregular boundary. |
| Bg2 | 20-44cm | brownish-yellow (10YR 6/6) clay loam with few soft silty sandstone fragments; firm to friable; massive; abundant light grey (5Y 7/1) mottles; many reddish-yellow (5YR 6/8) concretions; distinct boundary. |
| Bg3 | 44-63cm | strong brown (7.5 YR 5/8) sandy clay loam with few strongly weathered light grey (5Y 7/2) pumiceous lapilli; firm; massive; abundant mottles; distinct boundary. |
| <u>on</u> | | |
| 2C | | weakly consolidated silty sandstone, with abundant mottles. |

Plate 5.19

Eroded slope site, Area 1.

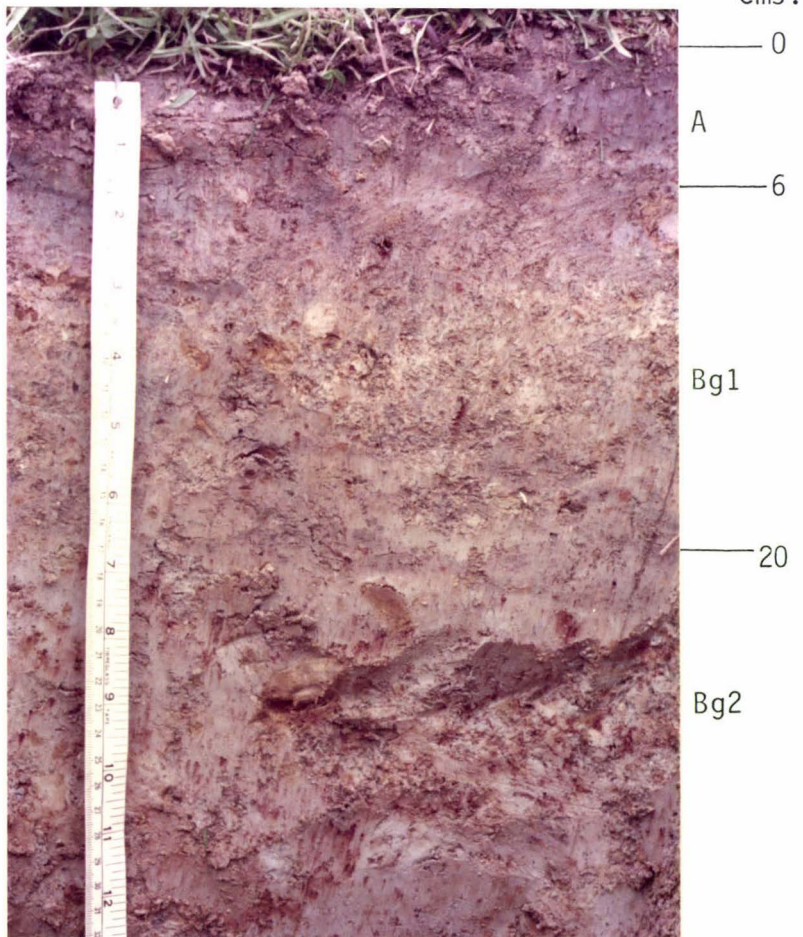


Plate 5.20

Profile from zone of local accumulation
at foot of eroded site.

Note thin, weakly structured topsoil.

Whangamomona Steepland soil (on accumulation slope). (Plate 5.21).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.

US Soil Taxonomy:- Andic Dystrochrept, clayey, mesic.

Location: Mangamingi. 0.5km west of Patea River.
R. Hardwick-Smith's property.
Profile located on lower part of valley side facing south-east.

N119/033492

Elevation: 150m

Slope: 9°

Rainfall: 1500-1900mm

Vegetation: Pasture and Juncus spp.

Parent material: Slope drift derived from quartzo-feldspathic silty sandstone.

Profile:

- | | | |
|-----|------------|--|
| A | 0-19cm | dark greyish-brown (10YR 4/2) loam to silt loam with few iron stained silty sandstone fragments averaging 20mm in diameter; friable; moderately developed fine nut structure; soft; many roots; distinct irregular boundary. |
| Bw1 | 19-38cm | yellowish-brown (10YR 5/4) sandy clay loam with few scattered, strongly weathered pumiceous lapilli and rare silty sandstone fragment, less than 20mm in diameter; friable; weakly weathered fine nut structure; soft; few roots; indistinct boundary. |
| Bw2 | 38-60cm | light yellowish-brown (10YR 6/4) sandy clay loam with traces of strongly weathered pumiceous lapilli and rare fragments of silty sandstone; friable; weakly developed medium blocky structure; soft; diffuse boundary. |
| Bw3 | 60-100cm + | pale brown to light yellowish-brown (10YR 6/3 - 6/4) sandy clay loam with scattered strongly weathered pumiceous lapilli; massive. |

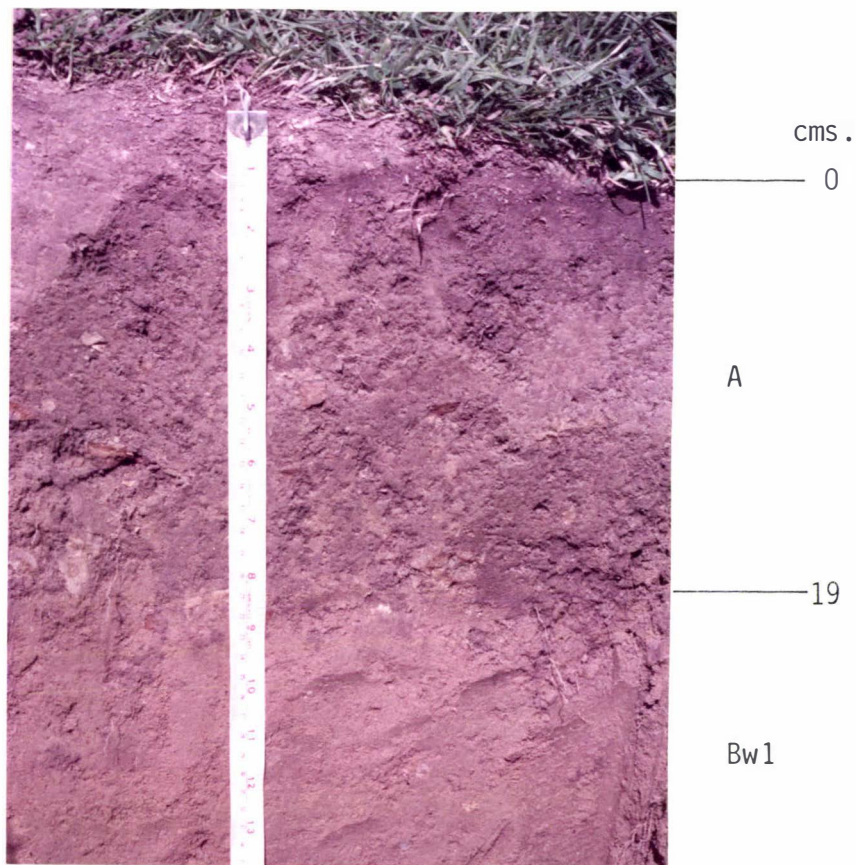


Plate 5.21

Accumulation slope profile, Area 1.

Note few iron stained fragments of silty sandstone in A horizon and few scattered, strongly weathered pumiceous lapilli in Bw1 horizon.

STUDY AREA 2 (Plate 5.13)

Tahora Steepland soil (on ridge top).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.

US Soil Taxonomy:- Andic Dystrochrept, fine-loamy, mesic.

Location: Mangamingi, west of Wingrove road, 1km from junction with Rawhitiroa road.

C.J. and J.F. Hainsworth's property.

Profile located on narrow ridge.

N119/989485

Elevation: 280m

Slope: 1⁰

Rainfall: 1500-1900mm

Vegetation: Improved pasture

Parent material: Quartzo-feldspathic mudstone

Profile:

A 0-25cm brown (10YR 5/3) loam; friable; strongly developed fine nut structure; soft; many roots; distinct wavy boundary.

BA 25-38cm brownish-yellow to brown (10YR 6/6 - 4/3) loam; friable; moderately developed fine medium nut structure; firm; common to few roots; distinct wavy boundary.

Bw1 38-78cm brownish-yellow (10YR 6/6) silt loam; friable; weakly developed medium nut structure; firm; few yellow (10YR 7/6) cutans; few roots; distinct wavy boundary.

Bw2 78-100cm + yellow (2.5Y 7/6) silt loam; massive; very firm.

Tahora Steepland soil (on intermediate steep slope). (Plate 5.18).

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.

US Soil Taxonomy:- Typic Dystrachrept, fine-loamy, mesic.

Location: Mangamingi, west of Wingrove road, 1km from junction with Rawhitiroa road.
C.J. and J.F. Hainsworth's property.
Profile located on valley side, facing south-east.
N119/988483

Elevation: 180m

Slope: 30°

Rainfall: 1500-1900mm

Vegetation: Improved pasture

Parent material: Quartzo-feldspathic mudstone

Profile:

A	0-19cm	dark greyish-brown (10YR 4/2) silt loam, few mudstone fragments, averaging 10mm in diameter; friable; strong to moderately developed fine nut structure; soft; many roots; distinct irregular boundary.
BA	19-27cm	light yellowish-brown (10YR 6/4) loam; friable; weakly developed fine nut structure; soft; common roots; distinct wavy boundary.
Bg	27-54cm	light grey (2.5Y 7/2) silt loam; massive; very soft; abundant distinct medium reddish-yellow (7.5YR 6/6) mottles; few light grey (2.5Y 7/2) mottles; few roots; distinct irregular boundary.

on

C strongly mottled mudstone.

Tahora Steepland soil (on eroded slope). (Plates 5.22 and 5.23)

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth
US Soil Taxonomy:- Aquic Dystrochrept, clayey, mesic.

Location: Mangamingi, west of Wingrove road, 1km from junction with Rawhitiroa road.
C.J. and J.F. Hainsworth's property.
Profile located on eroded slope facing south-east
N119/989484

Elevation: 180m

Slope: 22⁰ concave

Rainfall: 1500-1900mm

Vegetation: Juncus spp.

Parent material: Quartzo-feldspathic mudstone

Profile:

A	0-8cm	brown (10YR 5/3) silt loam; very friable; weakly developed fine nut and crumb structure; very soft; few yellowish-red (5YR 5/6 - 5/8) concretions; many roots; distinct irregular boundary
Bg1	8-30cm	light yellowish-brown (2.5Y 6/4) silty clay loam; friable; moderately developed fine nut structure; soft; many distinct medium light brownish-grey (2.5Y 6/2) mottles; few strong brown (7.5YR 5/6) soft concretions; common roots; indistinct boundary
Bg2	30-52cm	light grey (10YR 7/1) silty clay loam with few mudstone fragments; friable; massive; soft; many prominent coarse yellowish-red (5YR 5/6) mottles; few roots; sharp boundary.
<u>on</u>		
C		strong brown (7.5YR 5/8) mottled mudstone.

Plate 5.22

Eroded slope site, now stabilised.
The Juncus spp. are indicative of poor drainage.



cms.
0

A

8

Bg1

30

Bg2

52

C

Plate 5.23

Eroded slope profile.

Note thin, weakly structured topsoil and mottled subsoil.

Tahora Steepland soil (on accumulation slope). (Plates 5.24 and 5.25)

Classification: NZ Genetic Classification:- Steepland soil related to yellow-brown earth.

US Soil Taxonomy:- Andic Dystrachrept, clayey, mesic.

Location: Mangamingi, west of Wingrove road, 1km from junction with Rawhitiroa road.
C.J. and J.F. Hainsworth's property.

Profile located on lower part of valley side, facing south

N119/990484

Elevation: 150m

Slope: 14⁰

Rainfall: 1500-1900mm

Vegetation: Juncus spp.

Parent material: Slope drift derived from mudstone

Profile:

A	0-21cm	dark brown to brown (10YR 4/3) silt loam; few scattered pumiceous lapilli, greater than 20mm in diameter, strongly developed fine blocky and nut structure; firm; many roots; distinct wavy boundary.
Bw	21-42cm	yellowish-brown (10YR 5/4) sandy clay loam, with rare mudstone fragment, averaging 40mm in diameter; friable; moderately developed fine nut structure; soft; common roots; distinct wavy boundary
Bg1	42-68cm	light grey (10YR 7/1) silty clay, rare mudstone fragment; massive; soft; distinct, medium strong brown (7.5YR 5/6) mottles, few to many with depth; few roots; indistinct boundary
Bg2	68-84cm	brownish-yellow (10YR 6/6) silty clay with many mudstone fragments; massive; very firm; many distinct, coarse reddish-yellow (7.5YR 5/8) mottles; few roots; distinct wavy boundary
<u>on</u>		
C		light yellowish-brown (2.5Y 6/4) and strong brown (7.5YR 5/8) mottled mudstone drift.

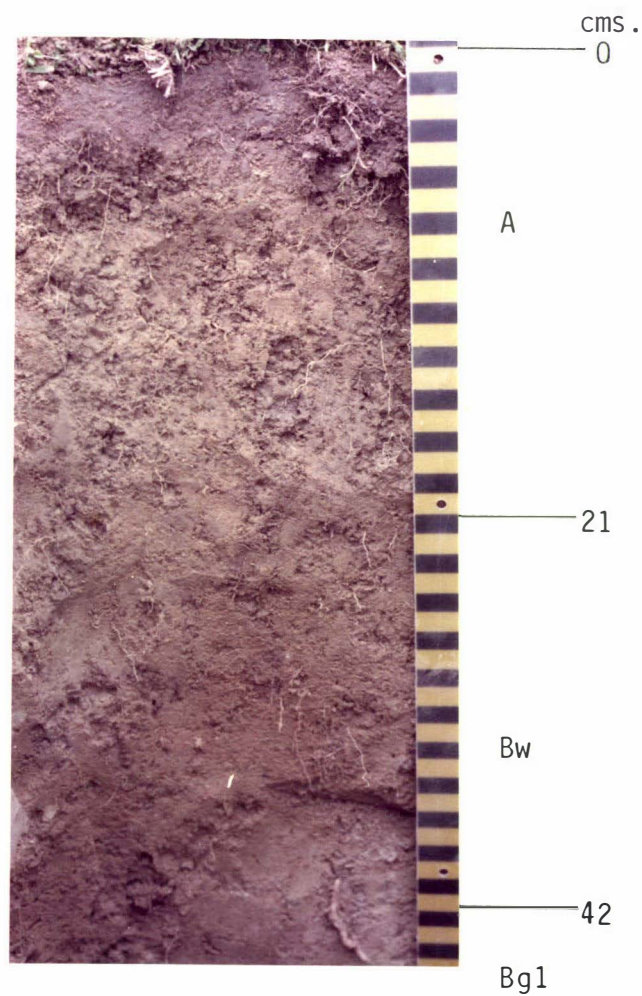
Plate 5.24

View north of accumulation slope site, Area 2.



Plate 5.25

Accumulation slope profile, showing strongly developed fine blocky and nut structure in the A horizon.



MORPHOLOGICAL CHARACTERISTICS
AND DISTINCTIONS BETWEEN PHASES

Soil profiles of the two study areas have been described in detail and there are certain similarities and differences in morphology at corresponding sites. In addition information on profiles in the vicinity of the study areas is drawn upon.

Ridge phase

The majority of ridges in the steepland terrain were very narrow (less than 1m) and the two ridges examined were no exception.

The ridge phase was the site of least slope movement so that these soils show the greatest profile development.

The profiles were deep, with parent rock greater than 1m depth. In both study areas the topsoil was friable and strongly developed, with Area 1 having a fine, blocky structure and Area 2, a fine nut structure. Other ridge topsoils examined contained pumiceous lapilli. A transition BA horizon was present in the well drained profile of Area 2 and iron cutans occurred in the Bw1 horizon. In the ridge phase of Area 1, the B horizons had a few mottles. However, an examination of other ridge phase profiles showed intensive mottling.

The lower B horizons in both study areas were massive and firm, with rock fragments absent from both of the profiles.

Intermediate steep slope

The soil found on intermediate steep slopes was the most extensive, occurring on steep sites on valley sides between ridges and the valley floor.

The friable topsoil had a strong to moderately developed fine nut structure and a transition worm-mixed BA horizon may be present. Fragments of silty sandstone averaging 10cm and mudstone, averaging 10mm in diameter were found in the topsoils of the two profiles examined.

The intermediate steep slope profiles were usually moderately well drained or imperfectly drained. The depth to parent rock tended to be shallower than in the ridge profile. In both profiles examined the underlying rock was mottled and occurred at less than 60cm depth.

Eroded slope phase

The eroded slope phase can occur on all eroded surfaces and so may be found on almost any part of the valley sides. Profile development depends upon the type and extent of the erosion so that a wide range of soils can be formed.

The topsoils were characteristically shallow. It was observed within the steepland terrain that where there had been recent erosion topsoils were less than 5cm thick.

The eroded slope profile differed from that of the intermediate steep slope by having a thin, weakly structured topsoil. The structure in both Areas 1 and 2 was weakly developed fine nut and crumb.

Lateral seepage was a common feature and iron concretions, averaging 1cm in diameter, were present in both eroded slope profiles, with mottles increasing in size and prominence with depth. Fragments of a thin (3mm) iron pan were encountered in other eroded slope phase profiles.

The depth to parent rock was usually shallower than in the intermediate steep slope profile and the silty sandstone and mudstone were both strongly mottled.

Accumulation slope phase

The accumulation slope phase usually occurred on the lower part of the valley sides, where the erosion debris has accumulated. However, this soil can also occur at higher sites, where such debris may have come to rest.

The accumulation slope profile differed from the intermediate steep slope profile by having more rock fragments, especially in the lower horizons and a much greater depth to parent rock.

A few, scattered, pumiceous lapilli were present in the upper part of both profiles. In Area 1, the pumiceous lapilli were strongly weathered and occurred in the Bw horizons (19 - >100cm). In Area 2 the pumiceous lapilli were restricted to the A horizon (0 - 21cm) and were greater than 20mm in diameter. In other accumulation slope profiles examined, the pumiceous lapilli were reduced to a speckled ash.

The sites were often less steeply sloping than the other phases, 9⁰ (Area 1) and 14⁰ (Area 2) and were subject to run-off and seepage from higher slopes so that soil drainage commonly was imperfect, with few to many mottles present.

Phosphate retention as an aid to soil variability

The aim behind this investigation was to gain some understanding of the pattern of parent material variability and, in particular, to obtain evidence for the presence or absence of volcanic ash. Since volcanic ash was not always visibly evident in the field, chemical methods were applied to detect the presence of allophane. The various sites in the study areas were used as a sampling framework.

Phosphate retention is a measure of the ability of a soil to rapidly remove phosphate from solution and is related to the composition of the soil and the parent material from which it is derived. As the allophane content in a soil increases so does the value for phosphate retention.

The phosphate retention method used measures percentage of added phosphate taken up in 24 hours by 5g of soil, shaken at 20°C with 25ml of NaOAc-HOAc buffer solution, at pH 4.6, with an initial phosphate concentration of 0.032M KH_2PO_4 . The method has been devised so that the concentration of phosphate used gives a strong degree of differentiation between soils of high and low retention capacity, with the pH of 4.6 being close to the point of maximum phosphate retention in many soils.

The Fieldes and Perrott (1966) test for allophane was carried out in the field by placing a small amount of soil on phenolphthalein paper and allowing a few drops of 1M NaF solution to wet the soil. If the allophane content is appreciable then the paper turns magenta red within two minutes. A pink colour indicates small amounts of allophane. A more detailed investigation of allophane content was also carried out in the laboratory, involving one drop of 1M NaF solution reacting with a small amount of soil to produce a high pH value. The pH_{NaF} values were taken at intervals of 2 minutes, 5 minutes and 60 minutes to observe the dynamics of the NaF reaction.

The sites where the phosphate or replacing fluoride are adsorbed are thought to be at defects in the allophane spherules where single Al-OH groups or substituting Fe-OH groups are exposed (Parfitt and Henmi, 1980).

The results of the investigations are shown in Table 5.14.

Table 5.14 Allophane Test and Phosphate Retention Values for Area 1 and Area 2.

AREA 1	Horizon and Depth (cm)	P Retention (%)	Allophane Test			Allophane Field Test	AREA 2	Horizon and Depth (cm)	P Retention (%)	Allophane Test			Allophane Field Test
			2 min.	5 min.	60 min.					2 min.	5 min.	60 min.	
RIDGE PHASE	A 0-22	52	8.0	8.4	8.9	Negative	RIDGE PHASE	A 0-25	70	8.6	9.1	9.8	Positive
	Bw1 22-44	45	8.1	8.4	8.7	Negative		BA 25-38	73	9.2	10.2	10.9	Positive
	Bg1 44-68	73	8.9	9.3	9.7	Positive		Bw1 38-78	72	9.5	10.0	10.8	Positive
	Bg2 68-100	71	8.3	8.6	9.1	Positive		Bw2 78-100	54	8.1	8.4	8.8	Negative
INTERMEDIATE STEEP SLOPE	A 0-24	72	8.6	8.9	9.8	Positive	INTERMEDIATE STEEP SLOPE	A 0-19	47	7.9	8.2	8.5	Negative
	Bw 24-41	81	9.6	10.3	10.9	Positive		BA 19-27	47	8.2	8.4	8.9	Negative
								Bg 27-54	32	8.0	8.1	8.5	Negative
ERODED SLOPE PHASE	A 0-6	71	7.8	8.1	8.7	Positive	ERODED SLOPE PHASE	A 0-8	48	7.8	8.1	8.4	Negative
	Bg1 6-20	68	7.9	8.0	8.7	Negative		Bg1 8-30	45	7.9	8.2	8.7	Negative
	Bg2 20-44	70	7.9	8.2	8.6	Negative		Bg2 30-50	30	7.6	7.7	8.1	Negative
	Bg3 44-63	70	8.0	8.3	8.7	Negative							
ACCUMULATION SLOPE PHASE	A 0-19	79	8.7	9.2	9.8	Positive	ACCUMULATION SLOPE PHASE	A 0-21	68	8.5	8.9	9.8	Positive
	Bw1 19-38	82	9.3	10.0	10.9	Positive		Bw 21-42	72	9.4	10.0	11.0	Positive
	Bw2 38-60	83	9.8	10.5	11.0	Positive		Bg1 42-68	50	7.9	8.3	8.8	Negative
	Bw3 60-100	83	9.7	10.4	11.0	Positive		Bg2 68-84	43	7.9	8.1	8.5	Negative

Ratings for Phosphate Retention

(N.Z. Soil Bureau Scientific Report 10A)

<u>Rating</u>	<u>% Phosphate Retention</u>
Very high	90 - 100
High	60 - 90
Medium	30 - 60
Low	10 - 30
Very low	0 - 10

The phosphate retention values were all medium to high and the ratings vary both within and between the two study areas. Most of the high value horizons responded positively to the allophane test. It is evident from the results that there can be either a negative or positive field test allophane response in soils with values of phosphate retention between 68-70%.

There was an increase in pH_{NaF} values with length of time, which was probably a measure of the amounts of crystalline material present.

The medium phosphate retention values (30-60%) and pH_{NaF} values of less than 8.8, that are predominant in Area 2, can be attributed to the presence of quartzo-feldspathic mudstone, with little fine weathered material capable of developing active sites for phosphate retention. The presence of organic matter and any additions of phosphorus fertilizers will also act to lower the phosphate retention values slightly.

Allophane is present throughout the profiles of the intermediate steep slope and accumulation slope phase in Area 1. Soils with such high phosphate retention values will require higher amounts of phosphate fertilizer to maintain pasture production than the soils with medium or low phosphate retention values predominant in Area 2.

Conclusion

The study provided an insight into the wide range of variability of the steepland soils. Distinctive morphologies in terms of profile depth, horizon expression, soil structure development and degree of mottling, were evident both between the soils of the two areas and between the soils from the four sites examined.

The eight profiles recorded show considerable predictive power, with correspondence in soil properties at equivalent sites. For example both eroded slope profiles were mottled, with weakly developed structures. However, predictions and application of soil information throughout the steepland terrain can be unreliable mainly due to parent rock and parent material variability.

The study also revealed that imperfect and poorly drained soils were widespread within the steepland area.

Volcanic ash has at one time covered the steepland area but erosion has meant a continual removal from steeper slopes and accumulation of ash on the lower slopes and in valley bottoms. A certain degree of mixing of ash and the underlying parent material has occurred, as indicated by the allophane test and phosphate retention results. The amount of ash present can provide an indication of site stability. The greater depth of ash present in the ridge profile of Area 2 indicates that it is either more stable than that of Area 1 or received a larger amount of ash. The intermediate steep slope soil in Area 1 was sited on a moderately steep 20° slope and had little evidence of ash. This suggests that volcanic ash can be expected to be found on moderately steep and slopes less than 20° but not on steep and very steep slopes due to the incidence of erosion.

The presence of volcanic ash has certain major soil fertility implications. As the allophane content in the soil increases not only does phosphate retention increase but porosity, water retention, sulphate adsorption and variable charge also increase while bulk density decreases. All of these properties will influence the soil as a medium for plant growth.

CHAPTER 6

CHAPTER 6

LABORATORY ANALYSES

1. SOILS AND SAMPLING SITES

Selected methods of analysis were chosen to characterise the chemical and physical properties of five yellow-brown loams, (Rowan, Makaka, Lowgarth, Riverlea and Stratford series), a gley soil (Mangawhero series), an intergrade between yellow-brown loams and recent soils (Hangatahua series) and an organic soil (Eltham series), in Eltham County. The yellow-brown loams and the gley soil were selected to investigate a toposequence (a sequence of drainage classes) and a climosequence (a sequence of leaching). Detailed analytical data from ten Soil Bureau reference sites, in Taranaki, were included for comparative purposes, (Table 6.1 and Figure 6.1).

Soils belonging to the toposequence were located in areas mapped as Rowan-Makaka and Makaka-Mangawhero associations, east of the Otakeho Stream and north of Opunake Road. Soil parent materials, in the toposequence, comprise in the upper part, moderately weathered lapilli, namely Kaupokonui, Maketawa and Manganui tephras, which are c. 3.300 years B.P., and total 250mm in thickness. These overlie in the lower part, tephras p2 and p1 (Druce, 1966), on laharic debris. The Rowan series is the strongly leached, well drained member of the toposequence. The Makaka series is the strongly leached, imperfectly drained member and the Mangawhero series is the poorly drained member. Details of each site and overall soil characteristics are presented in Table 6.1.

Soils belonging to the climosequence were all selected from well drained sites, which vary in elevation and age of parent material. The climosequence comprises soils belonging to the moderately leached Egmont, Stratford and Riverlea series, the moderately to strongly leached Lowgarth series, the strongly leached Rowan series and the very strongly leached Patua series. Details of each site and overall soil characteristics are presented in Table 6.1.

A well drained profile of the Hangatahua series, an intergrade between yellow-brown loams and recent soils is included from a flat site, near the Kaupokonui Stream, 2.5km south of Kaponga and a profile of the Eltham series, an organic soil, was sampled from the Eltham Swamp.

Table 6.1 DETAILS OF THE EIGHTEEN SOIL SITES IN TARANAKI

Site Number	Soil Series	Soil Group Leaching and Drainage Class	Site Elevation and Rainfall	Specific Andesitic Parent Material	Recent Top- Dressing History (at site)	Lab. Number	Grid Reference
1.	Rowan*	Yellow-brown loam Strongly leached Well drained	450m 3000mm	> 250mm <i>young lapilli showers,</i> p2/p1 (Druce,1966) on laharic debris.	3cwt 50% K Super- phosphate	S.B. 9707	N119/ 674526
2.	Makaka*	Yellow-brown loam Strongly leached Imperfectly drained	458m 3000mm	> 250mm <i>young lapilli showers,</i> p2/p1 (Druce,1966)	30% Potash Ammophos	S.B. 9703	N119/ 653504
3.	Lowgarth*	Yellow-brown loam Moderately-strongly leached Well drained	300m 1900mm	> 250mm <i>young lapilli showers</i> p2/p1 (Druce,1966) on > 2m volcanic ash (E5, E4)	4cwt 50% K Super- phosphate	S.B. 9706	N119/ 796515
4.	Riverlea*	Yellow-brown loam Moderately leached Well drained	225m 1600mm	> 250mm <i>young lapilli showers,</i> p2/p1 (Druce,1966) on laharic debris	8cwt 30% K Super- phosphate	S.B. 9705	N119/ 674449
5.	Stratford*	Yellow-brown loam Moderately leached Well drained	175m 1500mm	< 250mm <i>young lapilli showers</i> p2/p1 (Druce,1966) and E5, E4	5cwt Super- dolomite	S.B. 9708	N119/ 797423
6.	Mangawhero*	Gley Poorly drained	458m 3000mm	> 250mm <i>young lapilli showers,</i> p2/p1 (Druce,1966) on laharic debris	30% K Super- phosphate	S.B. 9709	N119/ 652505

* Eltham County Soils

Table 6.1 contd.

7.	Hangatahua*	Intergrade between yellow-brown loam and recent soil. Well drained	200m 1600mm	Andesitic alluvial sands and gravels <1000 years old	4cwt 50% K Super-phosphate	S.B. 9702	N119/ 718445
8.	Eltham*	Organic Poorly drained	200m 1500mm	Woody peat with interbedded tephra layers.	Lime and "Natumix"	S.B. 9704	N119/ 944455
9.	Warea series, hill soil	Yellow-brown loam Moderately leached Well drained	75m 1450mm	Volcanic ash (Oakura Tephra, possibly with Okato Tephra) on lahatic breccia (Pungarehu Formation).	30% K Super-phosphate and calcined magnesite	S.B. 9315A	N118/ 416583
10.	Warea	Yellow-brown loam Moderately leached Well drained	76m 1450mm	Volcanic ash (Oakura and Okato Tephra) on lahatic breccia (Pungarehu Formation).	30% K Super-phosphate and calcined magnesite	S.B. 9317A	N118/ 419587
11.	Tipoka	Yellow-brown loam Moderately leached Imperfectly drained	61m 1450mm	Volcanic ash (Oakura and Okato Tephra) on lahatic breccia (Pungarehu Formation).	30% K Super-phosphate and calcined magnesite	S.B. 9314A	N118/ 396615
12.	Opua	Yellow-brown loam Moderately leached Well drained	107m 1450mm	Lahatic breccia of central phase of the Opua Formation.	K Super-phosphate	S.B. 9313A	N118/ 475506

* Eltham County Soils

Table 6.1 contd.

13.	Te Kiri series, hill soil	Yellow-brown loam Moderately-strongly leached Well drained	214m 1600mm	Laharic breccia of central phase of Opuia Formation	-	S.B. 9319A	N118/ 513538
14.	Oaonui	Yellow-brown loam Imperfectly drained	107m 1450mm	Laharic breccia of central phase of Opuia Formation	K Super-phosphate	S.B. 9312A	N118/ 475506
15.	Awatuna	Gley Poorly drained	61m 1450mm	Volcanic ash (Oakura and Okato Tephtras) on laharic breccia (Pungarehu Formation).	30% K Super-phosphate and calcined magnesite	S.B. 9316A	N118/ 396614
16.	Punehu	Gley Poorly drained	107m 1450mm	Laharic breccia of central phase of Opuia Formation	K Super-phosphate	S.B. 9311A	N118/ 475506
17.	Patua	Yellow-brown loam Very strongly leached. Moderately well to imperfectly drained	430m 4050mm	p2/p1 (Druce,1966), Oakura and Okato Tephtras.	-	S.B. 9556A	N108/ 581746
18.	Egmont	Yellow-brown loam Moderately leached Well drained	60m 1010mm	Volcanic ash of Oakura and Okato Tephtras on laharic and fluvial sandstone and conglomerate (Opunake Formation).	-	S.B. 9557A	N129/ 931238

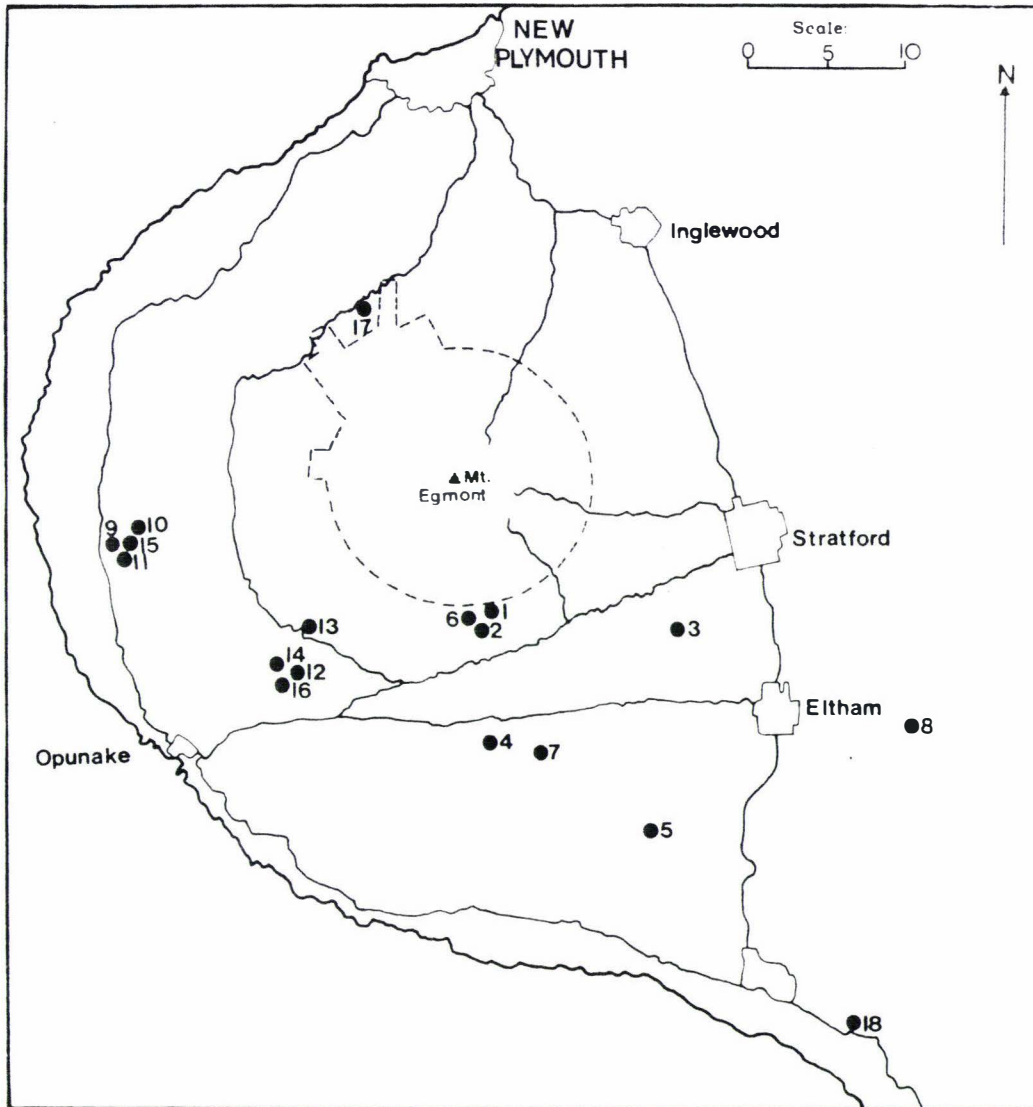


Figure 6.1 Location of soil site information referred to in soil analyses section

- | | |
|-------------------------------------|--|
| 1. Rowan - Rc | 10. Warea - Wr |
| 2. Makaka - Mk | 11. Tipoka - Tk |
| 3. Lowgarth - Lo | 12. Opuā - Ou |
| 4. Riverlea - Rv | 13. Te Kiri series,
hill soil - TzH |
| 5. Stratford - St | 14. Oaonui - Oi |
| 6. Mangawhero - Mw | 15. Awatuna - At |
| 7. Hangatahua - Hn | 16. Pūnehu - Pe |
| 8. Eltham - El | 17. Patua - Pua |
| 9. Warea series,
hill soil - WrH | 18. Egmont - Eg |

In Egmont County two toposequences were described by Palmer et al., (1981). The moderately leached Awatuna-Warea hill association comprises the poorly drained Awatuna series, the imperfectly drained Tipoka series, and the well drained Warea and Warea series, hill soil. Soil parent materials are volcanic ash consisting of Oakura and Okato Tephra overlying laharic breccia of the Pungarehu Formation. The second toposequence was selected from an area mapped as Opua-Punehu association. The Opua series is the moderately leached, well drained member, with the Oaonui series and Punehu series imperfectly and poorly drained members, respectively. The soil parent materials are laharic breccia of the central phase of Opua Formation with no volcanic ash present. Data from these toposequences has been included in this study for comparative purposes.

2. RESULTS

Results of chemical and physical analyses of the selected soils are shown in Table 6.2. Ratings for these properties (Blakemore et al., 1981) are summarised in Table 6.3.

The results are strongly dependent upon the high allophane content of the clay fraction in these soils. However, the past history of topdressing must also be taken into account. The chemical properties of high pH_{NaF} values, high phosphate retention values, pH-dependent cation exchange capacity, high levels of acid-oxalate extractable iron, aluminium and silicon and the physical properties, such as low bulk density and the irreversible effects on the water-holding capacity of air-drying soils, are all closely related to the allophane content of each soil.

Allophane is a mineral amorphous to X-rays but recent studies have shown it to have a degree of short-range structural order. It has a range of compositions, with Al/Si ratios from more than 2 to less than 1. Infrared evidence indicates that allophane (Al/Si = 2) has the same local structure as imogolite, though it appears under the electron microscope as spherical particles, 3.5 - 5 nm in diameter (Parfitt and Henmi, 1980). Imogolite is a mineral made up of fine tubes, 2.1 nm in diameter, with a gibbsitic outer wall and an orthosilicate inner wall (Childs et al., 1983).

Volcanic soils contain allophane, organic matter and certain non-crystalline hydrous oxides of iron and aluminium, which display "variable

Table 6.2 Results of chemical and physical analyses of selected Taranaki soils

Soil name	Lab. No.	Depth (cm)	pH	KCl	H ₂ O	NaF	Organic matter (%)			Truog	0.5M H ₂ SO ₄ (mg%)	Phosphorus			P Retention (%)	ECEC	CEC pH7+8.2 (me%)		Cation exchange		Ca	Mg	K	Na	Exchangeable Al (me.%)	Reserve X _C	Mg _r	Phosphate extractable S (ppm)	Acid oxalate extractable		Si	Na pyro-phosphate extr. (%)		Citrate-dithionite extractable (%)		Sample depth (cm)	Bulk density (Mg/m ³)	Total porosity (%)	Large pores (%)	Moisture retention (moiet) (dried) (%)		Decr. in WHC ⁺ (%)		
YELLOW-BROWN LOAMS from > 250 mm young lapilli showers on thin (with minor thick) volcanic ash, overlying laharic debris.																																												
- strongly leached																																												
1. Rowan series	9707	A 0-30	4.7	5.8	11.4	8.6	0.54	16	0.5	29	49	81	130	94	5.4	20.9	53	4.7	22	3.7	0.25	0.54	0.22	0.66	0.18	6.6	36	1.8	0.88	0.41	0.62	0.71	1.10	1.55	11-14	0.83	66.3	11.7						
		B 30-51	5.1	5.9	11.4	4.0	0.25	16		27	52	52	104	98	1.0	13.9	43	0.8	6	0.6	0.04	0.08	0.06	0.16	0.15	17.0	62	3.3	1.2	1.3	0.34	0.49	1.22	1.75	15-18	0.79	68.2	18.4	31.7	16.3	48.6			
		C 51-75	5.4	5.5	11.4	2.7	0.16	17		24	42	43	85	95	1.0	7.5	28	0.9	12	0.7	0.04	0.04	0.10	0.16	0.15	17.0	62	3.3	1.2	1.3	0.34	0.49	1.22	1.75	37-40	0.83	68.7	13.9						
		D 75-100	5.6	5.7	10.8	0.4	0.02	20		87	105	15	120	49	0.3	2.3	9	0.3	13	0.2	0.01	0.01	0.07	0.07		8.3	85	2.6	0.69	1.1	0.22	0.30	0.96	1.18	41-44	1.10	59.0	18.9	29.1	12.6	56.7			
																										8.3	85	2.6	0.69	1.1	0.22	0.30	0.96	1.18	59-62	0.87	67.7	12.7						
																											8.3	85	2.6	0.69	1.1	0.22	0.30	0.96	1.18	63-66	0.89	65.7	10.0	30.1	9.5	68.4		
																											8.3	85	2.6	0.69	1.1	0.22	0.30	0.96	1.18	83-86	1.34	50.6	30.7					
																											8.3	85	2.6	0.69	1.1	0.22	0.30	0.96	1.18	87-90	1.36	50.1	31.2	6.2	3.4	45.2		
- weakly gleyed																																												
2. Makaka series	9703	A 0-15	4.7	5.5	11.2	8.5	0.66	13	2	71	84	114	198	93	4.4	20.1	50	3.6	18	2.9	0.26	0.27	0.20	0.80	0.19	8.4	58	1.9	1.0	0.53	0.75	0.66	1.33	1.31	n.d.	n.d.	n.d.	n.d.	29.8	18.1	39.3			
		B 15-28	4.9	5.9	11.4	5.5	0.36	15		27	53	56	109	98	3.7	20.9	52	3.5	17	3.1	0.13	0.16	0.11	0.20	0.18	11.0	53	3.4	1.1	1.2	0.58	0.64	1.28	1.88	n.d.	n.d.	n.d.	n.d.	41.2	16.7	59.5			
		C 28-58	5.3	6.1	11.2	3.1	0.20	16		38	59	43	102	97	2.6	15.1	37	2.5	17	2.3	0.08	0.07	0.08	0.05		16.0	68	3.2	1.4	1.3	0.26	0.30	1.42	1.33	n.d.	n.d.	n.d.	n.d.	36.0	12.4	65.6			
		D 58-84	5.4	6.0	11.2	2.6	0.17	15		23	39	51	90	95	2.9	10.1	32	2.9	29	2.6	0.19	0.01	0.10	0.00		4.1	54	2.8	1.3	1.2	0.41	0.32	1.64	1.18	n.d.	n.d.	n.d.	n.d.	34.7	10.6	69.5			
		E 84-108	5.3	6.1	11.1	1.9	0.11	17		43	61	37	98	91	2.0	7.9	27	2.0	25	1.7	0.15	0.01	0.09	0.00		3.1	41	2.6	0.91	1.2	0.18	0.25	1.12	0.84	n.d.	n.d.	n.d.	n.d.	27.8	8.4	69.8			
from > 250 mm young lapilli showers on thick volcanic ash.																																												
- moderately to strongly leached																																												
3. Low-garth series	9706	A 0-23	4.6	5.6	10.7	6.7	0.52	13	4	116	130	111	241	81	6.4	18.8	43	5.7	30	4.6	0.45	0.45	0.21	0.65	0.16	8.8	44	1.8	0.87	0.58	0.44	0.45	1.03	0.88	7-10	1.01	60.9	14.9						
		B 23-52	5.3	5.8	10.9	2.2	0.16	14		63	88	35	123	87	3.5	9.2	28	3.4	37	2.9	0.23	0.17	0.07	0.08	0.14	21.0	26	2.4	1.1	1.1	0.20	0.26	1.07	0.76	11-14	1.00	61.9	16.6	20.8	14.7	29.3			
		C 52-92	5.7	5.8	10.9	2.2	0.16	14		75	89	39	128	95	6.9	10.6	33	6.8	64	5.6	0.45	0.52	0.23	0.08		5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	24-27	1.00	63.7	23.4						
		D 92-120	5.7	6.4	10.8	1.2	0.08	15		99	114	28	142	93	3.6	8.9	29	3.6	40	3.0	0.33	0.16	0.12	0.05		5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	28-31	1.07	61.7	21.0	19.9	9.4	52.8			
																											5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	66-69	0.85	67.4	13.4					
																											5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	70-73	0.83	68.1	11.8	33.2	11.9	64.2		
																											5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	101-104	0.88	67.0	21.7					
																											5.7	93	3.5	0.89	2.0	0.06	0.19	1.22	0.84	105-108	0.94	64.6	13.6	27.5	11.4	58.5		

Units used
 (i) % - grams per 100 grams oven-dry soil
 (ii) mg% - milligrams per 100 grams oven-dry soil
 (iii) me% - milliequivalents per 100 grams oven-dry soil
 me% = $\frac{\text{mmol}}{\text{ion charge no}}$
 (iv) ppm - parts per million
 (v) Mg/m³ - megagrammes per cubic metre.

Analysts: M.D. Taylor, M. Cullinane, K.H. Giddens, A. Hall, V. Vortmen, L.C. Blakemore

+ Water holding capacity

Soil name	Lab No.	Depth (cm)	pH			Organic Matter (%)			Truog	0.5M H ₂ SO ₄ (mq%)	Phosphorus			P Retn (%)	ECEC	CEC			Cation Exchange				Exchangeable Al (me%)	Reserve		Phosphate extractable (S) (ppm)	Acid oxalate extractable (%)			Na pyrophosphate extr. (%)		Citrate-dithionite extr. (%)		Sample depth (cm)	Bulk density Mg m ³	Total porosity (%)	Large pores (%)	Moisture retention 15 bar (moist) (%)	Water retention (dried) (%)	Decr. in WHC ⁺	
			KCl	H ₂ O	NaP	C	N	C/N			Inor-ganic	Org-anic	Total			pH7	B.2	TEB	BS	Ca	Mg	K		Na	Kc		Mgr	Al	Fe	Si	Fe	Al	Fe								Al
YELLOW BROWN LOAMS from pumiceous lapilli-bearing ash showers																																									
p2/p1 (Druce, 1966) Oakura and Okato Tephrae																																									
- very strongly leached																																									
Patua series																																									
9556	A	0-14	4.4	5.3	11.3	18	0.67	27	-	16	24	95	119	91	8.6	42.7	88.4	6.5	15	4.6	1.34	0.34	0.22	2.1	0.16	1.5	22	2.3	1.26	0.21	1.12	1.89	1.59	2.2	-	n.d.	n.d.	n.d.	57.8	25.4	56
	B14-	29	4.6	5.5	11.6	11.5	0.43	27		10	23	77	100	97	3.1	29.6	75.6	1.9	6	1.1	0.40	0.18	0.18	1.2	0.18	1.5	20	3.2	1.60	0.43	1.13	2.1	1.75	2.8	-	-	-	54.5	19.8	64	
	C29-	54	5.1	5.6	11.5	7.1	0.26	27		12	18	75	93	99	0.8	22.6	60.9	0.6	3	0.3	0.11	0.08	0.10	0.22	0.12	1.7	137	5.9	1.79	1.91	0.51	1.05	1.68	2.6	-	-	-	63.2	18.8	70	
	D54-	87	5.4	5.5	11.3	4.7	0.17	28		15	21	71	92	99	0.6	19.4	56.2	0.5	3	0.3	0.06	0.05	0.07	0.14	0.11	1.4	474	7.1	1.20	2.8	0.15	0.71	1.56	1.69	66-73	0.53	79.3	6.5	67.3	18.9	72
	E87-	100	5.5	5.4	11.0	4.1	0.15	27		17	26	74	100	99	0.6	16.7	53.2	0.5	3	0.3	0.05	0.04	0.07	0.13	0.05	0.9	710	6.9	0.82	2.9	0.06	0.60	1.42	1.66	88-95	0.52	80.0	3.9	68.8	17.7	74
from thick volcanic ash of Oakura and Okato Tephrae on laharic and fluvialite sandstone and conglomerate (Opunake Formation)																																									
- moderately leached																																									
Egmont series																																									
9557	A	0-21	5.9	6.6	10.7	10.1	0.64	16	-	143	143	156	299	88	39.0	39.4	73.4	38.7	98	32	6.2	0.29	0.25	0.26	0.16	3.6	22	3.2	1.02	1.15	0.14	0.56	1.49	0.93	7-14	0.75	68.2	16.4	29.8	23.4	21
	B	21-38	6.3	6.9	11.0	3.8	0.19	20		114	114	81	195	98	15.0	15.8	44.0	14.8	94	9.6	4.7	0.21	0.25	0.15	0.16	3.7	110	4.7	1.36	2.0	0.07	0.38	1.95	1.23	26-33	0.73	72.0	21.8	35.9	17.6	51
	C	38-55	6.1	6.7	10.8	2.2	0.12	18		91	91	52	143	99	8.5	12.1	38.4	8.3	69	3.6	4.0	0.47	0.22	0.15	0.18	4.9	257	4.9	1.40	2.3	0.04	0.31	2.2	1.09	43-50	0.66	75.1	29.3	39.4	15.9	60
	D	55-89	5.9	6.6	10.9	1.7	0.07	24		61	61	41	102	99	6.8	13.0	37.2	6.7	52	2.6	2.81	1.06	0.23	0.14	0.18	9.0	405	5.0	1.77	2.5	0.03	0.29	2.6	1.09	66-73	0.75	72.1	21.0	42.2	16.5	61
	E	89-115	5.7	6.7	10.7	1.1	0.05	22		33	33	35	68	96	5.9	10.7	29.1	5.8	54	1.7	1.16	2.64	0.26	0.12	0.35	16	193	2.9	1.18	1.47	0.02	0.23	1.94	0.98	98-105	1.00	62.6	12.0	30.8	14.9	52
	F	115-145	5.5	6.5	10.5	1.0	0.04	25		31	31	38	69	91	5.1	9.9	26.4	5.0	51	1.6	1.20	1.97	0.22	0.11	0.33	16	142	2.8	0.81	1.45	0.02	0.17	1.51	0.81				26.2	14.9	43	

+ Water holding capacity

Soil name	Lab. No.	Depth (cm)	Horizon	pH		Organic matter			Truog reagent	Phosphorus			P Retention (%)	Cation exchange				Exchangeable Al	Reserve K _t	Total P	Phosphate extr. S	Acid oxalate extractable			Bulk density	Moisture retention	Decr. in WHC*								
				H ₂ O	NaF	C (%)	N (%)	C/N		0.5M H ₂ SO ₄ (mg%)	Inorg. P (mg%)	Org. P (mg%)		Total P (mg%)	TEB	BS	Ca					Mg	K	Na				Al	K _t	Mg _t	S (ppm)	Al (%)	Fe (%)	Si (%)	(T/m ³)
YELLOW-BROWN LOAMS from volcanic ash (Oakura and Okato tephra) on laharic breccia (Pungarehu Formation)																																			
—moderately leached																																			
Warea series, hill soil	9315A	1-11	A	5.3	10.3	10.5	0.97	11	3	156	177	128	305	95	14.7	33.3	76	14.5	44	12.7	1.20	0.28	0.31	0.24	0.17	11	1700	73	4.6	1.5	1.58	0.75	35.9	27.8	23
		16-26	(B)	6.5	10.8	5.0	0.39	13		44	47	51	98	99	11.2	22.3	52	11.2	50	10.3	0.48	0.10	0.32	0.00	0.21	10	900	140	5.3	1.8	1.94	0.68	41.5	22.8	45
		35-50	II(B)	6.9	10.4	3.4	0.22	15		28	33	32	65	99	8.1	18.9	41	8.1	43	7.4	0.39	0.06	0.23	0.00			800	229	4.6	1.8	1.86	0.84	49.3	20.2	59
Warea series (flat site)	9317A	2-12	A ₁	5.4	10.0	12.2	1.08	11	4	167	165	178	343	95	19.6	40.6	84	19.4	48	17.1	1.79	0.25	0.29	0.21	0.14	5.3	1800	85	4.5	1.2	1.60	0.72	38.2	29.7	22
		19-28	(B) ₁	6.5	10.7	6.2	0.51	12		58	77	64	141	98	9.5	27.1	60	9.5	35	8.3	0.92	0.09	0.22	0.01	0.14	4.0	1000	122	6.4	1.5	2.40	0.65	56.3	26.2	53
		37-47	(B) ₂	6.8	10.3	3.0	0.41	7		38	39	35	74	99	6.5	18.8	39	6.5	35	5.7	0.64	0.05	0.15	0.01			1400	698	5.8	1.4	2.40	0.78	55.3	21.1	62
		55-70	II(B) ₃	7.0		2.3	0.18	13		29	40	26	66	99	7.4	17.7		7.3	41	6.5	0.63	0.06	0.15	0.02			1400	830	5.3	1.7	2.10	0.72	54.8	19.9	64
		79-89	II(B) ₄	6.9		2.0	0.14			19	29	24	53	98	6.2	17.1		6.1	36	5.3	0.60	0.06	0.16	0.03			1000	614	4.2	2.2	1.70	0.76	46.9	17.6	62
—weakly gleyed																																			
Tipoka series	9314A	2-11	A ₁	5.2	10.3	11.5	1.06	11	3	156	182	179	361	94	15.7	38.0	79	15.4	41	13.6	1.28	0.31	0.16	0.34	0.17	4.3	1900	85	4.2	1.8	1.24	0.67	42.5	27.5	35
		17-35	(B) ₁	6.2	10.4	5.4	0.43	13		82	83	77	160	99	6.1	21.4	55	6.1	29	5.3	0.55	0.15	0.11	0.00	0.19	3.1	1600	491	6.7	2.2	2.30	0.61	61.6	21.0	66
		44-51	(B) ₂	6.7	10.0	3.2	0.28	11		77	92	66	158	99	6.1	18.2	46	6.1	34	5.1	0.60	0.21	0.14	0.00			1800	730	6.7	2.4	2.50	0.66	59.9	19.0	68
		57-62	II(B) ₃	6.8		3.2	0.26	12		56	72	64	136	99	7.5	20.1		7.5	37	6.4	0.76	0.18	0.16	0.00			1500	469	6.4	2.1	2.40	0.64	66.1	18.8	71
		71-90	II G	7.1		1.2	0.12	10		30	36	32	68	97	6.4	13.4		6.4	48	5.5	0.55	0.11	0.19	0.00			800	130	3.6	0.5	1.64	0.82	43.9	12.7	71
from laharic breccia (central phase of Opuā Formation)																																			
—moderately leached																																			
Opuā series	9313A	3-12	A ₁	5.6	10.8	13.8	1.03	13	0.6	29	40	102	142	94	19.8	38.4	80	19.6	51	15.0	2.36	1.83	0.40	0.18	0.17	1.5	1600	54	3.0	1.2	0.83	0.71	43.6	25.5	41
		16-23	(B) ₁ A	6.2	11.1	7.6	0.49	16		12	25	48	73	99	11.3	30.7	75	11.2	37	8.4	1.63	1.01	0.20	0.04			1000	33	6.0	1.7	2.20	0.66	54.6	25.8	53
		24-44	(B)	6.7	11.2	5.5	0.37	15		17	27	48	75	99	8.8	23.1	63	8.8	38	6.1	1.64	0.84	0.20	0.01	0.09	2.6	900	54	6.6	1.3	2.60	0.73	50.1	22.1	44
		56-63	C	6.5		1.4	0.06	23		55	78	21	99	99	2.5	7.7		2.5	33	1.3	0.52	0.55	0.17	0.02			400	92	3.1	0.9	1.53				11.1
—moderately to strongly leached																																			
Te Kiri series, hill soil	9319A	2-12	A ₁	5.6		13.5	0.94	14	2	92	114	110	224	97	9.6	31.7		9.2	29	7.4	1.00	0.40	0.44	0.35			1700	118	4.3	1.7	1.20	0.64	47.0	26.8	43
		27-32	(B) ₁	6.3		8.6	0.48	18		15	30	72	102	99	7.5	25.3	58	7.5	30	6.3	0.86	0.16	0.15	0.06	0.13	1.8	1200	186	5.4	2.3	1.76	0.70	62.4	20.6	67
		40-50	(B) ₂	6.4		5.4	0.32	17		21	32	60	92	99	5.0	21.0	56	5.0	24	4.1	0.66	0.10	0.09	0.02			1200	314	6.2	2.0	2.40	0.73	61.8	18.6	70
			C _g	6.5	10.4	3.6	0.21	17		30	39	48	87	99	5.0	17.5		5.0	29	4.0	0.65	0.20	0.14	0.00			1000	238	6.8	1.0	2.80				17.9
GLEYSOILS																																			
Awatuna series																																			
	9316A	2-11	A ₁	5.4	10.6	10.5	0.90	12	4	186	205	144	349	95	16.9	35.6	77	16.8	47	15.1	1.19	0.28	0.27	0.13	0.19	4.7	1800	94	3.8	1.4	1.15	0.76	37.7	25.1	33
		15-20	BA	6.2	10.8	5.4	0.40	14		84	98	74	172	96	9.4	25.0	58	9.4	38	8.4	0.70	0.10	0.17	0.02			1300	63	5.0	1.4	1.70	0.78	48.3	21.8	55
		28-35	B _g	6.2	10.2	3.6	0.27	13		105	111	81	192	96	4.8	17.4	42	4.8	28	3.9	0.55	0.20	0.15	0.01	0.25	3.2	1700	219	5.0	1.0	1.97	0.78	51.5	18.3	64
		43-60	II G	6.5		1.9	0.17	11		162	184	56	240	97	5.1	16.1		5.1	32	3.9	0.81	0.18	0.20	0.00			2900	376	5.1	0.5	2.30	0.82	47.6		61
		70-75	II G	6.7		1.5	0.13	12		205	228	59	287	97	6.8	16.3		6.8	42	4.8	1.21	0.40	0.40	0.00			1800	241	4.7	0.7	2.10	0.89	43.7	18.6	57
Punehu series																																			
	9311A	3-13	A _g	5.3	10.2	10.8	0.89	12	3	100	111	170	281	95	13.7	36.6	77	13.4	37	11.8	0.90	0.42	0.30	0.32	0.18	2.8	1800	100	3.6	2.0	1.02	0.70	44.2	24.2	45
		21-31	B _g	5.9	10.9	5.9	0.45	13		70	92	136	228	98	7.7	29.3	68	7.6	26	6.6	0.72	0.12	0.16	0.05	0.18	2.1	1300	118	4.6	1.6	1.69	0.75	49.5	18.8	62
		45-55	C	6.1	10.7	2.7	0.16	17		104	125	52	177	91	4.2	14.2	33	4.1	29	3.3	0.57	0.05	0.20	0.04			700	84	2.3	1.8	0.85				9.9
INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS																																			
from recent sands and gravels (Hangatahau Gravels)																																			
—non-accumulating																																			
Hangatahau series	9318A	2-10	A ₁	5.0	9.6	8.5	0.70	12	2	68	99	92	191	81	6.4	21.9	45	5.4	2.5	4.0	0.93	0.26	0.25	0.97	0.14	3.1	1200	38	1.4	1.30	0.31	0.68*	25.0	14.6	42
		15-30	(B)	4.8	10.4	1.8	0.13	14		70	110	25	135	81	0.6	6.7	18	0.4	6	0.2	0.64	0.08	0.11	0.21	0.14	4.7	700	187	1.6	0.97	0.55	1.10*	15.7	6.2	61
		36-46	C	9.2	5.0	0.9	0.06	15		72	113	12	125	60	0.3	3.6	11	0.2	6	0.04	0.02	0.07	0.06	0.09			600	148	1.1	0.94	0.42	1.35*	9.0	3.8	58

Units used

- (i) % — grams per 100 grams oven-dry soil
- (ii) mg % — milligrams per 100 grams oven-dry soil
- (iii) me. % — milliequivalents per 100 grams oven-dry soil
- 1 me. % = $\frac{\text{mmol}}{\text{ion charge no.}}$

- (iv) ppm — parts per million
- (v) T.m³ — tonnes per cubic metre

Analysts: M. Cullinane, A. Hall, K.M. Giddens, V. Vortman, L.C. Blakemore

*Measurements corrected to allow for stone content of samples

*water holding capacity

Table 6.3 RATINGS FOR CHEMICAL PROPERTIES [Blakemore *et al.*, 1981]

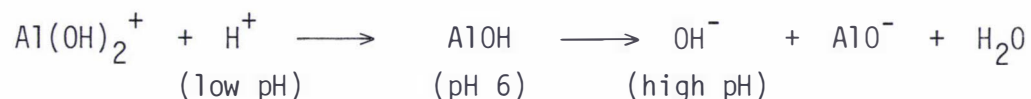
The following ratings of chemical properties are used by Soil Bureau for New Zealand soils¹

Rating	Phosphorus				P retention (%)	Oxalate-extractable			Phosphate extractable S (ppm S)	Organic C (%)	Total N (me.%)	C/N
	Truog	0.5 M	Org. (mg %)	Total (mg %)		Al (%)	Fe (%)	Si (%)				
		H ₂ SO ₄										
	(mg %)	(mg %)										
Very high	>5	>40	>70	>120	90-100	>3.0	>2.0	>0.5	>150	>20	>1.0	>24
High	3-5	20-40	50-70	80-120	60- 90	1.0-3.0	1.0-2.0	>0.5	50-150	10-20	0.6-1.0	16-24
Medium	2-3	10-20	20-50	40- 80	30- 60	0.5-1.0	0.5-1.0	0.15-0.5	15- 50	4-10	0.3-0.6	12-16
Low	1-2	5-10	10-20	20- 40	10- 30	0.2-0.5	0.2-0.5	0.05-0.15	5- 15	2- 4	0.1-0.3	10-12
Very low	<1	<5	<10	<20	0- 10	<0.2	<0.2	<0.05	<5	<2	<0.1	<10

Rating	pH (1:2.5 soil:water)	K _C (me.%)	Mg _r (me.%)	Cation-exchange properties							
				CEC (me.%)	TEB (me.%)	BS (%)	Exchangeable				
							Ca (me.%)	Mg (me.%)	K (me.%)	Na (me.%)	
V. high	>9.0 (extremely alkaline)	>0.5	>30	>40	>25	80-100	>20	>7	>1.2	>2	
	8.4-9.0 (strongly alkaline)										
	7.6-8.3 (moderately alkaline)										
High	7.1-7.5 (slightly alkaline)	0.35-0.5	15-30	25-40	15-25	60- 80	10-20	3-7	0.8-1.2	0.7-2.0	
	6.6-7.0 (near neutral)										
Medium	6.0-6.5 (slightly acid)	0.20-0.35	7-15	12-25	7-15	40- 60	5-10	1-3	0.5-0.8	0.3-0.7	
	5.3-5.9 (moderately acid)										
Low	4.5-5.2 (strongly acid)	0.10-0.20	3- 7	6-12	3- 7	20- 40	2- 5	0.5-1.0	0.3-0.5	0.1-0.3	
V. low	<4.5 (extremely acid)	<0.10	<3	<6	<3	<20	<2	<0.5	<0.3	<0.1	

¹For units used see footnotes to Table 6.2

charge". The surface chemistry of variable charge constituents is now thought to be mainly controlled by single Al-OH and Fe-OH groups. These occur at defective or active sites in the allophane spherules, where bonds such as Al-OH-Al are broken. Variable charge arises from reactions of groups such as Al-OH with H^+ and OH^- as the pH changes;



The variable charge should be >70% of the CEC at pH 8.2 when the exchange complex is dominated by allophane (Table 6.4). Phosphate and sulphate retention properties are directly related to the surface chemistry where the phosphate or sulphate ion replaces the hydroxyl ion in Al and Fe linkages.

The term active aluminium (Parfitt, 1979) has been suggested for the active sites, as it is no longer realistic to regard allophane as amorphous material. Two measures of the active aluminium in soils are acid-oxalate extractable aluminium (Blakemore and Parfitt, 1979) and 4N KOH extractable aluminium.

An appreciation of not only the chemical nature of allophane but also its physical structure can help to explain the distinctive properties it imparts to soils. For example, the existence of micropores in the walls of the allophane spherules results in the high water-holding capacity of allophanic soils, since water held in pores with diameters of less than 28 dimension is retained at a suction of 15-bars. Low bulk density and high porosity are attributable to the fine, crumb-like microstructure that results from the flocculation of the allophane spherules under field conditions.

In summary, as allophane content increases, bulk density decreases and porosity, water retention, acid-oxalate extractable aluminium and phosphate retention increase.

The Eltham peat is an exception to the other soils being characterised by low pH, a high carbon/nitrogen ratio, high cation exchange capacity and low base saturation. However, unlike other peats, the Eltham peat has very high phosphate retention values similar to those of the yellow-brown loams. This is due to the presence of volcanic ash within the peat. There is a marked effect on samples obtained from the tephra horizons where low carbon values, low Mg_r levels and high pH_{NaF} values are apparent. The characteristic physical properties are very low bulk density and high moisture retention.

Table 6.4

Diagnostic properties of
"Amorphous Material Dominant
in the Exchange Complex"

1. The bulk density of the fine earth fraction should be $< 0.85\text{g per cubic centimetre}$ at $\frac{1}{3}$ -bar tension with undried samples.
2. The pH of a suspension of 1g soil in 50ml 1MNaF is > 9.4 after 2 minutes.
3. The phosphate retention value should be $> 90\%$.
4. The Variable Charge should be > 0.7 of the CEC at pH 8.2 (using BaCl_2).

3. pH MEASUREMENTS

pH_{H₂O}:

The pH_{H₂O} values of the yellow-brown loams tend to be high due to the buffering effect of the allophane. The A horizons are moderately to strongly acid but pH values rise with depth so that the subsoil horizons are only slightly acid or near neutral (Figures 6.2 and 6.3).

In the toposequences, Rowan-Mangawhero, Opuia-Punehu and Warea hill-Awatuna, the pH_{H₂O} values are all moderately acid in the topsoil and tend to become slightly acid with increase in gleying in the subsoils.

In the climosequence, the Patua and Rowan soils are only moderately acid, despite the fact that they are strongly leached, as reflected by their low base status. This is due to the "buffering effect" referred to above. The Lowgarth soil is moderately to slightly acid, the Stratford soil is moderately acid to near neutral and the Egmont soil is near neutral.

The effect of the organic parent material, with its high proportion of humic substances is evident in the strongly acid pH_{H₂O} values in the Eltham peat. Thus, despite the high exchangeable calcium values, the pH_{H₂O} is low.

pH_{NaF}:

The Fieldes and Perrott (1966) field test for the presence of active aluminium involves a molar solution of sodium fluoride reacting with a soil to produce a high pH value. It is based on the fact that the aluminium-bonded hydroxyl ion, OH⁻, can be readily replaced by the fluoride ion. The reaction is not specific for allophane and aluminium combined with humus, because non-crystalline hydrous oxides of aluminium can also produce high pH values in a sodium fluoride solution (Wada, 1977 in Parfitt, 1980). However, in volcanic soils, sudden rises in pH_{NaF} are nearly always due to the presence of allophane, imogolite, non-crystalline hydrous aluminium oxides and aluminium combined with humus.

All the pH_{NaF} values measured in this study tend to be greater than 10 indicating the ubiquitous presence of these components.

It is notable how the pH_{NaF} values greater than 9.0 in the Eltham peat coincide with the presence of lithic and pumiceous lapilli horizons.

Figure 6.2 Values for pH_{H_2O} and pH_{NaF} in the soil
toposequence of this study

(For Key to symbols see text. Values plotted at midpoint of depth sampled).

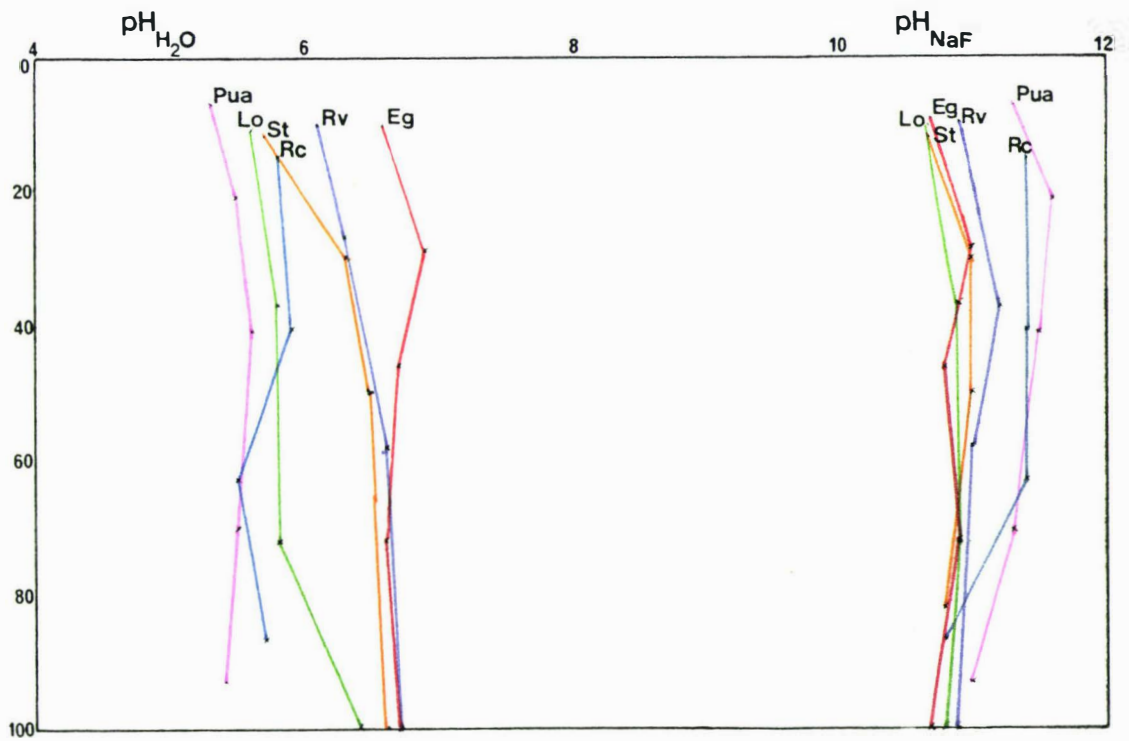
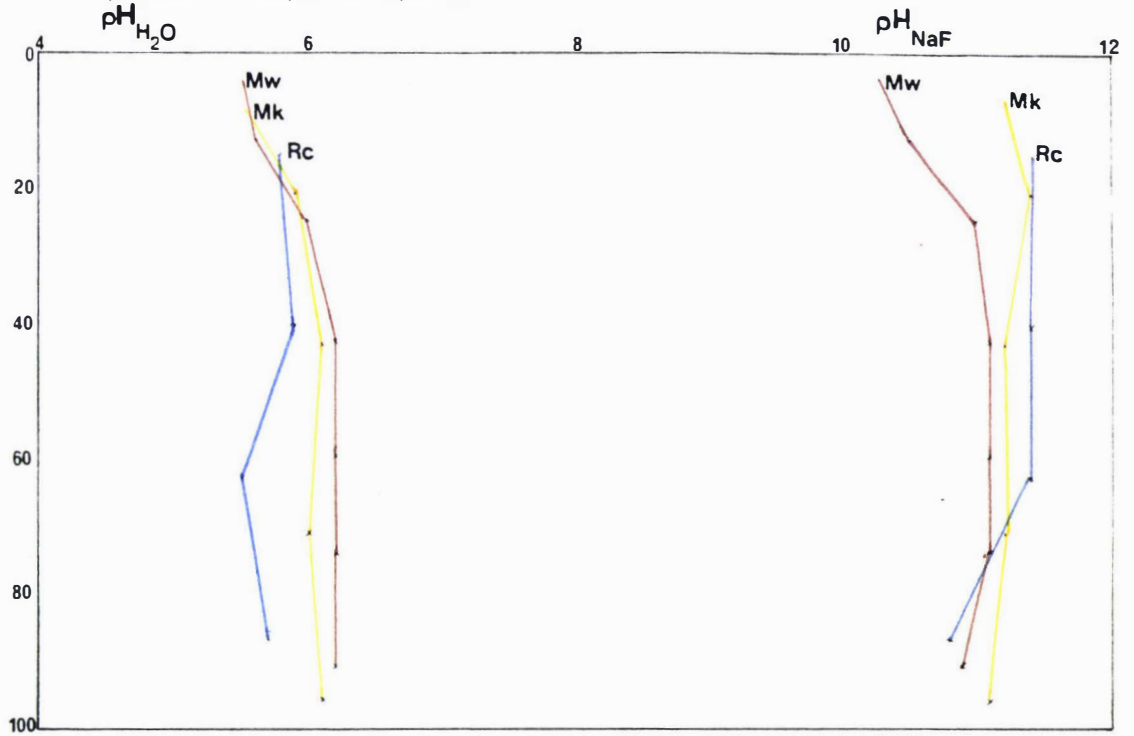


Figure 6.3 Values for pH_{H_2O} and pH_{NaF} in the soil
climosequence of this study

pH_{KCl}:

The pH_{KCl} method gives results which are more reproducible than those obtained with water. Also the values obtained are less dependent on the positioning of the electrodes compared with the pH_{H₂O} method.

The pH_{KCl} results are often more than one pH unit lower than the pH_{H₂O} results (Table 6.2). This can be attributed to the extensive ion exchange taking place, including the release of aluminium, with hydronium and other proton donors being brought into solution, influencing the glass electrode and lowering the measured pH (Black, 1968).

4. ORGANIC MATTER

The organic carbon percentage multiplied by 1.7 provides an approximate measure of the organic matter present (Blakemore and Miller, 1968), (Table 6.5). The ratio of the carbon and nitrogen percentages indicates the state of decomposition of the soil organic matter.

The yellow-brown loams sampled have high levels of organic matter in the A horizons, which decrease steadily with profile depth. However, on a volume weight basis organic matter is not unusually high in many yellow-brown loams (Broadbent *et al.*, 1964). The higher amounts of organic matter in the A horizons is not only due to the microbiological activity and the return of plant litter but also to the presence of allophane, which binds the organic compounds in stable complexes (Fieldes, 1955). Once formed these complexes are very stable against microbial degradation. In the gleyed soils the high values can be attributed to the high water-table level, which inhibits decomposition of the organic matter due to lack of aeration.

In general the carbon/nitrogen ratios in the A horizons of the toposequence and climosequence are of medium value indicating the well decomposed state of the organic matter. The Patua and Rowan soils have high carbon/nitrogen values showing that in these soils the decomposition of the organic matter by microbiological activity is inhibited. This is probably due to the high elevation and resultant cooler temperatures at these sites, together with lack of nutrients.

The very high organic content and high to very high carbon/nitrogen

Table 6.5 Organic matter (% Organic C x 1.7) in seventeen Taranaki soils

Rowan	14.6 (Ap)	6.8 (Bs)	4.6 (Bw1)	0.6 (2C)			
Makaka	14.5 (Ap)	9.4 (BA)	5.3 (Bw)	4.4 (Bg1)	3.2 (Bg2)		
Lowgarth	11.4 (Ap)	3.7 (Bw1)	3.7 (Bw2)	2.0 (Bw3)			
Riverlea	14.5 (Ap)	6.5 (BA)	4.3 (Bw1)	3.2 (Bw2)			
Stratford	12.2 (Ap1)	7.8 (Ap2)	5.3 (Bw1)	3.4 (Bw2)			
Mangawhero	18.9 (Ap)	12.9 (Bg1)	5.8 (Bg2)	4.8 (Bg3)	4.6 (Bg4)	4.6 (Bg5)	3.2 (2C)
Hangatahua	13.8 (Ap)	4.9 (Bw1)	3.1 (Bw2)	1.4 (2C)	1.9 (3C)		
Eltham	54.4 (Ap)	15.5 (Bu)	54.4 (Oh1)	30.6 (Bh1)	68.0 (Oh2)	49.3 (Bh2)	68.0 (Oh3)
Warea hill	10.5 (Ap)	8.5 (Bw1)	5.8 (Bw2)				
Warea	20.7 (Ap)	10.5 (Bw1)	5.1 (Bw2)	3.9 (Bw3)	3.4 (Bw4)		
Tipoka	19.6 (Ap)	9.2 (Bw1)	3.8 (Bw2)	3.8 (Bw3)	2.0 (2Cg)		
Opuia	23.4 (Ap)	12.9 (BA)	9.4 (Bw)	2.4 (C)			
Oaonui	23.0 (Ap)	14.6 (Bw)	9.2 (Bg)	6.1 (Cg)			
Awatuna	17.9 (Ap)	9.2 (BA)	6.1 (Bg)	3.2 (2Cg1)	2.6 (2Cg2)		
Punehu	18.4 (Ag)	10.0 (Bg)	4.6 (C)				
Patua	30.6 (Ah)	19.6 (AB)	12.1 (Bwg)	8.0 (Bws)	7.0 (Bwg2)		
Egmont	17.2 (Ap)	6.5 (Bw1)	3.7 (Bw1)	2.9 (Bw2)	1.9 (2Bw3)	1.7 (2C)	

ratios in the Eltham peat are self-evident, with the tephra horizons producing lower carbon values, with less than 50% organic matter content. The high to very high carbon/nitrogen ratios suggest that humification is not very effective. This could be due to the woody nature of the parent material, which is relatively resistant to decomposition.

5. PHOSPHORUS

The amounts, forms and distribution of phosphorus in soils can assist considerably in understanding pedogenesis. It has in fact been stated by Walker (1964) that because of its great ecological significance phosphorus is perhaps the key element in pedogenesis.

Forms of Phosphorus

Determinations of total phosphorus are used in conjunction with phosphorus fractions to elucidate the degree of weathering and leaching of a soil. Walker (1964) separates total phosphorus (P_T) into three fractions:

$$P_T = P_a + P_f + P_o$$

Where

P_a is inorganic P extracted by 0.5M H_2SO_4 .

P_f is inorganic P not extracted by 0.5M H_2SO_4 .

P_o is organic P.

The inorganic P fractions can also be subdivided (after Williams et al., 1967) into:

- 1) acid-extractable P_{Ca} (includes apatite and lattice-P, where present. These may not be fully extracted by HCl and are determined as residual inorganic P).
- 2) non-occluded P = $NH_4Cl - P + NH_4F - P + 1^{st} NaOH - P$
- 3) occluded P = reductant soluble-P + $2^{nd} NaOH - P +$ "residual" inorganic P.

The distinction between non-occluded and occluded P is by no means absolute.

Total Phosphorus:

In all the soils the highest values of P_T are in the A horizons. This is due to the P topdressing and also reflects the phosphorus accumulation associated with organic matter return because P_0 values are highest in the A horizons compared with all the subsoil horizons.

Wells and Saunders (1960) found in a wide range of topsoils from andesitic parent materials, a general decrease of total phosphorus values with increasing soil maturity. This was not encountered in the soils examined.

In the three toposequences, with increase in gleying in the soils, there is a distinct increase in the P_T reflecting a decrease in weathering.

In Taranaki, leaching intensity increases with increasing rainfall at higher elevations. In the climosequence studied there is a tendency for P_T levels to decrease with increased leaching.

0.5M Sulphuric acid extractable Phosphorus:

This measure assesses the amount of inorganic phosphorus, which is present in a soil but not fixed and is thus an indication of the calcium-bound phosphorus and the non-occluded inorganic phosphorus. The values so obtained are useful in pedological studies because they provide an insight into the degree of weathering and leaching processes.

Wells and Saunders (1960) found that in sequences of soils from different compositional parent materials the proportion of the inorganic phosphorus soluble in 1M H_2SO_4 decreased with increasing weathering and leaching.

The yellow-brown loams and the organic Eltham peat have high to very high levels, which reflect the high amounts of phosphorus within unweathered apatite in these soils.

In the Rowan-Mangawhero toposequence the inorganic phosphorus fraction soluble in 0.5M H_2SO_4 increases from 52% to 99%. In samples from the Warea hill soil - Awatuna toposequence, between 66% and 100% of the inorganic phosphorus fraction is soluble in 0.5M H_2SO_4 , with two-thirds of the values showing a proportion greater than 80%. In the Opua-Punehu toposequence, the proportions of inorganic phosphorus soluble in acid are more evenly distributed over a range from 48% to 91% (Table 6.6).

In the climosequence studied, the decrease of inorganic phosphorus soluble in 0.5M H₂SO₄, as a % of P_T, with increase in leaching is clearly evident, from 100% for the Egmont soil to 43% for the Patua soil (Table 6.6), (Figure 6.4).

Organic Phosphorus:

Organic phosphorus is determined from the increase in 0.5M H₂SO₄-soluble phosphorus caused by ignition of the soil, which converts organic phosphorus to inorganic phosphate.

Organic phosphorus is always highest in the surface horizons. Williams and Saunders (1956) found organic phosphorus to be very low in gleyed horizons and according to Walker and Syers (1976) there appeared to be little doubt that P₀ is less stable under poorly drained conditions. However, the values obtained from the weakly gleyed and gleyed volcanic ash soils analysed in this study are medium to very high and do not support this observation. The reasons for this are not clear.

Phosphorus soluble in Truog's reagent:

The phosphorus extracted by Truog's reagent represents only a small fraction of that extracted by 0.5M H₂SO₄. Truog P determinations were carried out on topsoil samples only. The Truog reagent removes readily extractable phosphorus and may be used with some limitations, as a guide to soil fertility. The test tends to overestimate the phosphorus status of soils not currently topdressed but which may have been regularly and heavily topdressed in the past (During, 1967).

Truog phosphorus values are very low for yellow-brown loams, the values for the Rowan, Makaka, Opuia and Riverlea being typical.

However, high values are obtained for the gley soils (Mangawhero, Awatuna and Punehu soils), and the Hangatahua soil, which is derived from alluvial sands and gravels.

Phosphate Retention:

Phosphate retention is an empirical measure of the ability of a soil to remove phosphate rapidly from solution. The method used has been devised so that the concentration of phosphate used gives a high degree of differentiation between soils of high and low phosphate retention capacity. The pH of 4.6 used is close to the point of maximum phosphate retention in

Table 6.6 Inorganic Phosphorus Fraction Soluble in 0.5M H₂SO₄
as a percentage of Inorganic Phosphorus in seventeen Taranaki Soils

Rowan	59 (Ap)	52 (Bs)	57 (Bw1)	83 (2C)			
Makaka	85 (Ap)	95 (BA)	64 (Bw)	59 (Bg1)	70 (Bg2)		
Lowgarth	89 (Ap)	72 (Bw1)	84 (Bw2)	87 (Bw3)			
Riverlea	87 (Ap)	76 (BA)	85 (Bw1)	82 (Bw2)			
Stratford	95 (Ap1)	91 (Ap2)	100 (Bw1)	92 (Bw2)			
Mangawhero	99 (Ap)	92 (Bg1)	76 (Bg2)	82 (Bg3)	68 (Bg4)	68 (Bg5)	69 (2C)
Hangatahua	93 (Ap)	87 (Bw1)	84 (Bw2)	73 (2C)	79 (3C)		
Eltham	100 (Ap)	61 (Bu)	53 (Oh1)	57 (Bh1)	44 (Oh2)	85 (Bh2)	88 (Oh3)
Warea hill	88 (Ap)	94 (Bw1)	85 (Bw2)				
Warea	100 (Ap)	75 (Bw1)	97 (Bw2)	73 (Bw3)	66 (Bw4)		
Tipoka	86 (Ap)	99 (Bw1)	84 (Bw2)	78 (Bw3)	83 (2Cg1)		
Opuia	73 (Ap)	48 (BA)	63 (Bw)	71 (C)			
Oaonui	81 (Ap)	50 (Bw)	66 (Bg)	77 (Cg)			
Awatuna	91 (Ap)	86 (BA)	95 (Bg)	88 (2Cg1)	90 (2Cg2)		
Punehu	91 (Ag)	76 (Bg)	83 (C)				
Patua	67 (Ah)	43 (AB)	67 (Bwg)	71 (Bws)	65 (Bwg2)		
Egmont	100 (Ap)	100 (Bw1)	100 (Bw1)	100 (Bw2)	100 (2Bw3)	100 (2C)	

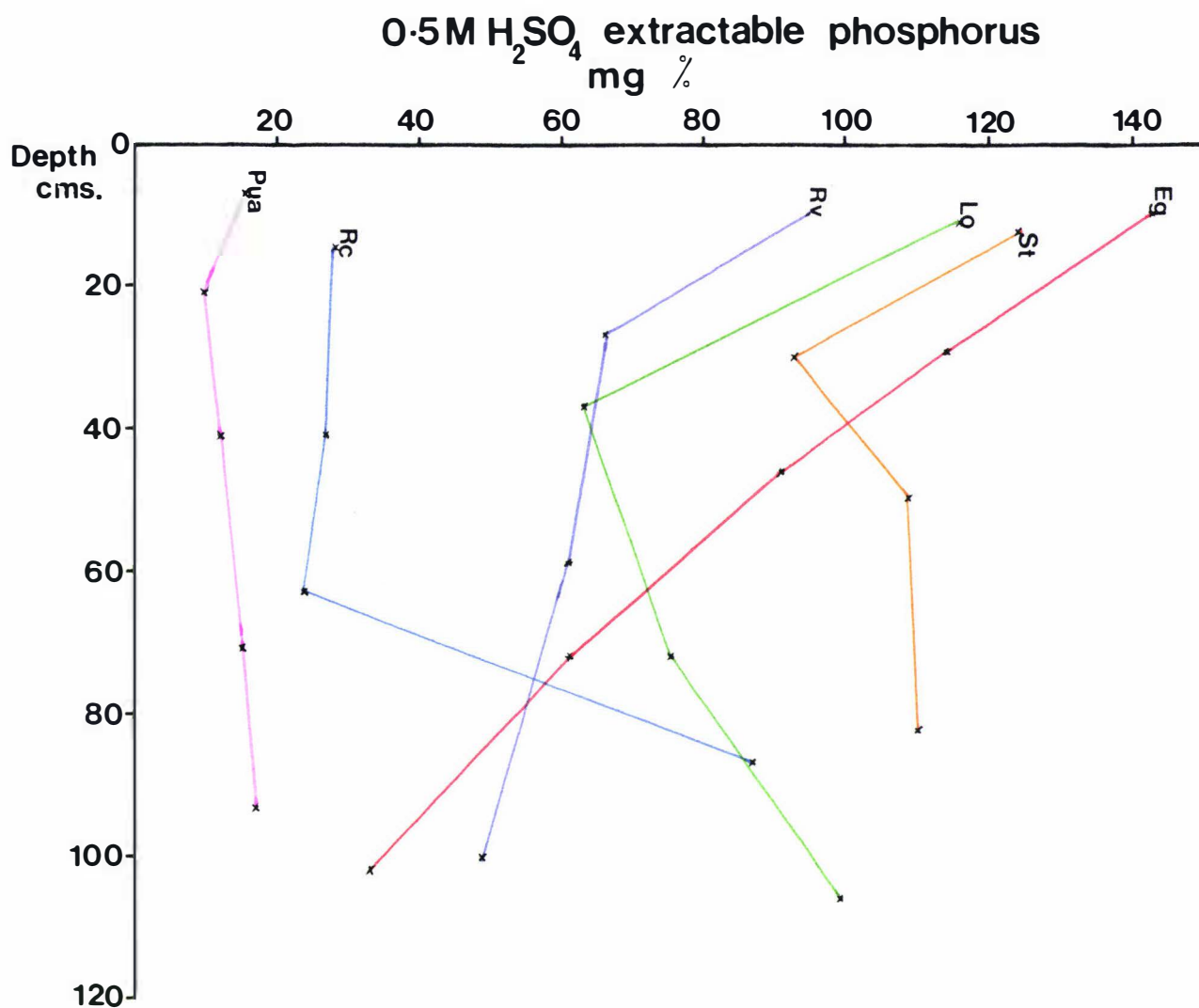


Figure 6.4 0.5M H₂SO₄ extractable phosphorus values in the soil climosequence of this study

many soils. The slower process of phosphorus fixation occurs after retention and results in retained phosphate eventually becoming unavailable to the plants.

The presence of active iron and aluminium in the yellow-brown loams influences the processes of both retention and fixation of phosphate. It is significant that the changes in phosphate retention, within soil profiles, follow the changes in the amounts of acid-oxalate iron and aluminium.

The phosphate retention values are all high to very high and the values tend to increase with depth down the profile, indicating a potentially large inorganic P sink (Figure 6.5). The sharp decrease in the Rowan soil is attributed to the presence of unweathered laharic debris, with little fine weathered materials capable of developing active sites for phosphate retention. The sites where phosphate is adsorbed on allophane are thought to be at defects in the spherules where single Al - OH groups or substituting Fe - OH groups are exposed (Parfitt and Henmi, 1980) and it has been estimated that each allophane spherule can strongly adsorb six phosphate ions.

Phosphate retention can be lowered slightly by additions of phosphorus fertilizers and by organic matter. The lower P adsorption in topsoils may be partly due to the higher organic matter content, although the work of Perrott (1978) has indicated that organic treatment of synthetic amorphous alumino-silicates and allophanic clays does not always decrease P adsorption.

The Eltham peat has very high phosphate retention values due to the presence of volcanic ash and so differs from most other peats, where the phosphate retention values are very low.

6. CATION EXCHANGE PROPERTIES

Cation exchange capacity:

The cation exchange capacity (CEC) is a measure of negative charge and is very dependent on the method of measurement. The concentration, type of cation, pH of the solution and the washing method, each have a marked effect on the measured CEC. The CEC of allophane increases while the anion exchange capacity (AEC) decreases, with increase in pH of the solution (Fieldes and Schofield, 1960; Birrell, 1961 and Iimura, 1966).

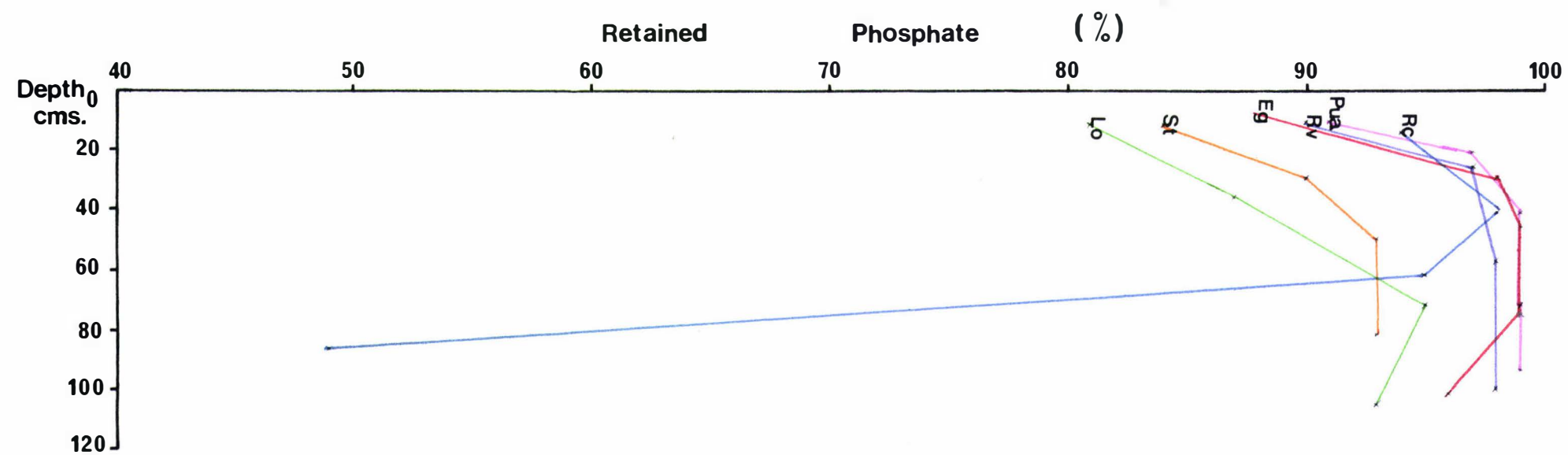


Figure 6.5 Phosphate retention values in the soil climosequence of this study for six selected Taranaki soils

Since the natural pH values of the soils in these analyses are less than pH 7, even the ammonium acetate method at pH 7 gives values far in excess of the CEC at natural pH and electrolyte levels.

Table 6.2 gives the effective cation exchange capacities (ECEC) for the soils as well as the markedly increased values for CEC at pH 7 and pH 8.2. The ECEC is an attempt to measure the CEC of the soil at natural pH. It can be obtained by adding the values of the exchangeable bases and KCl-extractable aluminium together. Exchangeable hydrogen is not included since it is very low in these soils.

The yellow-brown loams tend to have medium ECEC values in the A horizon, which decrease to low and very low values in the subsoil. The very low values in all the horizons of the Te Kiri sample and in the subsoils of the Rowan and Hangatahua soils, reflect the sandy texture and low clay contents of these soils due to laharic debris and alluvial parent materials.

In the Eltham peat, the high negative charge density of the humic acids derived from the organic matter, contributes substantially to the very high cation exchange capacity of this soil. The cation exchange capacity of a peat will vary according to the degree of decomposition, the plant species present and, in this case, the presence of bands of tephra. Lower cation exchange capacity values are obtained in the tephra horizons of the Eltham peat. It is noteworthy that the highest values for cation exchange capacity are associated with high levels of exchangeable calcium.

Base Saturation:

Base saturation is a measure of the percentage of the cation exchange capacity occupied by calcium, magnesium, potassium and sodium ions. It may be calculated as a percentage of the effective cation exchange capacity (here referred to as the effective base saturation) or more commonly as a percentage of the cation exchange capacity as measured at pH 7 (Table 6.2).

Since the exchangeable aluminium values are usually very low and can be zero, the ECEC values determined are almost equal to the sums of the exchangeable bases. The effective base saturation figures are thus very high and in several cases are 100% (Table 6.7).

The base saturation calculated as a percentage of the CEC at pH 7 (Figure 6.6) seems to be a good measure of the degree of leaching in the

Table 6.7 Effective base saturation of eighteen soils from Taranaki

$$\left(\frac{\sum \text{bases}}{\sum \text{bases} + \text{KCl extr. Al}} \right)$$

Rowan	88 (Ap)	83 (Bs)	93 (Bw1)	88 (2C)			
Makaka	82 (Ap)	95 (BA)	98 (Bw)	100 (Bg1)	100 (Bg2)		
Lowgarth	90 (Ap)	98 (Bw1)	99 (Bw2)	100 (Bw3)			
Riverlea	99 (Ap)	50 (BA)	99 (Bw1)	100 (Bw2)			
Stratford	97 (Ap1)	99 (Ap2)	100 (Bw1)	100 (Bw2)			
Mangawhero	49 (Ap)	95 (Bg1)	97 (Bg2)	96 (Bg3)	97 (Bg4)	96 (Bg5)	95 (2C)
Hangatahua	98 (Ap)	97 (Bw1)	96 (Bw2)	92 (2C)	98 (3C)		
Eltham	90 (Ap)	58 (Bu)	68 (Oh1)	80 (Bh1)	98 (Oh2)	98 (Bh2)	99 (Oh3)
Warea hill	98 (Ap)	-	-				
Warea	99 (Ap)	100 (Bw1)	100 (Bw2)	100 (Bw3)	100 (Bw4)		
Tipoka	100 (Ap)	-	-	-	-		
Opuia	99 (Ap)	100 (BA)	100 (Bw)	99 (C)			
Te Kiri hill	96 (Ap)	99 (Bw1)	99 (Bw2)				
Oaonui	99 (Ap)	97 (Bw)	100 (Bg)	-			
Awatuna	99 (Ap)	98 (BA)	97 (Bg)	-	-		
Punehu	98 (Ag)	99 (Bg)	99 (C)				
Patua	76 (Ah)	61 (AB)	73 (Bwg)	77 (Bws)	78 (Bwg2)		
Egmont	99 (Ap)	99 (Bw1)	98 (Bw1)	98 (Bw2)	98 (2Bw3)	98 (2C)	

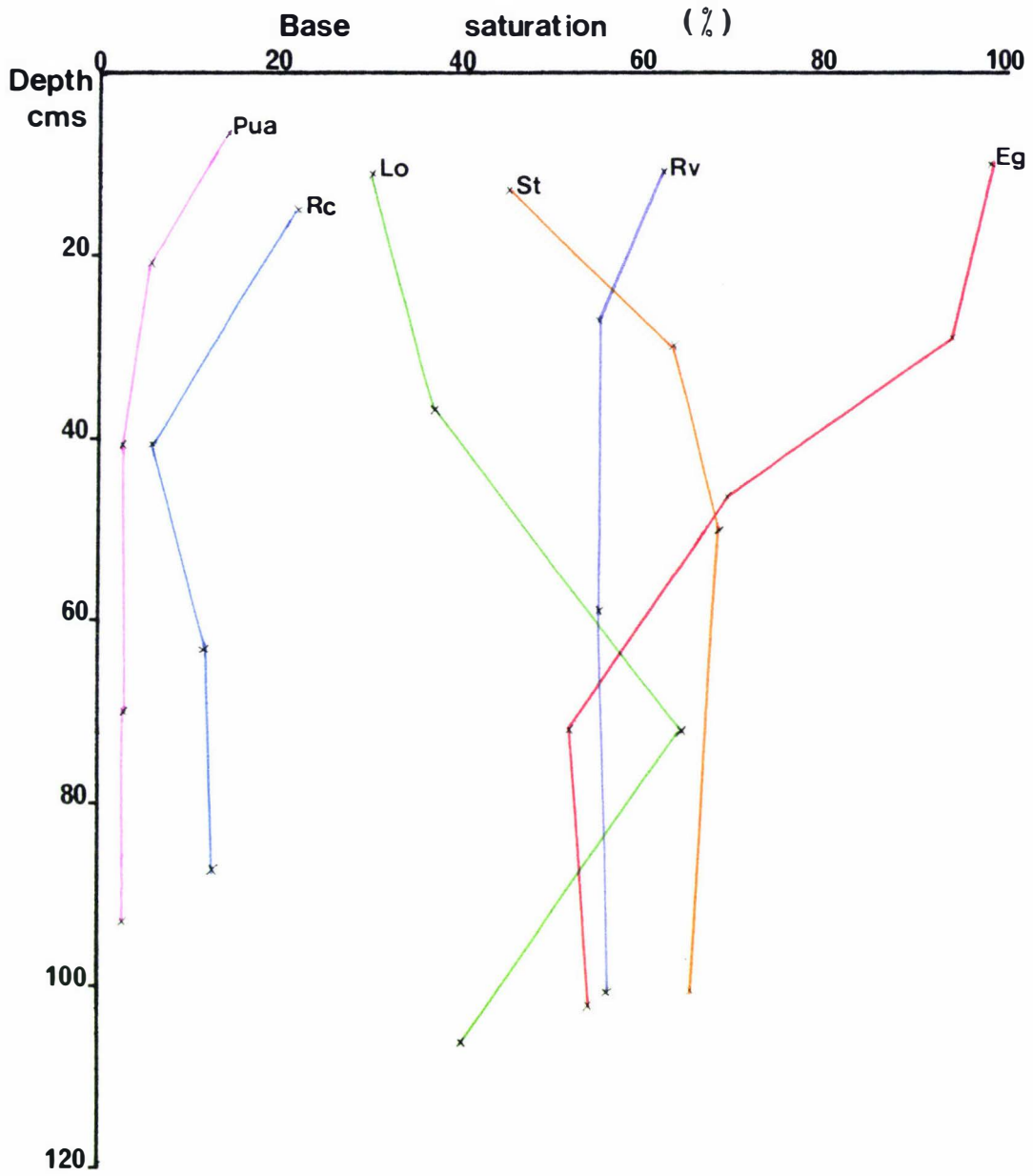


Figure 6.6

Σ Bases
Base saturation CEC pH7NH₄OAc
in the soil climosequence

soil climosequence. In the very strongly leached Patua soil the values are all very low, in the strongly leached Rowan soil the values are low to very low while in the moderately to strongly leached Lowgarth soil the values are low to medium. In the moderately leached Riverlea and Stratford soils high and medium values occur while in the Egmont soil the values range from very high to medium base saturation.

The values for exchangeable calcium show a distinct trend with leaching. Very low and low values are recorded in the very strongly leached and strongly leached soils. Low and medium values are obtained in the moderately to strongly leached Lowgarth soil, medium values in the moderately leached Stratford soil, medium and high values in the moderately leached Riverlea soils and very high to very low values in the moderately leached Egmont soil. In the Riverlea and Egmont soils the comparatively high level of exchangeable bases in the A horizons is due to the high level of exchangeable calcium, probably contributed by regular fertilizer applications.

The exchangeable magnesium levels for all horizons are generally very low and low. The topsoils tend to be higher than the subsoils probably due to magnesium in the organic-cycle. Exchangeable magnesium levels in Taranaki soils varies with soil texture and intensity of leaching (Turner *et al.*, 1978). A trend with leaching is evident in the climo-sequence of soils with the Patua, Rowan and Lowgarth soils having lower exchangeable magnesium contents compared with the other soils examined. It is possible that the original magnesium contents of certain tephras, within which most of these soils are developed, vary, with consequent effects on initial magnesium contents. However, in the case of the Stratford soil, fertilizer practices have probably influenced and obscured any inherited patterns of soil magnesium content, with super-dolomite having been applied over the past three years. Addition of large amounts of potassium fertilizers, which can depress magnesium levels in plants, have been applied on all the soils, except Patua, Stratford and Te Kiri hill soil.

The low exchangeable magnesium levels, combined in some cases with low reserve magnesium supplies and slow rates of release of the reserves suggest that magnesium deficiency could occur, especially in the strongly leached soils.

The Stratford soil has values of exchangeable potassium ranging

from very low to medium and the Opuia soil medium to very high values. In all the other yellow-brown loams the values for exchangeable potassium are very low and low and this is in accordance with the long-known potassium deficiency in these soils.

In the Eltham peat the values of exchangeable calcium and exchangeable magnesium are high and very high, especially in the subsoil, due to the high organic matter effect and enrichment by ground-water. The levels of exchangeable calcium are much greater in the Eltham peat, compared with the yellow-brown loams. The presence of thin, tephra layers causes the levels of exchangeable bases to drop to markedly low and medium values.

Exchangeable Aluminium:

Exchangeable aluminium is measured by leaching the soil with 1M KCl and measuring the amount of aluminium in the extract.

The proportion of the effective cation exchange capacity contributed by exchangeable aluminium tends to be low in most of the soils analysed (Table 6.8).

The largest contribution occurs in the Eltham peat horizons where an unusually high amount, 42.3% of the ECEC is contributed by exchangeable aluminium in the Bu horizon. In the very strongly leached Patua soil 39% of the ECEC is contributed by exchangeable aluminium in the AB horizon. Exchangeable aluminium contributes a significant, 16.7% to the ECEC in the Bs horizon of the strongly leached Rowan soil. In the A horizon of the Makaka soil 18% of the ECEC is contributed by exchangeable aluminium, there being no contributions in the lower horizons of the soil. The high values obtained are due to the low pH conditions in these soils. In the A horizon of the Te Kiri sample exchangeable aluminium contributes a slightly higher percentage (4%) of the ECEC compared with 1% in the Opuia series. This may reflect greater leaching in Te Kiri series, compared with Opuia series. Aluminium in soil solution increases with percent aluminium saturation, and aluminium toxicity can be a cause of infertility, especially in acid soils.

For the remaining soil series the contribution from exchangeable aluminium is negligible and there can be no contribution in the lower horizons of the soil in some cases.

Table 6.8 Exchangeable Aluminium as a percentage of ECEC of seventeen soils from Taranaki

Rowan	12	(Ap)	16.7	(Bs)	7.2	(Bw1)	11.8	(2C)						
Makaka	18	(Ap)	5	(BA)	2	(Bw)	-		-					
Lowgarth	10	(Ap)	2	(Bw1)	0.7	(Bw2)	0.2	(Bw3)						
Riverlea	0.8	(Ap)	0.7	(BA)	0.7	(Bw1)	0.3	(Bw2)						
Stratford	3	(Ap1)	0.5	(Ap2)	0.3	(Bw1)	0.3	(Bw2)						
Mangawhero	4	(Ap)	5	(Bg1)	2.5	(Bg2)	4	(Bg3)	3	(Bg4)	4	(Bg5)	5	(2C)
Hangatahua	2	(Ap)	3	(Bw1)	4	(Bw2)	8	(2C)	2	(3C)				
Eltham	10.3	(Ap)	42.3	(Bu)	32.4	(Oh1)	20.3	(Bh1)	1.4	(Oh2)	2.1	(Bh2)	1.4	(Oh3)
Warea hill	2	(Ap)	-		-									
Warea	1	(Ap)	0.1	(Bw1)	0.2	(Bw2)	0.3	(Bw3)	0.5	(Bw4)				
Tipoka	2	(Ap)	-		-		-		-					
Opuā	1	(Ap)	0.4	(BA)	0.1	(Bw)	1	(C)						
Oaonui	1	(Ap)	1	(Bw)	0.4	(Bg)	-							
Awatuna	1	(Ap)	0.2	(BA)	0.2	(Bg)	-		-					
Punehu	2	(Ag)	1	(B)	1	(C)								
Patua	24	(Ah)	39	(AB)	28	(Bwg)								
Egmont	0.7	(Ap)	1	(Bw1)	1.7	(Bw1)	2	(Bw2)	2	(2Bw3)	2	(2C)		

7. RESERVE POTASSIUM AND MAGNESIUM

The reserve potassium and magnesium were determined in order to assess the soils' capacity for long term supplying power of these nutrients. The methods applied were the acid extraction procedures outlined in Metson et al., (1956) for reserve potassium (K_c) and Metson and Brooks (1975) for reserve magnesium (Mg_r) (Figures 6.7 and 6.8).

The levels of reserve potassium in all the soils are low and apart from the Egmont subsoil are all below the proposed critical level (Metson, 1959) of 0.30%, indicating that potassium deficiency can be expected under conditions of high demand.

The rate of release of Mg_r is very dependent on prevailing environmental conditions so that a strongly weathering environment will release greater quantities of Mg_r compared with a weakly weathering environment. The absolute size of the reserve pool of magnesium is thus not a reliable index of potentially available magnesium. The levels of reserve magnesium in the yellow-brown loams range from very low to high. Reserve magnesium is higher in the samples from the Awatuna-Warea hill soil toposequence than in those from the Opua-Punehu soil toposequence. In the Rowan-Mangawhero toposequence there is a trend towards higher values in the imperfectly drained Makaka and poorly drained Mangawhero soils. In the climosequence the reserve magnesium is very low throughout the Patua soil but varies in the other soils, with at least one horizon having a high or medium value, usually coinciding with the presence of the Manganui tephra (Figure 6.8). The values of reserve magnesium in the Eltham peat range from very low to high. These values are dependent on the presence or absence of lithic or pumiceous lapilli layers, which tend to have lower Mg_r levels than the interbedded organic horizons.

8. SULPHUR

Sulphur is present in the soil in four main forms:

- 1) in the soil solution as sulphate ions (dissolved sulphate).
- 2) attached to the surface of soil colloids as sulphate ions (adsorbed sulphate).
- 3) as organic sulphur compounds in the organic matter of the soil (organic sulphur).

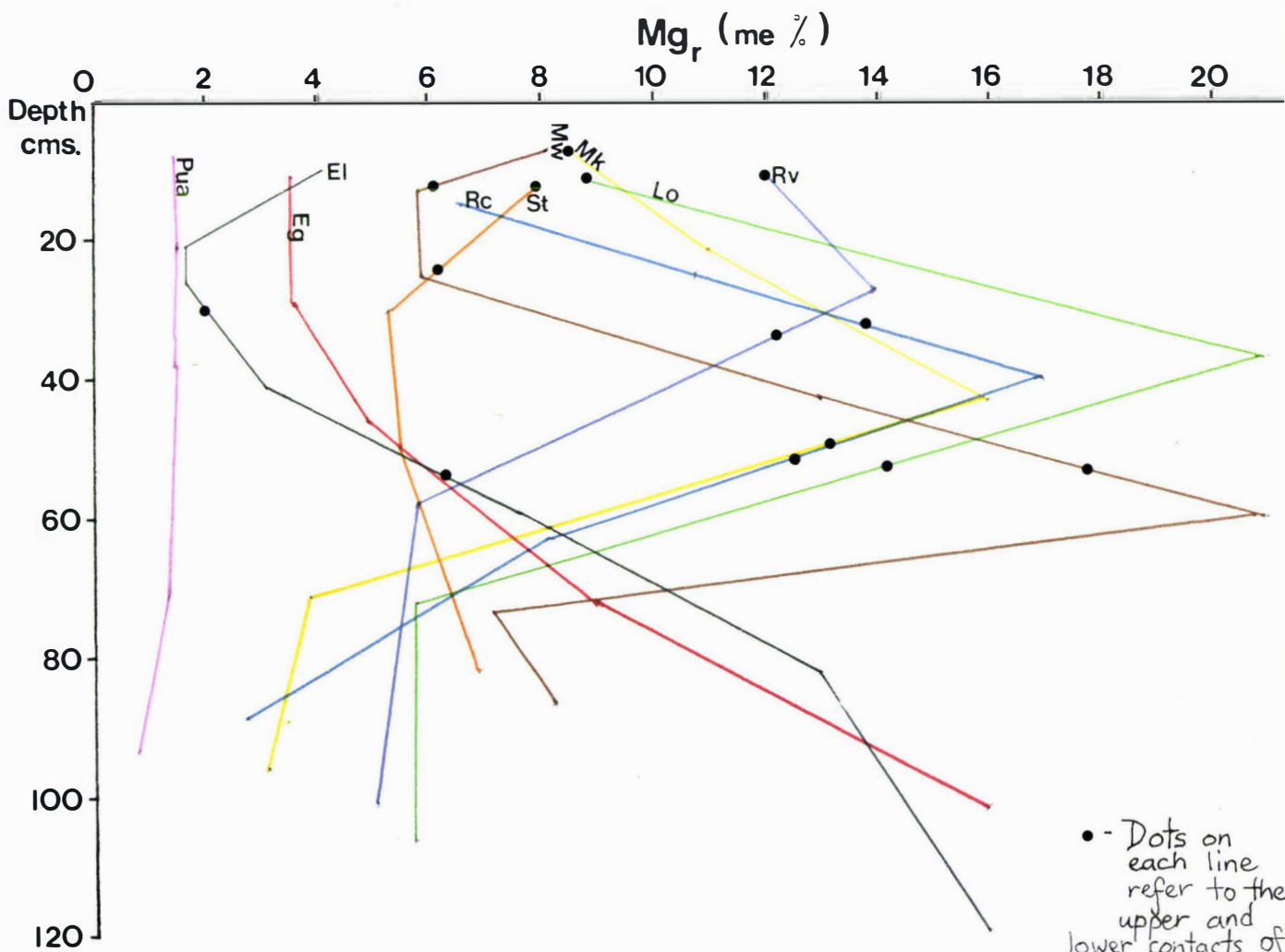
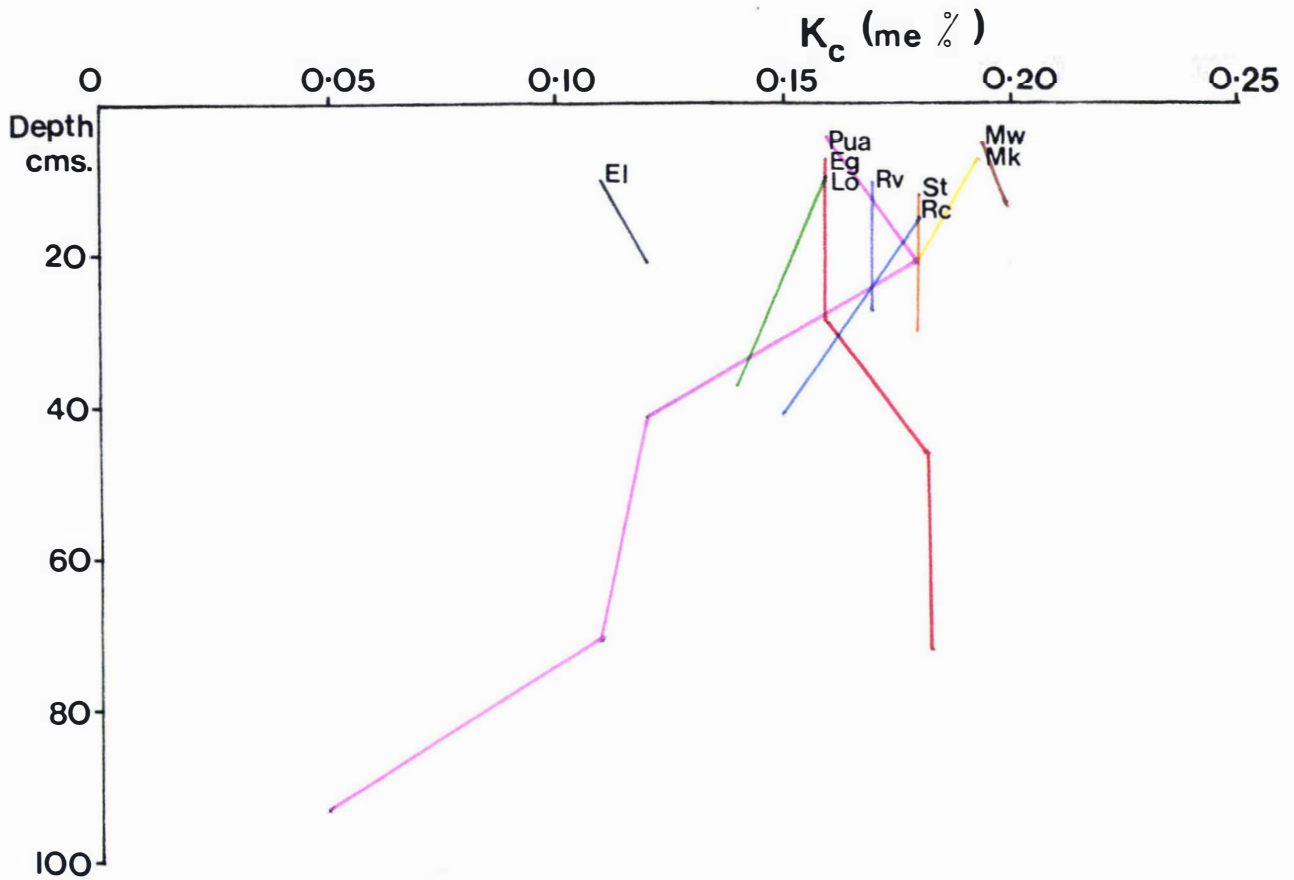


Figure 6.8 Reserve magnesium values for nine Taranaki soils

• - Dots on each line refer to the upper and lower contacts of the Manganai tephra.

4) as sulphur-bearing minerals.

Phosphate-extractable sulphate, previously called adsorbed sulphate-S, is a measure of the sulphur available to plants. It cannot be regarded as a specific fraction of the soil sulphur as the desorption process extracts small amounts of both soluble inorganic-S and organic-S. Levels of phosphate-extractable sulphate in the soils analysed are variable and range from low to very high. In general the levels are medium to high in the topsoils and are probably sufficient to sustain adequate pasture growth.

The subsoil contents of phosphate-extractable sulphate are usually higher than topsoil contents largely due to the allophane and iron oxides present, which are capable of high sulphate adsorption (Metson, 1979). This means that the graphs for phosphate retention and acid-oxalate extractable iron and aluminium can be related to the graph for phosphate-extractable sulphate (Figures 6.5, 6.10 - 6.13). Although there is a significant correlation between phosphate retention and phosphate-extractable sulphate (Table 6.9) it would appear that the relationship is not linear (Figure 6.9) but rather sulphate levels tend to increase markedly at very high levels of phosphate retention.

The lower levels of sulphate in A horizons may be attributed to competition for adsorption sites by more strongly adsorbed anions such as phosphate, humate and hydroxyl (Figures 6.10, 6.11).

The amount of adsorbed sulphate can be limited by high base saturation and tends to increase with decreasing base saturation. This is demonstrated in the toposequence of Rowan, Makaka and Mangawhero soils, where drainage is imperfect or poor, leaching of sulphate may not occur despite low sulphate retention.

In the Eltham peat the levels of phosphate-extractable sulphate are high to very high with depth. This suggests that the ground-water may be high in reduced sulphur and contributes to the very high value obtained. The medium value in the Bh1 horizon is due to the presence of the Manganui tephra.

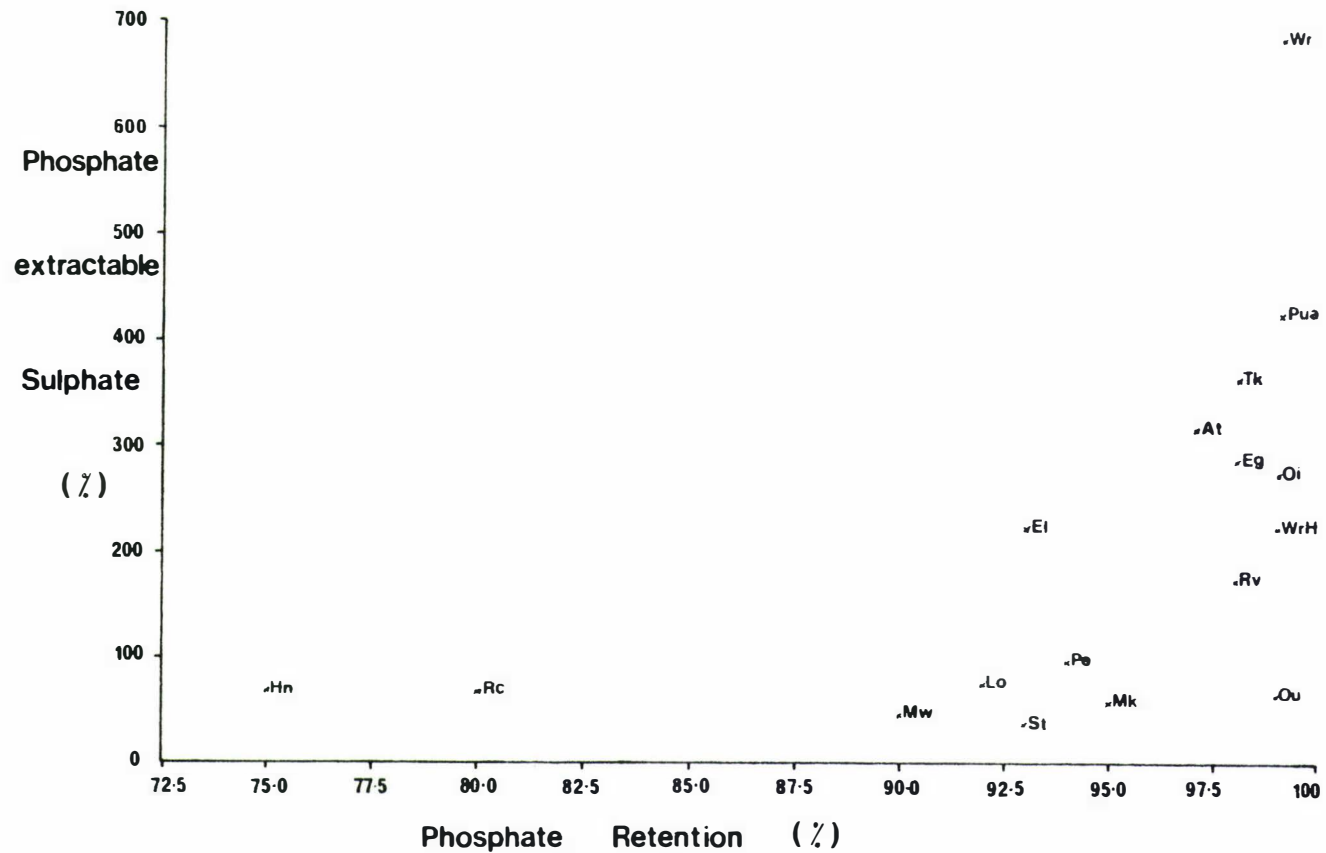


Figure 6.9

Phosphate-extractable sulphate versus phosphate retention for seventeen selected Taranaki soils

(Values are the weighted average from 25cm to 1m depth)

Table 6.9 Correlation matrix between all variables

Phosphate Retention	1	1.0000				
Phosphate extractable Sulphate	2	0.5106 [*]	1.0000			
Acid-oxalate extractable Al	3	0.3290	0.4244	1.0000		
Acid-oxalate extractable Fe	4	0.5904 [*]	0.3541	0.2137	1.0000	
Elevation	5	-0.4041	-0.3608	0.2411	-0.1987	1.0000
		1	2	3	4	5

*0.05

(15 degrees of freedom)

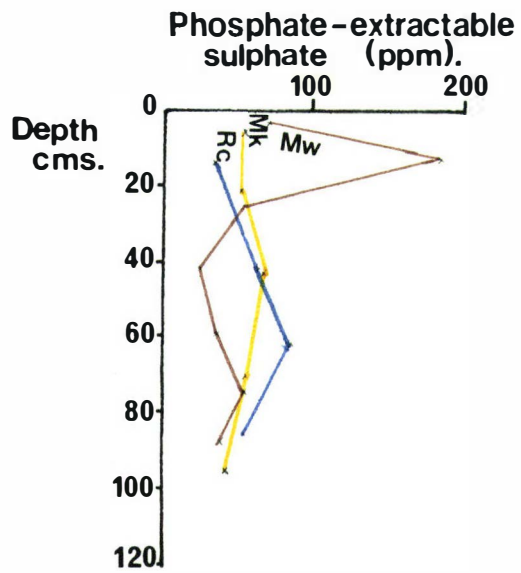


Figure 6.10

Phosphate-extractable sulphate values in a soil toposes of this study

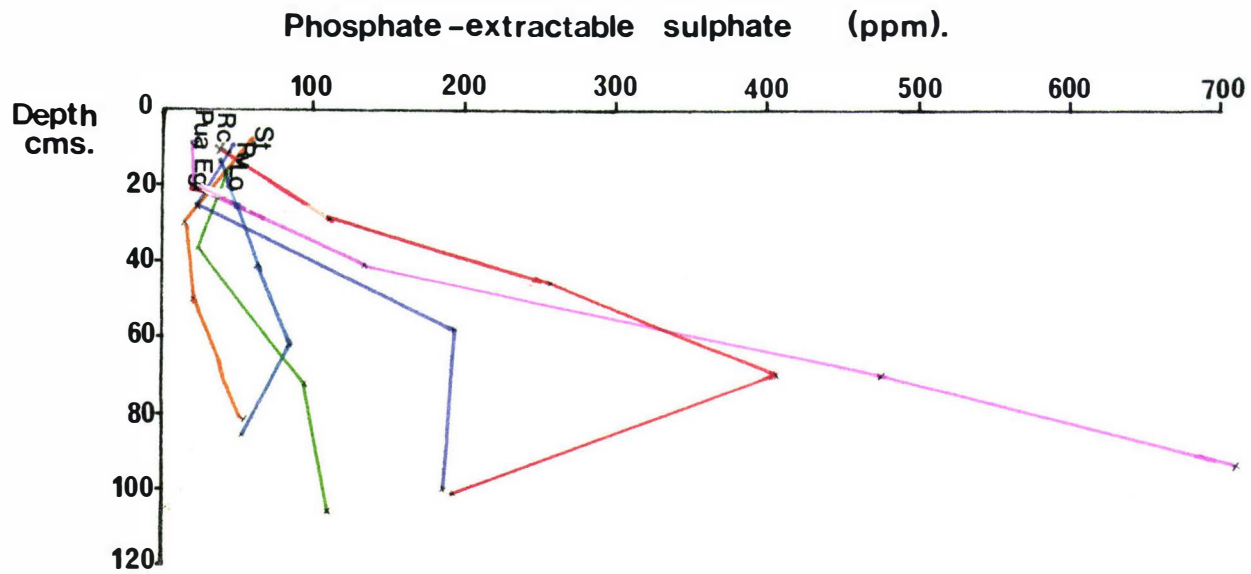


Figure 6.11

Phosphate-extractable sulphate values in the soil climosequence of this study

9. ACID-OXALATE EXTRACTABLE IRON, ALUMINIUM AND SILICON

Acid-oxalate reagent can be used as an extractant to indicate the amount of iron, aluminium and silicon present in the form of allophanic clay and non-crystalline hydrous oxides of iron and aluminium. Acid-oxalate is also known to extract fulvic acid-bound aluminium (McKeague *et al.*, 1971).

The method depends mainly on the complexing affinity of acid-oxalate to extract colloid complexes. The forms which it dissolves contribute strongly to the variable charge of soils and play a major part in cation and anion retention and other surface phenomena.

In general, high levels of aluminium, iron and silicon were obtained from the soils analysed. The results are in accordance with trends noted in the analysis of central yellow-brown loams by Saunders (1968).

In the majority of soils, higher amounts of extractable aluminium were obtained compared with iron. This could be due to iron being removed in ground-water or being converted to more crystalline forms or, most likely, to the high content of allophane.

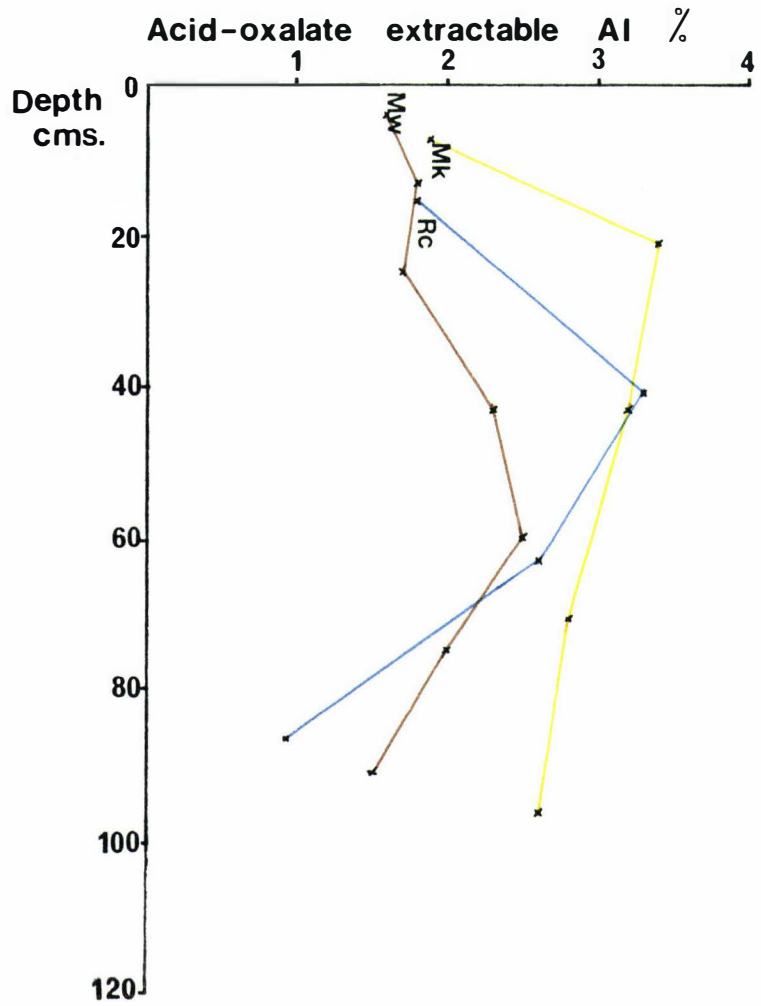
In most of the soils there is a peak in the values of extractable iron, aluminium and silicon in the upper B horizons. This increase could be due to weathering *in situ* and some incipient downward movement from the A horizon (Figures 6.12 and 6.13).

In the poorly drained Mangawhero, Awatuna and Pūnehu samples extractable iron is an exception, tending to decrease from A to B horizons because of reduction to less extractable forms.

The question arises as to whether podzolisation is occurring in the soils. Podzolisation, according to traditional theory, is the process whereby iron and aluminium are translocated down a soil profile, in an organically complexed form. Recent work by Farmer *et al.*, (1980) has indicated that Al-Si complexes are also involved in the podzolisation process. McKeague and Day (1969) proposed the use of the acid-oxalate extractable aluminium value of B horizons alone as evidence for the podzolisation process. However, the most specific reagent for the forms of aluminium and iron involved in podzolisation appears to be pyrophosphate extractable iron and aluminium ($Fe_p + Al_p$).

Figure 6.12

Acid-oxalate extractable aluminium
values in a soil toposequence
of this study



Acid-oxalate extractable aluminium
values in the soil climosequence
of this study

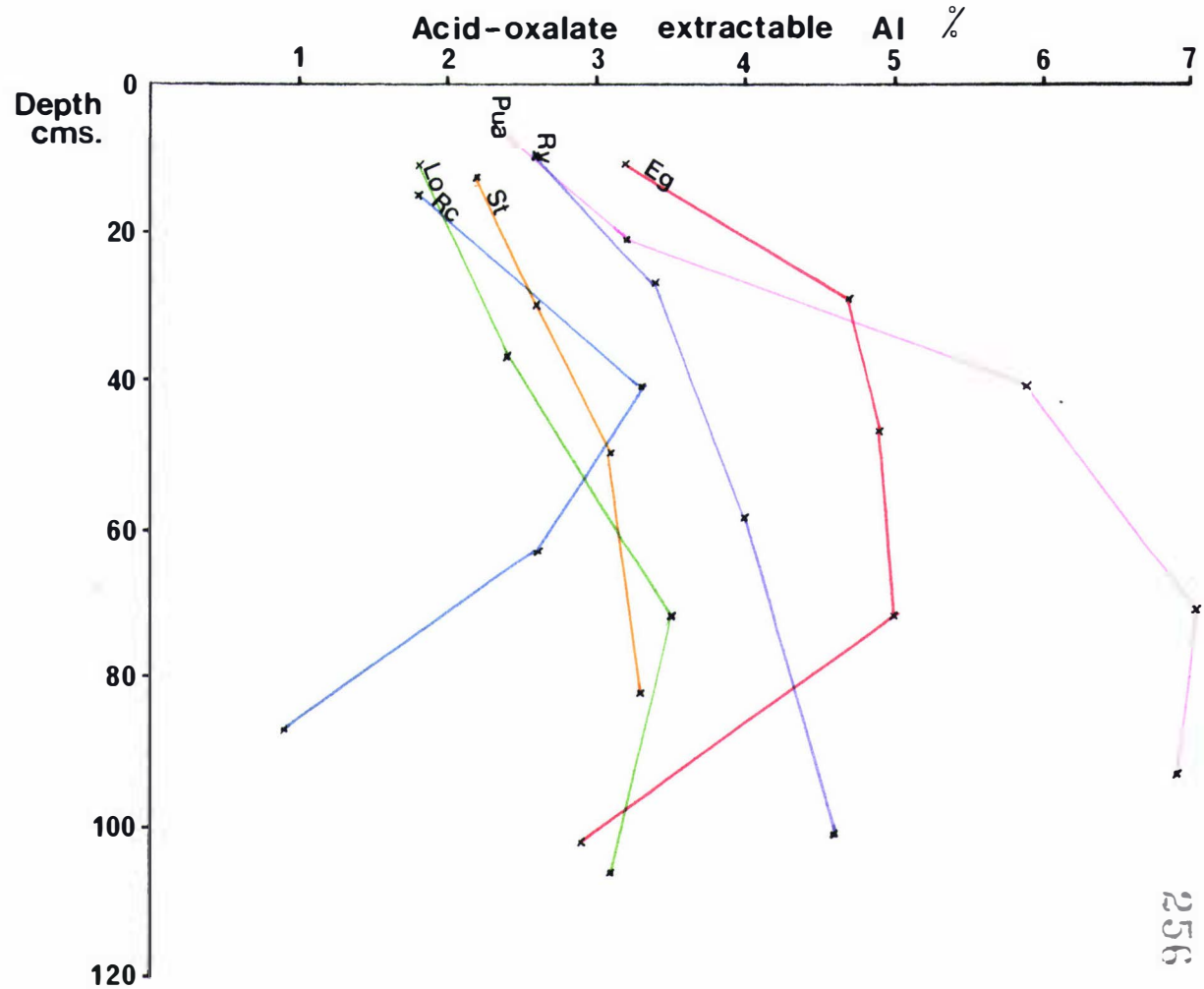
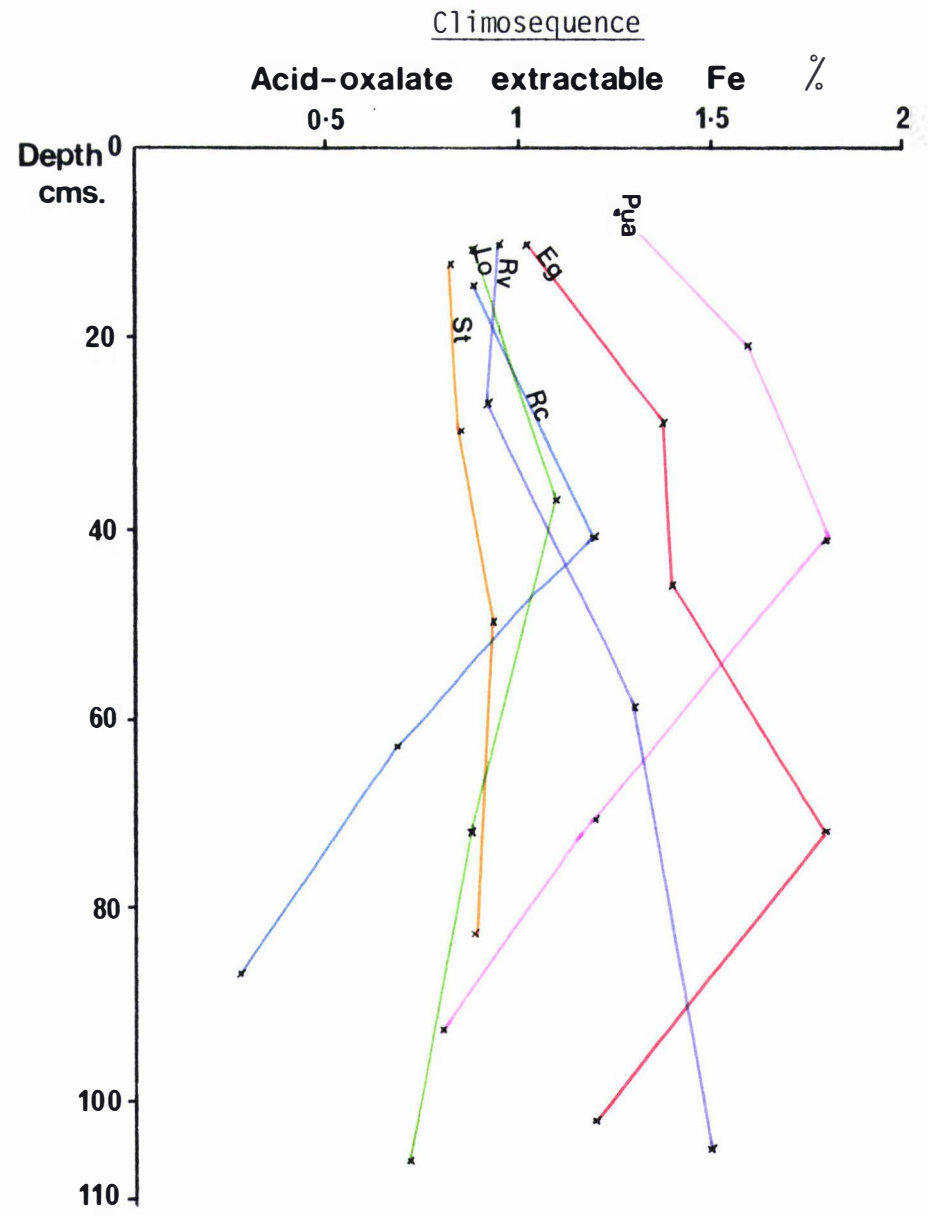
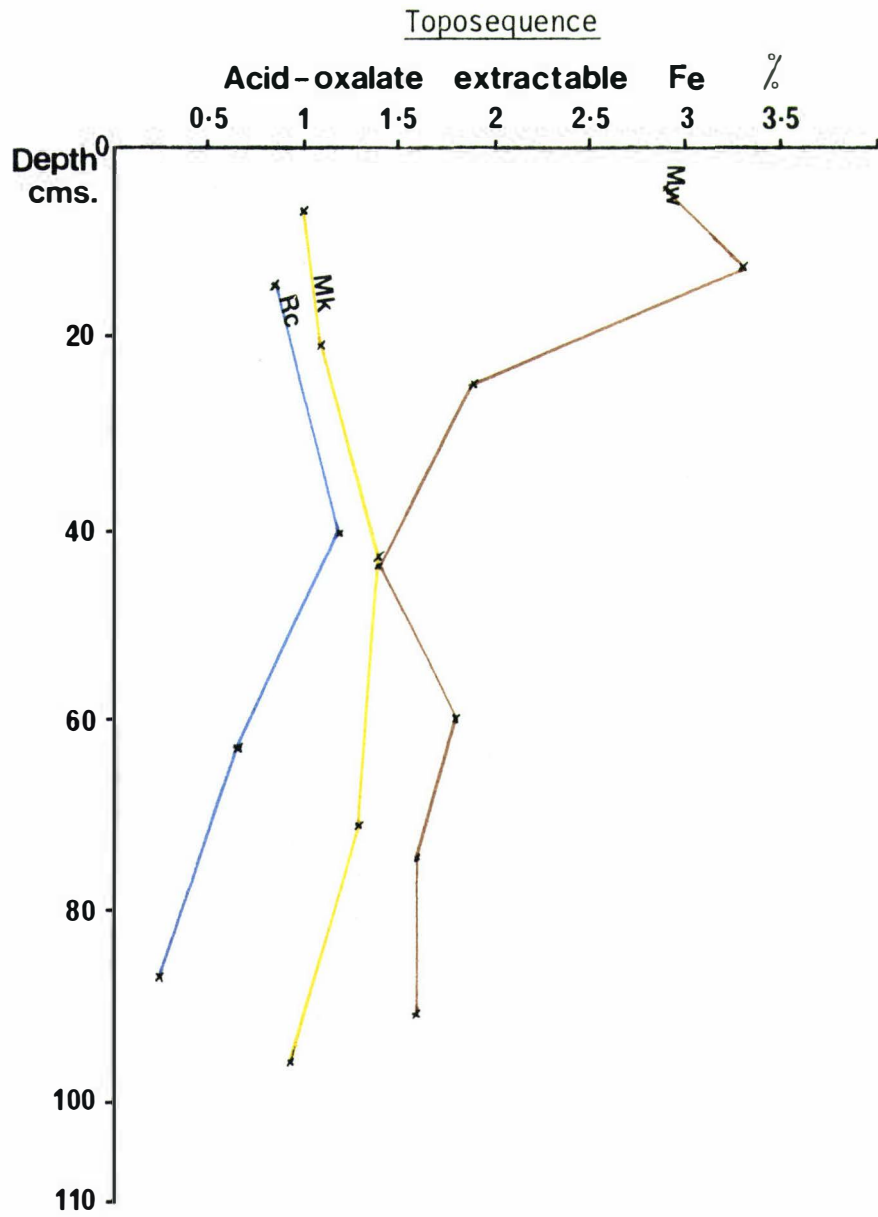


Figure 6.13

Acid-oxalate extractable iron in the soil climosequence and toposequence of this study



In the U.S. Soil Taxonomy (Soil Survey Staff, 1975) for a spodic horizon to be positively identified it must meet one or more of the following requirements; (if no continuously cemented horizon or pelleted/coated sandy or coarse loamy horizon is present).

- i) $Fe_p + Al_p/Fe_d > 0.5$
- ii) $Fe_p + Al_p/\% \text{ clay} > 0.2$
 - where p = pyrophosphate
 - d = dithionite-citrate
- iii) Index of Accumulation (CEC(pH 8.2) - $\frac{1}{2}\%$ clay x thickness of horizon (cm)) > 65

In the discussion of the "exchange complex dominated by amorphous material" (ECDAM) included with the Andisol proposal (Smith, 1978), Blakemore reports that the ratio between pyrophosphate and dithionite-extractable iron and aluminium of 0.5 or more, as a chemical criterion for a spodic horizon, adequately separates Spodosols from Andisols in New Zealand.

Table 6.10 shows that the soils in this survey fail to satisfy the first criterion for a spodic horizon because the ratios are all less than 0.5.

As a measure of high activity in soils containing short-range order colloids the amounts of aluminium extracted by dithionite-citrate reagent are not easy to interpret, although they usually approximate the amounts removed by acid-oxalate. In some podzols and volcanic ash soils acid-oxalate extracts larger amounts of aluminium than does dithionite-citrate. It was suggested at the 1981 Soils with Variable Charge Conference that acid-oxalate extractable aluminium (critical value of 2.4% or more) could be a better and more simple measure of the high activity of volcanic ash soils. In the soils analysed acid-oxalate extractable aluminium ranges in value from 7.1% (Patua soil) to 0.9% (Te Kiri hill soil). On the basis of the weighted averages of all horizons between 25cm and 1m the Rowan, Mangawhero, Hangatahua and Te Kiri hill soil all have values of acid-oxalate extractable aluminium less than 2.4%. This is due to the presence of either laharc debris, tephra or alluvium in these soils.

A significant correlation is evident between phosphate retention and the level of acid-oxalate extractable iron, as shown by Table 6.9. Figure 6.14 demonstrates the positive linear relationship.

Table 6.10

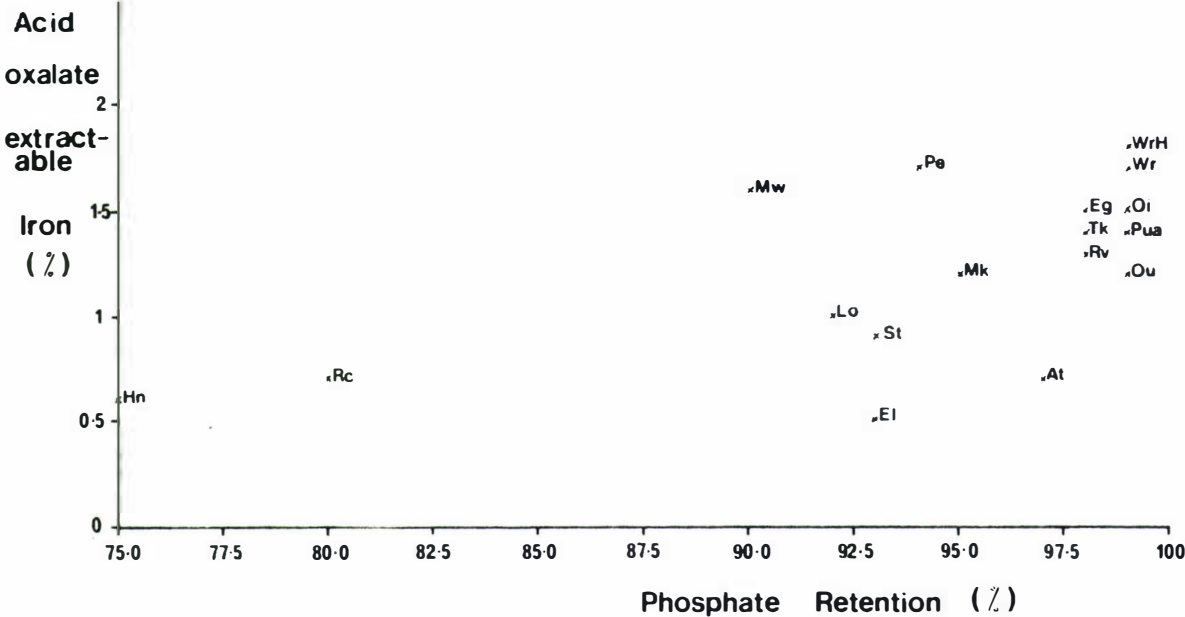
Ratio between Sodium Pyrophosphate Extractable
Aluminium and Iron and Citrate-Dithionite
Aluminium and Iron

	Sodium pyrophosphate Al + Fe (%)	Citrate- dithionite Al + Fe (%)	<u>Sodium pyrophosphate Al + Fe</u> <u>Citrate-dithionite Al + Fe</u>
Rowan Bs (30-51cm)	0.83	2.97	0.28
Makaka Bw1 (28-58cm)	0.56	2.75	0.20
Lowgarth Bw1 (23-52cm)	0.46	1.83	0.25
Riverlea BA (21-34cm)	0.58	2.50	0.23
Stratford Ap2 (25-35cm)	0.90	2.30	0.39
Mangawhero Bg3 (34-53cm)	0.84	2.42	0.35
Patua Bwg (29-54cm)	1.56	4.28	0.36
Egmont Bw1 (21-38cm)	0.45	3.18	0.14

ALL < 0.5

Figure 6.14

Acid-oxalate extractable iron versus phosphate retention for seventeen selected Taranaki soils



The high acid-oxalate extractable silicon values in nearly all the soils are due to the dissolution of the allophanic clay (Parfitt, 1980). In the lower B horizons of the Hangatahua, Rowan and Mangawhero soils, relatively lower values of acid-oxalate extractable silicon were obtained due to the lower clay content. In the Eltham peat the levels of silicon are very low to medium, reflecting the low mineral content of the organic matter. Levels of acid-oxalate extractable aluminium are medium to high and those of iron low to high.

10. BULK DENSITY

The pattern of root growth is affected by soil density and a low bulk density encourages deep and widespread root growth. Bulk density measurements were made on oven dried (105°C) core samples taken from each horizon, with corrections for stone content made where necessary.

The yellow-brown loams mostly have low bulk densities, averaging 0.8 Mg/m^3 . In the case of Hangatahua and Rowan soils the higher subsoil values of 1.1 Mg/m^3 and 1.4 Mg/m^3 , are due to the presence of sandy textured alluvial and laharic debris, respectively. The low bulk density values and the high porosity (Figure 6.15) obtained for the mineral soils are related to the high specific surface area characteristic of allophane-rich soils. In the A horizons of the yellow-brown loams, the organic matter content and the moderately to strongly developed structure, lower the bulk density slightly. The bulk densities do not increase steadily with depth; instead there are irregularities related to the presence of tephra horizons. The variable bulk density distribution of the Lowgarth soil in particular is due to the presence of the Manganui tephra, which causes an increase in bulk density, in the Ap and Bw1 horizons.

In the Eltham peat the bulk density values are low, decreasing to very low values in the subsoil, as would be expected for an organic soil. The relatively higher value in the Bh1 horizon can be attributed to the presence of the Manganui tephra.

Associated with the low bulk density of yellow-brown loams are high macroporosity values (large-sized pores, larger than 60 microns). These macroporosity values are consistently greater than the values of several other New Zealand soil groups for which comparable data are available

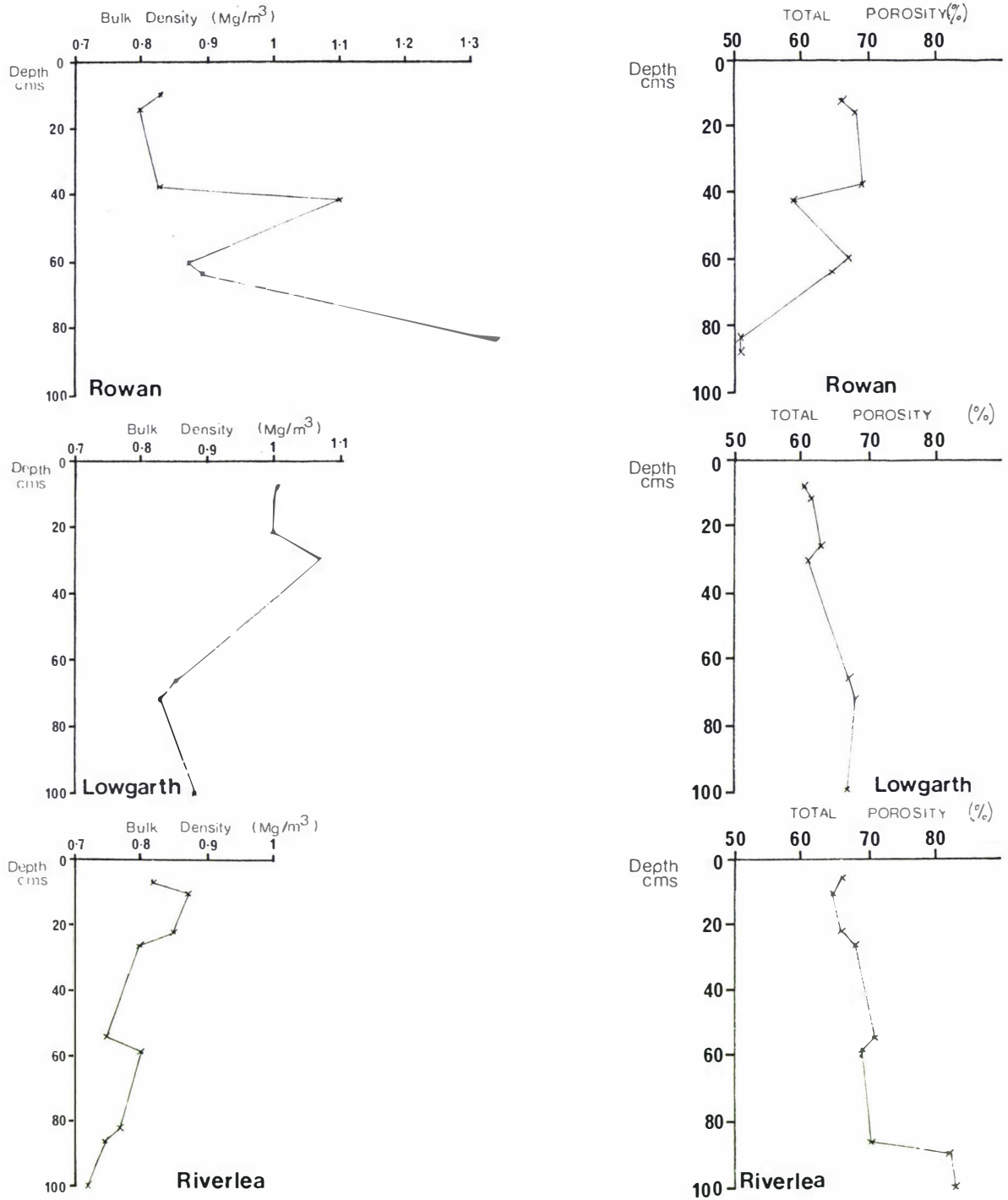


Figure 6.15

Bulk density and total porosity
of six selected Taranaki soils

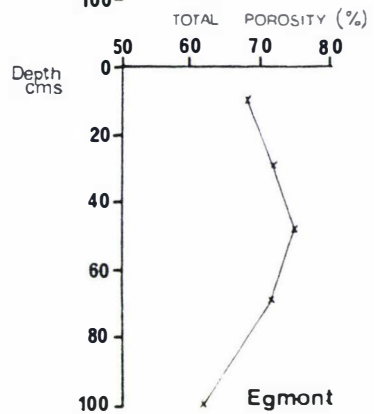
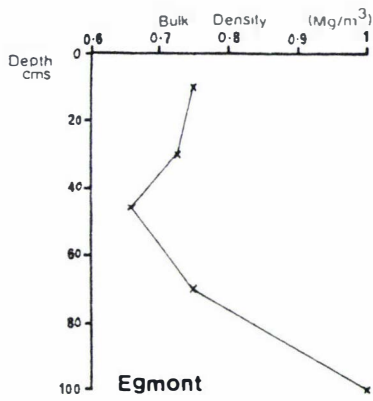
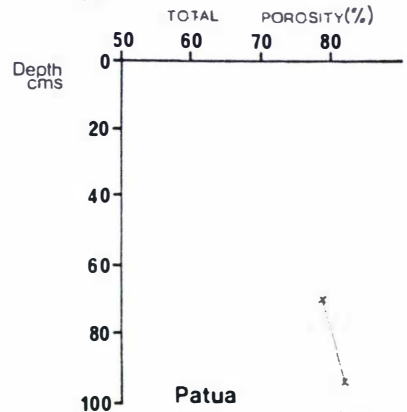
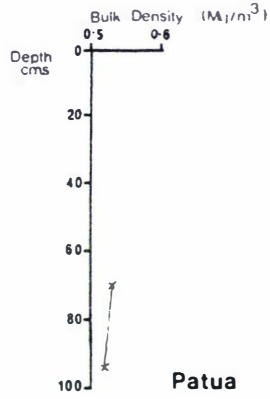
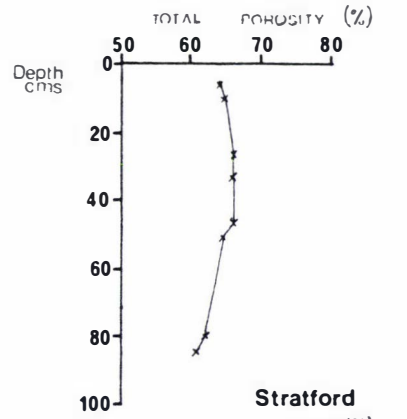
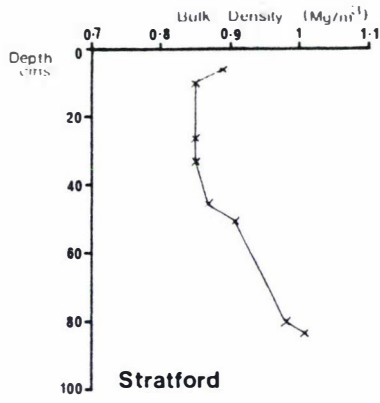


Figure 6.15 contd.

(Gradwell, 1978). The high content of large pores is very evident in the B horizons of the yellow-brown loams analysed, with an average of 26% by volume occupied by pores larger than 60 microns diameter. In most soil groups the volume of such pores decreases with increasing depth. The abundance of large pores to a considerable depth in the yellow-brown loams promotes rapid drainage in these soils (Gradwell, 1978).

11. MOISTURE RETENTION

The low bulk density of yellow-brown loams suggests that large volumes of water can be stored in the soil profile. The water is thought to be held dominantly in small voids rather than on clay surfaces (Maeda and Warkentin, 1975; Rousseaux and Warkentin, 1976). Just how much of this water is available for plant growth depends upon the water content at the upper (field capacity) and lower (wilting point percentage) ends of the available water range. The permanent wilting point is conventionally taken as the moisture held in the soil at a tension of 15-bars and it is influenced by the type and amount of clay minerals present. The differences between the 15-bar moisture contents of previously dried and undried soil samples is not only related to the allophane content but to the amount of natural drying that has occurred in the soil.

A pressure plate apparatus was used to determine the moisture held at a tension of 15-bars on saturated samples. For each soil horizon one set of duplicate samples was kept continually moist and another set was air dried and then rewetted before being brought to 15-bar tensions.

The results are shown in Table 6.2 and are characteristic of soils containing allophanic clay.

The moderate to high 15-bar moisture values of the moist samples demonstrate that the soils have a capacity to retain moisture at high tensions and that this capacity decreases markedly on drying. It is possible that the topsoils of some profiles have at some point undergone a severe drying that has not occurred in the underlying subsoils. In the case of the Rowan and Hangatahua soils the subsoil values reflect the sandy texture and low clay content, which results in less moisture being retained at 15-bars. In addition lapilli horizons in the soil profiles contribute to the variability of values obtained. In most subsoils the wilting points of the samples exceed those of the upper horizons

consistent with higher subsoil allophane contents, despite the contribution of soil organic matter to the retention of moisture in the upper horizons. The available water capacities of A horizons of yellow-brown loams depend strongly on organic matter content (Bonfils and Moinereau, 1971; Maeda *et al.*, 1976) so the capacities cannot be attributed to the allophane content alone.

The Eltham peat has the capacity to absorb and retain large quantities of water due to its high organic matter content. The high 15-bar values of the moist samples demonstrate this characteristic. The low values in this profile are due to the presence of tephra horizons.

The percentage decreases in 15-bar moisture values, as a result of air drying are very high and are thought to be due to the loss of very fine microscopic pores and intra-colloidal cavities during the air-drying process. The percentage decreases are lowest in the A horizons and increase in subsoils to values as high as 74%.

The yellow-brown loams have been shown to contain significantly more pores from 3 to 30 microns diameter, in their subsoils than most other New Zealand soil groups (Gradwell, 1978). Water held in such pores is readily withdrawn by plants, so that growth is maintained during periods of moisture stress.

Compaction, as well as drying, can decrease the volume of small voids and the figures obtained confirm the higher the bulk density the lower the 15-bar moisture values. This is in contrast with crystalline clays where the volume of small voids increases with compaction.

The 15-bar moisture characteristics of yellow-brown loams have implications for soil classification. In the Andisol proposals for the reclassification of Andepts (Smith, 1978), the figure of 15% water retention at 15-bars of previously dried samples and of 30% on undried samples on the weighted average of all horizons, in the control section (25cm to 1m), is used as the boundary between Vitrudands and Hapludands. The coarse textured Rowan, Opua, Lowgarth and Hangatahua soils all have less than 30% on undried samples (Table 6.11) and are classified as Vitrudands (Table 6.12). The 15-bar water contents have been used to define the soil families as combinations of particle size and mineralogy (Table 6.12).

Table 6.11 15-bar Water Content
for seventeen soils in Taranaki

SOIL	0 - 1m		25cm - 1m	
	Moist (%)	Air-dry (%)	Moist (%)	Air-dry (%)
Rowan	24.4	10.7	21.9	8.8
Makaka	24.4	12.7	34	11
Lowgarth	26	11.8	27.8	10.9
Riverlea	37.9	15.3	30.2	10.5
Stratford	26.9	14	27.5	12.3
Mangawhero	29.2	12.3	26.3	9.9
Hangatahua	21.3	9.5	18.7	6.8
Eltham	62	35	63	34
Warea hill	42.9	23.2	48.8	20.4
Warea	50.6	22.6	45.8	20.1
Tipoka	53	16.8	53.7	16.5
Opuā	17	11.2	-	19
Oaonui	54	21.2	-	18.2
Awatuna	45.8	21.4	48.2	18.4
Punehu	31.2	17.6	-	17.9
Patua	63.2	19.8	49	14
Egmont	36.8	17.9	38.8	16.3

12. ALLOPHANE AND TOTAL CLAY

The determination of the amount of clay in allophanic soils is extremely difficult due to problems of dispersion (Birrell and Fieldes, 1952).

Two indirect methods have been proposed. The first is to estimate the total clay present by taking the values for 15-bar water percentage of air dried samples since this value (or measurement) appears to be a function of the amount of allophane present. The second is for the value of acid-oxalate extractable silicon to be used (Parfitt and Henmi, 1982) to estimate the amount of allophane present.

These two methods were employed and the results are presented in Figure 6.16.

The histograms reveal that, except for Ap horizons, the estimated amount of allophane in each horizon is a reflection of the relative changes in the estimated amount of total clay. This is not surprising because the clay fraction is thought to be dominated by imogolite and allophane, together with hydrous feldspar. The exception of the Ap horizons is probably due to the contribution of organic matter to the air-dry 15-bar water percentages causing the total clay value to be overestimated. Equally the empirical multiplication of acid-oxalate extractable silicon by a factor of 8 may not be appropriate for topsoils resulting in an overestimation. It is significant that the estimated amounts of allophane peak in the Bw (cambic) horizons and that the greatest allophane content is in the subsoil of the Patua soil. Wada (1980) considers that allophane is a major constituent of subsurface horizons for Andisols in an early or middle stage of development.

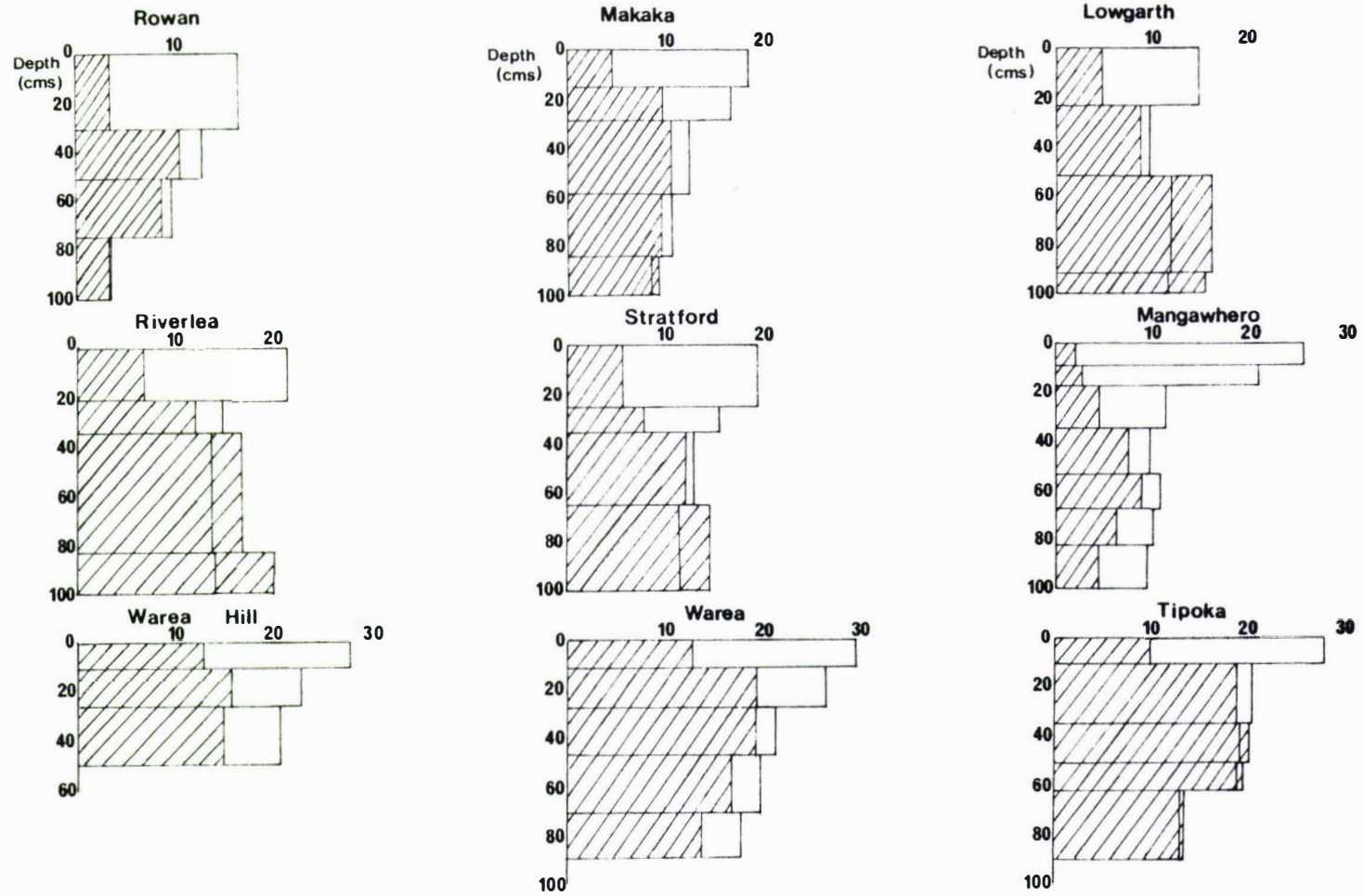
13. CONCLUSION

The results obtained in the analyses of the yellow-brown loams of Taranaki can be largely explained by the presence of variable charge materials. The soils that were analysed conform to the pattern observed in other yellow-brown loams in New Zealand.

The toposequence (drainage sequence) and climosequence approach reveals trends in the various analyses. In the toposequences the trends

Figure 6.16

Histograms to show relative amounts of Total Clay and
Allophane in fifteen Taranaki soils





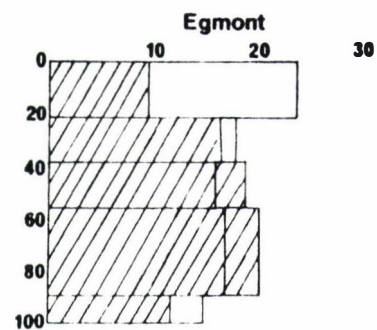
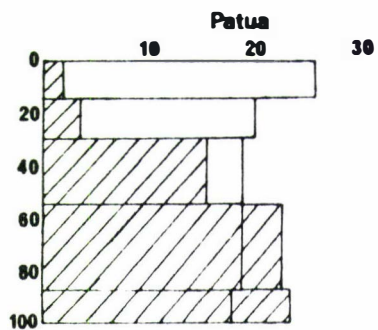
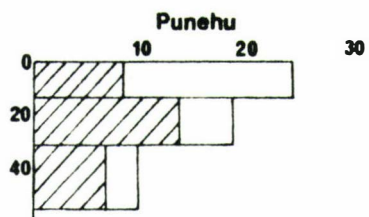
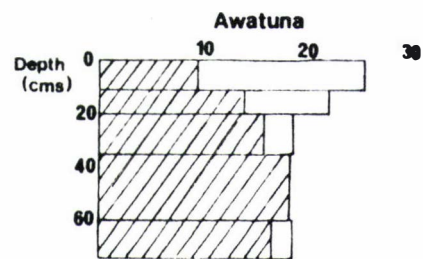
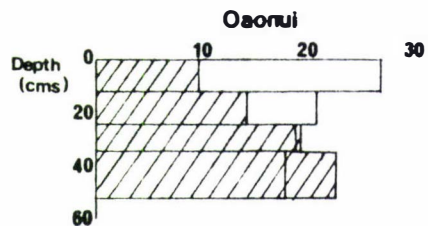
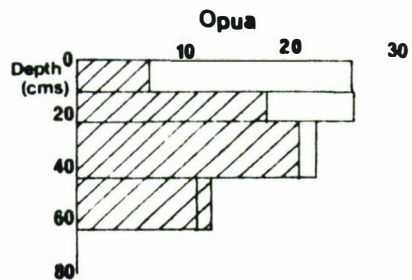
-  - Estimated amount of Total Clay (15-bar air-dry water value)
-  - Estimated amount of Allophane (acid-oxalate extractable Si x 8)

Figure 6.16 contd.



- detected include:-
- i) $\text{pH}_{\text{H}_2\text{O}}$ values tend to become slightly more acid with increasing gleying
 - ii) total phosphorus levels increase with intensity of gleying reflecting a decrease in weathering.

The degree of leaching in the soil climosequence Patua, Rowan, Lowgarth, Riverlea, Stratford and Egmont soils is evident in most of the analyses. The best indicator of leaching status was exchangeable calcium. Very low and low values were recorded in the very strongly leached and strongly leached soils and very high values in the moderately leached soils. The total phosphorus levels tend to decrease with increased leaching while there is a distinct decrease of inorganic phosphorus soluble in $0.5\text{M H}_2\text{SO}_4$ with increased leaching.

Significant soil property variations occur in the Rowan and Hangatahua soils, which are due to the heterogeneity of laharic debris, tephra and alluvium, in the soil profiles. In addition, the occurrence of bands of concentrated lithic lapilli, such as the Manganui tephra can exert a significant influence upon the results.

In the case of the Eltham peat, the characteristic properties of peat have also been modified by the presence of lithic and pumiceous lapilli horizons, producing low carbon values and low reserve magnesium levels. The analyses have drawn attention to the fact that the Eltham peat has certain properties in common with Andisols. The Eltham peat has variable negative charge arising from organic functional groups and has a high specific surface area. Consequently, criteria which are satisfied when the exchange complex is dominated by amorphous material (ECDAM) are also satisfied by the Eltham peat. Although the exchangeable aluminium values in the Eltham peat tend to be very high, the acid-oxalate extractable aluminium values are all less than 2.4%, unlike in the Andisols where values are greater than 2.4%.

The information obtained from the analyses enables classification of the soils according to Soil Taxonomy (Soil Survey Staff, 1975). Certain criteria, such as the cation exchange capacity, base saturation and moisture retention are used to define great groups, within the suborder Andepts, but these criteria have proved inadequate and unreliable. In order to construct a more meaningful classification of the Andepts new proposals to elevate these soils to the order Andisols and to select more

appropriate criteria have been advanced. These proposals (Smith, 1978) have subsequently been summarised by Leamy et al., (1980).

Classifications of the soils according to Soil Taxonomy (Soil Survey Staff, 1975) and the Andisol Proposal (Smith, 1978) are shown in Table 6.12.

Table 6.12 Classification of soils from Taranaki according to Soil Taxonomy and the 1978 Andisol Proposal

Soil series	U.S. Soil Taxonomy to subgroup level	Andisol Proposal (Smith, 1978) to family level
Rowan*	Typic Vitrandept	Typic Vitrudand (ashy over medial, ashy-skeletal, mesic)
Makaka*	Aquic Vitrandept	Aquic Hapludand (medial, medial-skeletal, mesic)
Lowgarth*	Typic Vitrandept	Typic Vitrudand (ashy-pumiceous, mesic)
Riverlea*	Mollic Vitrandept	Typic Hapludand (medial, medial-skeletal, mesic)
Stratford*	Entic Dystrandept	Typic Hapludand (medial, mesic)
Mangawhero*	Typic Andaquept	Typic Vitraquand (ashy, ashy-skeletal, mesic)
Hangatahua*	Typic Vitrandept	Typic Vitrudand (ashy, mesic)
Okato*	Haplic Andaquept	Entic Vitraquand (ashy, mesic)
Kahui*	Typic Dystrandept	Typic Hapludand (medial, mesic)
Tipoka*	Aquic Vitrandept	Aquic Hapludand (medial, mesic)
Awatuna*	Haplic Andaquept	Typic Haplaquand (medial, mesic)
Ngaere*	Aquic Dystrandept	Aquic Hapludand (medial, mesic)
Warea	Entic Dystrandept	Typic Hapludand (medial, mesic)
Opuā	Typic Vitrandept	Typic Vitrudand (ashy over skeletal, mesic)
Te Kiri	Typic Vitrandept	Typic Vitrudand (ashy, mesic)
Punehu	Haplic Andaquept	Typic Vitraquand (medial-skeletal, mesic)
Patua	Typic (Hydric?) Dystrandept	Acric (-Allic) Hapludand (medial, mesic)
Egmont	Entic Dystrandept	Typic Hapludand (medial, mesic)
<u>Classification in U.S. Soil Taxonomy to family level</u>		
Whangamomona*	Typic Dystrochrept (fine-loamy mixed, mesic shallow)	
Eltham*	Fibric Terric Medisaprist (medial, mesic)	

* Eltham County Soils.

CHAPTER 7

CHAPTER 7

CONCLUSIONS

1. Eight new tephra units (p2, p1, E5, E4, E3, E2, E1 and Mahoe) were described from Eltham and Stratford Counties. Correlations were established with tephras in northern Taranaki. The uppermost p2 tephra has been found to correlate with Neall's (1972) Inglewood Tephra, which has been dated 3,800 years B.P. The p1 tephra has been correlated with Neall's (1972) Korito Tephra, which has been dated at less than 5,150 years B.P. E5 and E4 tephras are tentatively correlated with part of the Oakura Tephra, which is dated at greater than 5,000 years B.P. and less than 7,000 years B.P. E3, E2, E1 and Mahoe tephras are successfully correlated from Eltham County to northern Taranaki, with the prominent basal band of E1 tephra correlated with Neall's Ahuahu Lapilli.

The discovery of the rhyolitic Aokautere Ash and Omahina Tephra in Eltham County has widespread stratigraphic implications. Since the Omahina Tephra overlies Eltham Lahars then Eltham Lahars are considered older than 370,000 years B.P. and must therefore have originated from the Kaitake centre. The Aokautere Ash has been found at depths of up to 7.5m beneath a deep tephra sequence, including tephric loess, close to Mt. Egmont, demonstrating the rapid accumulation rate of tephra in the last 20,000 years. The presence of the Ash also aids the dating of underlying laharcic deposits.

2. Positive tephra identification and correlation was achieved with varying success by applying X-ray fluorescence analyses, elemental analysis of titanomagnetites and mineralogical studies.

The results of the titanomagnetite analyses confirm that a fairly homogeneous magma was present over the time period of the tephra emissions, as suggested by Gow (1968). Groups of tephra were successfully separated by plotting Mn to Zn values but no one element was found to be useful for distinguishing any single tephra. The

XRF characterised the unweathered tephra near to source and established the variability which occurs with distal tephra due to weathering. It was observed that it is decreasing grain size and increasing mean annual temperature and not rainfall that has the greater effect on the weathering of pumiceous lapilli in Taranaki. Correlation was also achieved using three groups of ferromagnesian assemblages, as defined by Gow (1968) in combination with stratigraphic position. The composition of the lithic Manganui tephra was found to be basaltic, as revealed by bulk chemistry analysis and the presence of olivine.

3. The soil map and accompanying pedological discussion provide up to date information for correlation and reference purposes that is compatible with recently mapped adjacent Counties. Age relationships between soils were established by means of identifying different tephra and laharic deposits and mapping their distribution. Tephra present to 1m depth were found to be critical to the mapping of soils in Eltham County. The 250mm isopach map of the *young lapilli showers* (Kaupokonui, Maketawa and Manganui tephra) combined with the depth of volcanic ash above laharic deposits was used to separate the younger Lowgarth series from the older Stratford series. The same isopach was used in combination with drainage and leaching to separate Riverlea from Kahui series, Makaka from Tipoka series and Mangawhero from Awatuna series. It was found necessary to introduce four new soil series and one new variant to an established soil series. These were the Makaka, Riverlea, Mangawhero, Ngaere series and the Stratford series, fine topsoil variant. The introduction of the Stratford series, fine topsoil variant, meant that the otherwise gradational boundary between the Stratford and Egmont series could be resolved in terms of an intermediate soil category. Egmont series, Stratford series and Stratford series, fine topsoil variant were defined in this study on precise tephra and lithology of parent materials and a key was provided for field identification. Attempts to characterise and separate the soil series by laboratory analyses were not successful and there were problems involved with identification of distal tephra. Further work is still required on the position of the boundary in the area between Hawera and Normanby.

The steep-land study showed that distinctive morphologies were evident both between the soils of the two areas and between the soils from the four sites examined. The study revealed distinctive morphologies in terms of profile depth, horizon expression, soil structure development and degree of mottling, with imperfect and poorly drained soils widespread within the steep-land area. However, despite correspondence in soil properties at equivalent sites, parent rock and parent material variability is so great that predictions and application of soil information throughout the steep-land terrain are unreliable. The allophane test and phosphate retention results indicated that widescale mixing of volcanic ash and the underlying parent material had occurred. The investigation suggested that volcanic ash can be expected to be found on slopes less than 26° due to erosion.

4. The chemical and physical properties of selected yellow-brown loams, gleys, intergrades between yellow-brown loams and recent soils and organic soils were examined using laboratory analyses. Several significant trends were revealed in both the toposequence and climosequence of the yellow-brown loams examined. The presence of laharcic deposits, tephra or alluvium in a profile had a marked influence upon properties. The lithic Manganui tephra, where present exerts a significant influence on horizon properties.

The properties of the peat in the Eltham soil were modified by the presence of pumiceous and lithic lapilli. Analyses established that the Eltham peat has certain properties that are also common to Andisols. Criteria such as $\text{pH}_{\text{NaF}} > 9.4$, phosphate retention $> 90\%$ and low bulk density, which are satisfied when the exchange complex is dominated by amorphous material (ECDAM) are also satisfied by the Eltham peat. This is due to variable negative charge arising from organic functional groups, a high specific surface area and the presence of pumiceous and lithic lapilli in the profile. It is this latter feature which makes the Eltham peat unique amongst New Zealand organic soils because of its volcanic additions.

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APPENDICES

APPENDIX I

List of stratigraphic sections mentioned in text.

*NZMS Grid 260 Reference.

1. Opunake Road adjacent to Mangatoki stream at N119/757532 (Q20/118025)*
2. Opunake Road at Mahoe at N119/754532 (Q20/115026)
3. Upper Palmer Road, 1km from the junction with Opunake Road, at N119/746545 (Q20/108038)
4. Opunake Road, 0.4km from Mahoe at N119/744533 (Q20/106027)
5. Opunake Road, 0.6km from Mahoe at N119/741530 (Q20/102024)
6. Opunake Road, 0.8km from Mahoe at N119/738528 (Q20/101022)
7. Manaia Road, below Dawson Falls at N119/698575 (P20/065066)
8. Manaia Road, near Dawson Falls at N119/687587 (P20/055078)
9. Upper Palmer Road, at the Kapuni Stream bridge at N119/746497 (Q20/107994)
10. Upper Hastings Road, 0.5km from Opunake Road at N119/769544 (Q20/129036)
11. Finnerty Road, junction with Ronald Road at N119/810516 (Q20/166009)
12. Opunake Road, 0.6km from Cardiff, above Waingongoro River at N119/797550 (Q20/155041)
13. Top of Waingongoro Road at N119/748586 (Q20/111075)
14. Cardiff Road, after Waingongoro Road at N119/801572 (Q20/159061)
15. At Pembroke on Cardiff Road at N119/802596 (Q20/161083)
16. Pembroke Road, 1.5km south from Barclay Road, at N119/778597 (Q20/139084)
17. Pembroke Road, Stratford Plateau at N119/687616 (P20/056104)
18. Monmouth Road, 1km east of Pembroke at N110/813603 (Q20/171089)
19. Monmouth Road, 2.7km from junction with State Highway 3 at N119/815604 (Q20/173090)
20. Near York Road. Dairy Farm No. 1115 at N119/818653 (Q20/177134)
21. State Highway 3, near Tariki, beside the railway line at N109/815703 (Q20/175180)
22. Durham Road, drainage ditch, at N109/779754 (Q19/144228)

23. Bedford Road. Drainage ditch between Dudley and Durham Road at N109/763742 (Q19/129217)
24. North Egmont Mangaoraka Picnic Area at N119/690694 (P20/061175)
25. North Egmont Track at N119/673654 (P20/044139)
26. Maude Road, 0.2km from the junction with Kent Road, at N109/673752 (P19/047229)
27. Korito Road, 3.8km due south-west of junction of Korito and Kent Roads at N190/650745 (P19/026223).

APPENDIX II

AOKAUTERE ASH LOCALITIES

Locations in the north-east.

- 1) N119/798551 (Q20/156041) Waingongoro River, Opunake Road.
80mm thickness of Aokautere Ash at a depth of 7m.
- 2) N119/795550 (Q20/153042) Opunake Road, near Ronald Road.
80mm thickness thinning to 60mm, sharp base, at a depth of 7m.
- 3) N119/777541 (Q20/137034) Opunake Road, near Hastings Road.
30mm thickness at a depth of 6.80m.
- 4) N119/757532 (Q20/118026) Mangatoki River, Opunake Road.
70mm thickness at a depth of 6.90m.
- 5) N119/746544 (Q20/108036) Upper Palmer Road.
40mm thickness at a depth of 7.5m.
- 6) N119/815515 (Q20/171008) Finnerty Road, near Upper Stuart Road.
60mm thickness at a depth of 3.60m.
- 7) N119/785478 (Q20/143975) Eltham Road before Upper Duthie Road,
Metal Pit (Dairy No. 252).
40mm thickness at a depth of 3.25m.
- 8) N119/756470 (Q20/116969) Kapuni Stream, Eltham Road, near
Upper Palmer Road.
50mm thickness at a depth of 4.80m.
- 9) N119/779456 (Q20/137955) Lower Duthie Road, exposure by stream
(Dairy No. 261).
Overthickened to 70mm thickness at a depth of 3.20m.
- 10) N119/752405 (Q20/109909) Skeet Road, exposure above Kapuni Stream
(Dairy No. 433).
25mm thickness at a depth of 2.80m.

- 11) N119/785427 (Q20/141929) Lower Duthie Road, near Inaha Stream
bridge.
25mm thickness at a depth of 1.30m.
- 12) N119/911430 (Q20/255928) Campbell Road, near junction with
Rotokare and Tirimoana Roads.
25mm thickness at a depth of 3m.

Location in the west.

- 13) N118/635456 (P20/004959) Eltham Road, near Awatuna,
exposure in paddock.
20mm thickness at a depth of 3.20m.

APPENDIX III

Section 1.

Location : Cutting on the south side of Opunake Road, up from
Mangatoki Stream at N119/757532.

Elevation : 380m.

Rainfall : 2400mm.

Terrain : Tephra mantled laharic terrain. On Stratford Formation.

Additional Points of Importance : Type Section for E4.
Reference locality for E3 and E1.

Thickness (in mm)	Description	Formation	Member	Symbol
300	5Y 3/2 (dark olive grey), scoriaceous, loose, lithic lapilli, with phenocrysts. Lapilli average 10mm in diameter. Indistinct boundary.	MANGANUI TEPHRA		Mn
150	10YR 5/6 (yellowish-brown), sandy loam. Coarse ash with many 10YR 8/2 (white) pumiceous lapilli and blocks and minor grey dense andesite lapilli, averaging 20mm in diameter. Distinct boundary.	p2	p2B	p2B
80	10YR 4/3 (dark brown to brown), sandy loam, moderately blocky, coarse ash. Wavy indistinct, gradational boundary.		p2A Buried soil	p2A B.S.
300	10YR 8/3 (very pale brown) pumiceous lapilli, averaging 20mm in diameter. Coarse ashy matrix 10YR 4/4 (dark yellowish-brown), coarse sandy loam, friable, weakly blocky. Irregular boundary.		p2A lapilli	p2A

————— PARACONFORMITY —————

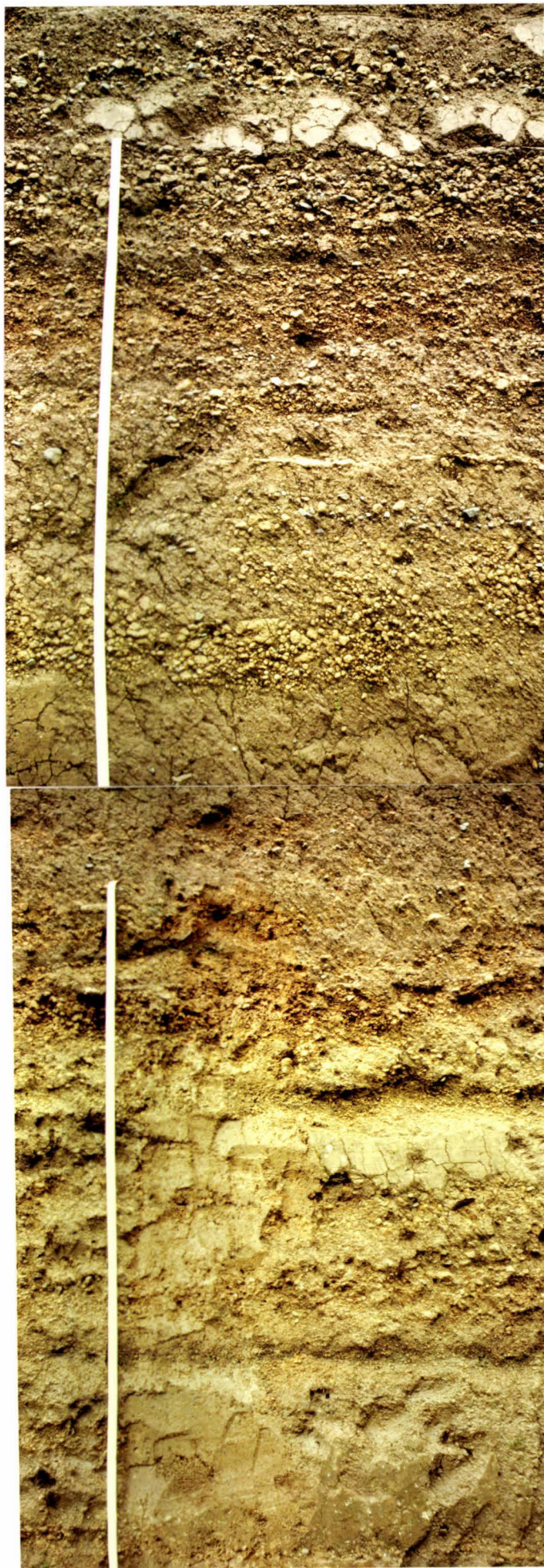
Thickness (in mm)	Description	Formation	Member	Symbol
120	10YR 4/4 (dark yellowish-brown) sandy loam, weakly blocky coarse ash. Irregular distinct boundary.	p1	p1 Buried soil	p1 B.S.
50	10YR 8/2 (white), pumiceous lapilli, averaging 20mm or less in diameter. Greater content of lithic lapilli than p2B and p2A. Moderately distinct, irregular boundary.		p1 lapilli	p1
----- PARACONFORMITY -----				
120	10YR 5/8 (yellowish-brown), moderately blocky, coarse ash. Irregular boundary.		Buried soil	B.S.
80	Upper spalling layer, "pocketing" comprising 10YR 5/1 (grey) pumiceous lapilli, averaging 5mm in diameter and lithic lapilli, averaging 10mm in diameter.	E5	E5 upper lapilli	E5
60	10YR 4/4 (dark yellowish-brown), friable, sandy clay loam, blocky ash, with white speckles.		E5 ash	E5
120	10YR 8/1 (white) pumiceous and lithic lapilli, greater than 20mm in diameter. Distinct wavy boundary.		E5 basal lapilli	E5
40	10YR 5/3 (brown), strongly blocky, sandy clay loam, coarse ash. Distinct sharp boundary.		Unnamed ash	
200	Discontinuous layer of cemented fine ash ("cream cakes"). Predominantly lithic towards the top and contains 7.5YR 5/6 (strong brown) pumiceous lapilli, averaging 20mm in diameter with pumiceous blocks concentrated on top.	E4	E4 upper lapilli	E4
40	Internally stratified central "spalling" bed with the upper part containing lithic lapilli, averaging less than 10mm in diameter.		E4 central	E4

Thickness (in mm)	Description	Formation	Member	Symbol
120	Middle part contains pumiceous lapilli less than 20mm in diameter.	E4	E4 central	E4
100	Lower part contains lithic-rich pumiceous lapilli.			
80-100	Lower bed has an upper lithic-rich layer overlying a basal pumiceous layer, 10YR 6/4 (light yellowish-brown), averaging 20mm in diameter, with minor lithic lapilli. Distinct wavy boundary.		E4 basal lapilli	E4
----- PARACONFORMITY -----				
100	10YR 5/8 (yellowish-brown) sandy clay loam, friable, weakly blocky.	E3	E3 Buried soil	E3 B.S.
70	"Ledge" of cemented fine ash ("cream cakes"), with few pumiceous blocks and lithic lapilli, in coarse ashy matrix, 10YR 5/8 - 5/6 (yellowish-brown).			E3
280	Discontinuous layer of 2.5YR 4/2 (weak red), cemented fine ash ("cream cakes"). The loose, densely packed pumiceous lapilli beneath are inversely graded and vary in colour from 10 YR 8/1 (white) to 7.5YR 5/6 (strong brown), ranging from between 10 and 20mm in diameter. Lithic lapilli are less than 20mm in diameter and concentrated in the upper part of the tephra. Distinct, wavy boundary.		E3 lapilli	E3
----- PARACONFORMITY -----				
150	10YR 4/4 (dark yellowish-brown), sandy clay loam. Coarse ash containing scattered lithic lapilli and pumiceous lapilli.		Unnamed ash	
----- PARACONFORMITY -----				

Thickness (in mm)	Description	Formation	Member	Symbol
40	10YR 4/4 (dark yellowish-brown) coarse sandy loam ash, with a few lithic lapilli, averaging 10mm in diameter. Gradational boundary.			E1
120	Basal band of pumiceous blocks and lapilli and fine lithic lapilli, 5mm and less in diameter, with many mafic crystals. Distinct, wavy boundary.			E1
----- PARACONFORMITY -----				
130	10YR 5/6 (yellowish-brown) sandy clay loam, coarse ash, friable, massive, with weak blocks.		Buried soil on ash	
100	10YR 6/8 (brownish-yellow) pumiceous lapilli 20mm and less in diameter.		Unnamed ash	
100	10YR 5/6 (yellowish-brown) sandy clay loam. Coarse ash, firm with coarse blocks. Distinct, wavy boundary.		Unnamed ash	
400	7.5YR 5/8 - 5/6 (strong brown) pumiceous lapilli, closely packed. Numerous lithic lapilli, averaging 20mm and greater in diameter, grade downwards to very fine 2-5mm lithic lapilli. The pumiceous lapilli are firm and have a distinctive 10YR 4/1 (dark grey) internal colour, with a "honey-comb" appearance. The bed is characteristically loose and strongly iron stained, with 5YR 4/6 (yellowish-red) coatings. Distinct undulating boundary.	MAHOE TEPHRA		Ma
80	7.5YR 5/6 (strong brown) coarse sandy loam, lithic lapilli-studded ash, with minor pumiceous lapilli band.		Unnamed ash	
80	7.5YR 7/8 (reddish-yellow) sandy clay loam. Firmly friable ash.		Unnamed ash	

Thickness (in mm)	Description	Formation	Member	Symbol
100	Pumiceous lapilli, with minor lithic lapilli.		Unnamed ash	
1/2m	10YR 4/3 (dark brown to brown) sandy clay loam. Firm, moderately blocky, gradational boundary to		Buried soil	B.S.
1/2m	10YR 5/3 - 5/4 (brown to yellowish-brown) loam. Firm, massive strongly weathered ash. Speckled appearance, with scattered mafic crystals.		? Tephric loess	? T.L.
100	10YR 5/6 (yellowish-brown) coarse sandy loam, firm, weakly blocky, coarse ash. Few pumiceous and lithic lapilli. Weakly distinct wavy boundary.		Unnamed ash	
60	7.5YR 5/6 (strong brown) coarse sandy loam, firm lithic lapilli-studded coarse ash.		Unnamed ash	
80	5YR 5/8 (yellowish-red) pumiceous lapilli, less than 10mm in diameter, with very fine lithic lapilli and mafic crystals.			
120	7.5YR 4/4 (brown to dark brown) sandy clay loam, firm, massive coarse ash.		Unnamed ash	
100	7.5YR 6/8 (reddish-yellow) pumiceous lapilli, averaging 20mm and greater. The lapilli are loose, iron stained and firm. Lithic lapilli average less than 10mm in diameter. Distinct, straight boundary.		Unnamed ash	
100	10YR 5/6 (yellowish-brown) sandy clay loam. Coarse ash, lithic studded with mafic crystals.			

Thickness (in mm)	Description	Formation	Member	Symbol
50	7.5YR 5/6 (strong brown) pumiceous lapilli, averaging 20mm and less. The lapilli are loose, iron stained and firm. Many lithic lapilli.		Unnamed ash	
50	7.5YR 5/8 (strong brown) sandy clay loam. Lithic lapilli-studded ash.			
70	7.5YR 6/4 (light brown) pumiceous sand. Distinct sharp, undulating boundary.	AOKAUTERE ASH		Ao
90	7.5YR 5/6 (strong brown) sandy clay loam. Coarse ash.			
80	Many fine lithic lapilli and mafic crystals.			
$\frac{1}{2}$ m to ground level	Laharic breccia and conglomerate.	PUNGAREHU FORMATION		Pg



Formation	Member
E5	Upper lapilli ash Basal lapilli
	Unnamed ash
	cemented fine ash Upper lapilli
E4	Central 'spalling' member
	Basal lapilli
E3	E3 Buried soil cemented fine ash
E3	E3 lapilli
	Unnamed ash
	Unnamed ash
E2	E2 Buried soil
E2	
E1	E1 Buried soil
E1	
	Buried soil on ash
	Unnamed ash
	Unnamed ash

Section 1, cutting on the south side of Opunake Road, up from Mangatoki Stream at N119/757532. Type section for E4. Reference locality for E3 and E1.

Section continued on next page.



Formation

Member

Mahoe tephra

Unnamed ash

Unnamed ash

Unnamed ash

Buried soil

Tephric Loess

Unnamed ash

Unnamed ash

Unnamed ash

Unnamed ash

Unnamed ash

Unnamed ash

Aokautere Ash

Unnamed ash

Unnamed ash

Unnamed ash

Unnamed ash

Pungarehu
Formation

Section 18.

Location : Cutting on south side of Monmouth Road, 2.7km from junction with State Highway 3, at N119/815604.

Elevation : 380m.

Rainfall : 2400mm.

Terrain : Tephra mantled ring plain.

Additional Points of Importance : Reference localities for p1 and E2.

Thickness (in mm)	Description	Formation	Member	Symbol
100	5Y 3/2 (dark olive grey) lithic lapilli, with phenocrysts. Lapilli average 15mm in diameter. Irregular boundary.	MANGANUI TEPHRA		Mn
100	10YR 8/2 (white) pumiceous lapilli, averaging 20mm in diameter with few lithic lapilli, averaging 20mm in diameter. Distinct wavy boundary.	p2	p2B	p2B
80	10YR 4/4 (dark yellowish-brown) fine sandy loam, moderately blocky. Wavy gradational boundary.		p2A Buried soil	p2A B.S.
200	10YR 8/3 (very pale brown) pumiceous lapilli, averaging 25mm in diameter, concentrated in a band. Few lithic and pumiceous blocks. Irregular boundary.		p2A lapilli	p2A
----- PARACONFORMITY -----				
100	10YR 3/4 (dark yellowish-brown) sandy clay loam, friable, weak blocky coarse ash. Indistinct boundary.	p1	p1 Buried soil	p1 B.S.

Thickness (in mm)	Description	Formation	Member	Symbol
300	10YR 8/2 (white) pumiceous lapilli, averaging 20mm in diameter, with pumiceous blocks and scattered lithic lapilli. Coarse ashy matrix 10YR 4/3 (brown) coarse sandy loam, friable, weakly blocky. Irregular boundary.		p1 lapilli	p1
150	10YR 4/3 - 4/4 (brown to dark yellowish-brown) moderately blocky coarse ash. Irregular boundary.		Buried soil	B.S.
120	10YR 4/3 (brown) coarse sandy loam with scattered pumiceous lapilli, pumiceous blocks and lithic lapilli. Distinct boundary.	E5		E5
110	10YR 3/4 (dark yellowish-brown) sandy loam with pumiceous lapilli and blocks. Lithic lapilli, averaging 20mm in diameter, concentrated at top.	E4	E4 upper lapilli	E4
200	Internally stratified central "spalling" bed, with the upper part containing lithic lapilli averaging less than 10mm in diameter. The middle part contains pumiceous lapilli, less than 20mm in diameter, with a 10YR 5/1 (grey) massive "cream cake" structure standing out as a "ledge". Very fine lithic lapilli, less than 5mm occur directly below.	E4	E4 central	E4
180	Lower bed has pumiceous and lithic lapilli, averaging less than 10mm in diameter in a coarse ash matrix 10YR 5/4 (yellowish-brown). The basal pumiceous and lithic lapilli average 20mm in diameter. Irregular boundary.		E4 basal lapilli	E4
150	10YR 5/6 (yellowish-brown) speckled ash, moderately blocky with traces of strongly weathered pumiceous lapilli.	E3	E3 Buried soil	E3 B.S.

Thickness (in mm)	Description	Formation	Member	Symbol
250	Loose densely packed 10YR 7/6 (yellow) on iron stained 7.5YR 5/8 (strong brown) pumiceous lapilli. The lapilli are rounded and firm. Few lithic lapilli mainly at top. Distinct wavy boundary.		E3 lapilli	E3
----- PARACONFORMITY -----				
150	10YR 6/4 (light yellowish-brown) loam; very friable, speckled appearance.		Unnamed ash	
50	Rare scattered lithic lapilli.			
150	10YR 7/3 (very pale brown) sandy loam, friable, coarse blocky structure.	E2	E2 Buried soil	E2 B.S.
100	Scattered pumiceous and lithic lapilli, averaging 20mm in diameter, in 10YR 7/4 (very pale brown) coarse ash. Irregular boundary.			E2
120	Pumiceous loose sand "spalling", with lithic lapilli, averaging less than 10mm in diameter, concentrated on top. Distinct wavy boundary.			E2
80	5YR 5/8 (yellowish-red) strongly weathered ("soft") pumiceous lapilli in coarse ash. Indistinct boundary.			E2
150	10YR 8/8 (yellow) pumiceous lapilli and pumiceous blocks. Indistinct boundary.			E2
50	10YR 5/6 (yellowish-brown) sandy clay loam; coarse blocky structure. Distinct wavy boundary.	E1	E1 Buried soil	E1 B.S.
60	10YR 3/3 (dark brown) lithic-studded ash. Lithic lapilli 10mm and less in diameter. Indistinct boundary.			E1

Thickness (in mm)	Description	Formation	Member	Symbol
50	Abundant mafic crystals. Distinct wavy boundary.	E1		E1
----- PARACONFORMITY -----				
50	10YR 5/8 (yellowish-brown) loam, weak blocky structure. Indistinct boundary.		Buried soil on ash	
100	Band of pumiceous lapilli 20mm and less in diameter in 10YR 5/6 (yellowish-brown) coarse ash. Indistinct boundary.		Unnamed ash	
100	Pumiceous lapilli, 20mm and less in diameter in 10YR 5/6 (yellowish-brown) coarse ash. Indistinct boundary.		Unnamed ash	
350	10YR 5/4 - 5/6 (yellowish- brown) sandy clay loam, firm, moderately blocky structure. Speckled appearance.		Unnamed ash	
160	7.5YR 5/8 (strong brown) pumiceous lapilli, concentrated in a distinct band. Few lithic lapilli.	MAHOE TEPHRA		Ma
100	10YR 5/4 (yellowish-brown) sandy clay loam, massive speckled ash. Indistinct boundary.		Unnamed ash	
80	10YR 3/4 (dark yellowish-brown) sandy clay loam with strongly weathered pumiceous lapilli, less than 20mm in diameter.		Unnamed ash	
120	10YR 3/3 (dark brown) sandy clay loam, massive firm ash.		Unnamed ash	



p2B + p2A
Buried soil
p1
Buried soil
E5
E4
Buried soil
E3
Buried soil
E2
Buried soil
E1
Unnamed ash
Unnamed ash

General view of section 18 exposed on Monmouth Road, 2.7km from junction with State Highway 3 at N119/815604.

Length of tape 1.52m.

APPENDIX IV

EXTENDED LEGEND

In this extended legend, the characteristics and properties of the soils and components (members) of the mapping units are described. In the case of soil associations the dominant soil within the mapping unit is described.

Explanatory Notes

1. MAP SYMBOL - This designates the soil unit shown on the soil map.
2. SOIL NAME - This gives the name of the soil unit.
3. PARENT MATERIAL - Parent material is the weathered unconsolidated material from which the soil has been formed.
Symbols used for the *young lapilli showers* recognised in the soil profile are;
Kk - Kaupokonui tephra
Mt - Maketawa tephra
Mn - Manganui tephra
4. PHYSIOGRAPHIC POSITION AND SLOPE - The position of the soil in the landscape is given.
5. ELEVATION RANGE (m) - The altitudinal range in metres above mean sea level over which the soil occurs within the survey area.
6. MEAN ANNUAL RAINFALL RANGE (mm) - The geographic range of mean annual rainfall over which the soil occurs within the survey area (R. Aldridge pers. comm.). Figures are to the nearest 10 millimetres.
7. BRIEF SOIL PROFILE DESCRIPTION - A brief description of a representative soil profile for the soil. In the mapping unit, some variation of this representative profile can be expected and the more important variations are given under "Inclusions and Variants".
Horizon designation is in accordance with FAO/UNESCO (FAO, 1974).

8. CHARACTERISTIC SOIL AND SITE FEATURES - This indicates the soil morphological and environmental features which are characteristic of the soil and which distinguish it from other soils.
9. INCLUSIONS AND VARIANTS - Most of the soil mapping units contain inclusions of soils other than the major named taxonomic units. These minor inclusions are too small to be separated out at the scale of mapping used and often consist of taxonomic units which are dominant in adjacent mapping units. Variants found within the mapping unit include unnamed soils which differ in some important morphological features from the defined range of the dominant soil taxonomic unit(s).
10. OVERALL DRAINAGE (CLASS) - The overall drainage of the soil, under the prevailing conditions of the site, is based on the classes defined by Taylor and Pohlen (1970). The class refers to natural drainage conditions and, for some soils, artificial drainage may raise the drainage class given by one or more classes.
11. SOIL LIMITATION CLASSES - The dominant soil within the mapping unit is rated according to the type and degree of soil limitations for various kinds of land use, namely, pastoral farming, cropping, horticulture, food production, forestry and urban use. For details of the classes used, see pp. 319-327.
12. LIMITATIONS FOR INTENSIVE SOIL USE - This gives a general indication of the main soil limitations for intensive use.
13. SOIL CLASSIFICATION - Classification of the soil is given in the common terms of the New Zealand genetic soil classification (Taylor and Pohlen, 1970).
14. SOIL CORRELATION - Correlations are given with the North Island soil sets (N.Z. Soil Bureau, 1954).
15. SOIL MAPPING UNITS AND AREA (ha) - The total area covered by the mapping unit is specified. Where a mapping unit is a complex of two or more soils no indication is given of the percentage area covered by each soil. Soil areas were calculated by a planimeter. Figures are given to the nearest ha.

22. REPRESENTATIVE PROFILE - In some cases a typifying profile has already been established for a soil series in which case the profile in this survey is referred to as a representative profile.

Map symbol (1)	Soil name (2)	Parent material (3)	Physiographic position and slope (4)	Elevation range (m) (5)	Mean annual rainfall range (mm) (6)	Brief soil profile description (7)	Characteristic soil and site features (8)	Inclusions and variants (9)	Overall drainage (class) (10)	Soil limitation classes (11)	Limitations for intensive soil use (12)	Soil classification (13)	Soil correlation (NZ Soil Bureau, 1954) (14)	Soil mapping units and area (ha) (15)
YELLOW-BROWN LOAMS														
Rc	Rowan soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephra > 250mm in thickness, overlying tephra p2 and p1 (Druce, 1966) on thin (with minor thick) volcanic ash, overlying laharic debris of Warea Formation. Depth of volcanic ash over Warea Formation ranges from 0.80 to >2m.	Level to very gently sloping sites on flat to rolling land, in tephra mantled upland laharic terrain.	310-760	2060-3860	A 30cm dark reddish-brown loam; friable; moderate fine nut structure; many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Bs 21cm dark yellowish-brown sandy loam; friable; weak fine nut structure; abundant iron coated lithic lapilli (Mn tephra). Bw 24cm dark brown loam; friable; weak medium blocky structure; few strongly weathered pumiceous lapilli. 2C dark greyish-brown coarse sand, with gravels; loose.	A well drained strongly leached, coarse textured soil. Upper horizons containing pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Dark reddish-brown top soils of moderately developed nut structure overlie yellowish-brown subsoils of weak blocky structure. Profiles are characterised by illuvial iron oxide coatings on ped faces and on the few to many lithic and pumiceous lapilli. Rowan soils grade into Riverlea soils as leaching becomes less intense.	No inclusions noted. Mapped only within soil associations. A placic variant is recognised.	Well drained.	Pastoral farming, 1A (below 460m) 3D (above 460m) Cropping, 3B Horticulture, 4 Food production, 2 (below 460m) 3 (above 460m) Forestry, 2A (below 460m) 2C (above 460m) Urban use, 1	Low nutrient status due to strong leaching and coarse textures. Limitations of slope at higher elevations.	Strongly leached iron illuvial yellow-brown loam.	Patua sandy loam and loam (70).	Rc-Mw 940; Rc-Mk 890.
RCh	Rowan hill soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephra, > 250mm in thickness, overlying tephra p2 and p1 (Druce, 1966) on thin (with minor thick) volcanic ash overlying laharic debris of Warea Formation.	Sides and crests of lahar mounds in tephra mantled upland laharic terrain.	360-460	2260-2680	A 12cm very dark greyish-brown coarse sandy loam; very friable; moderately developed, fine nut structure; many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). BA 6cm dark yellowish-brown sandy loam; very friable; weakly developed fine nut structure; many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Bw 36cm dark brown loam; firm; weak coarse blocky structure; few iron coated pumiceous lapilli. 2C grey loamy coarse sand; loose; massive; many gravels.	A well drained, strongly leached, coarse textured soil. Profiles similar to Rowan soils but shallower than those on adjacent level sites. Stones and fragments of laharic material may be incorporated in the profile. Boulders may be present on the surface.	No inclusions noted.	Well drained.	Pastoral farming, 4A Cropping, 4 Horticulture, 4 Food production, 3 Forestry, 4 Urban use, 4	Low nutrient status due to strong leaching and coarse textures. Profiles can have cemented laharic materials at shallow depths and contain boulders and stones.	Strongly leached, iron illuvial yellow-brown loam.	Patua sandy loam and loam (70).	RCh-Mw 40.

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Rv	Riverlea soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephra > 250mm in thickness, overlying tephra p2 and p1 (Druce, 1966) on thin (with minor thick) volcanic ash, overlying laharic debris.	Level to very gently sloping sites in flat to easy rolling land, in tephra mantled lowland laharic terrain.	220-310	1730-2060	Ap 21cm very dark greyish-brown loam with gritty modification; very friable; moderately developed fine nut structure; abundant gravels (Manganui tephra). BA 13cm dark brown sandy loam; friable; moderately developed fine crumb and nut structure; many gravels (Manganui tephra). Bw1 49cm dark brown loam with gritty modification; friable; moderately coarse blocky structure; few moderately to strongly weathered pumiceous lapilli. Bw2 35cm dark yellowish-brown sandy clay loam; firm; weak blocky structure. Cr dark greyish-brown, weakly cemented laharic debris.	A well drained loamy textured soil, characterised by lithic and pumiceous lapilli Kaupokonui, Maketawa and Manganui tephra are concentrated in the A and upper B horizon. Very dark greyish-brown to very dark brown topsoils of moderately well developed fine nut and crumb structure overlie dark brown to dark yellowish-brown, weakly structured B horizons. Lithic and pumiceous lapilli occur, scattered or concentrated in bands, in the lower B horizons and become more strongly weathered with depth. Associated with Makaka and Mangawhero soils.	Deep phase where depth to laharic deposits is >2m. Localised bouldery and stony phases.	Well drained.	Pastoral farming, 1A Cropping, 1B Horticulture, 2 Food production, 1A Forestry, 2A Urban use, 1	Occasional boulders in a few profiles may restrict deep root development.	Moderately to strongly leached yellow-brown loam.	Stratford sand (68)	Rv-Mw 620 (Rv >50%) Rv-Mk 770
Mk	Makaka soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephra > 250mm in thickness, overlying tephra p2 and p1 (Druce, 1966) on thin (with minor thick) volcanic ash overlying laharic debris. The thickness of volcanic ash over laharic debris ranges from 0.60 to 2m.	Depressions in flat to gently undulating land, in tephra mantled upland and lowland laharic terrain.	220-760	1730-3860	Ap 15cm dark brown loam; very friable; moderately developed fine nut and crumb structure; few to many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). BA 13cm dark greyish-brown sandy loam; very friable; strongly developed medium nut structure; few to many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Bw 30cm brown sandy loam; very friable; weak medium blocky structure a few red mottles; many iron coated lithic lapilli (Manganui tephra). Bg1 26cm dark yellowish-brown loam; friable; weak coarse blocky structure; few to many dark reddish-brown mottles; few iron oxide concretions; few to many pumiceous lapilli. Bg2 24cm yellowish-brown sandy clay loam; friable; weak coarse blocky structure; many dark reddish-brown mottles; many iron oxide concretions; many pumiceous lapilli. Cg dark greyish-brown loamy sand; loose; massive; stones, gravels and concretions present.	Imperfectly drained coarse-textured soil. Upper horizons formed from Kaupokonui, Maketawa and Manganui tephra. Upper horizons are well drained and resemble those of Rowan or Riverlea soils. Lower horizons show the influence of ground water, within 1m of the surface and have pale colours, mottles and concretions. Occurs in association with Rowan and Mangawhero soils.	Deep phase where depth to laharic deposits is >2m. Localised bouldery and stony phases.	Imperfectly drained.	Pastoral farming, 1B Cropping, 1C (below 320m) 3B (between 320-400m) Horticulture, 2 Food production, 1B, 2 Forestry, 2A Urban use, 2	Poor drainage of lower sub-soil. Iron oxide pans in some profiles. Piped drainage would minimise periods of waterlogging and reduce poaching of pastures.	Weakly gleyed yellow-brown loam.	Inglewood coarse sandy loam (69).	Mk-Mw 1330 Mk-Rv 100 (Mk >50%)

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Lo	Lowgarth soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) comprised of young <i>lapilli showera</i> Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness overlying tephras p2 and p1. (Druce, 1966) E5 and E4. Volcanic ash is > 2m thick.	Level or gently sloping sites on flat to rolling land, in tephra mantled lowland laharic terrain.	230-340	2050-2260	Ap 23cm dark brown loam; very friable; moderately fine nut and crumb structure; abundant lithic lapilli (Manganui tephra) Bw1 29cm dark yellowish-brown sandy loam; friable; weak fine crumb structure; abundant lithic lapilli (Manganui tephra). Bw2 40cm yellowish-brown sandy clay loam; friable; weak coarse blocky structure; many pumiceous lapilli averaging 20mm in diameter. Bw3 yellowish-brown sandy clay loam; firm; weak coarse blocky structure; abundant strongly weathered pumiceous lapilli.	A deep well drained, sandy loam textured soil, with many lithic and pumiceous lapilli. Very dark greyish-brown to dark brown topsoils of moderately well developed nut and crumb structure overlie weakly structured yellowish-brown subsoils. Profiles are characterised by gravelly upper horizons, while the lower horizons contain pumiceous lapilli, either scattered or concentrated in bands.	Stratford soils. An imperfectly drained variant is recognised.	Well drained.	Pastoral farming, 1A Cropping, 1B Horticulture, 2 Food production, 1A Forestry, 1A Urban use, 1	Coarse textures and low nutrient status due to leaching.	Moderately to strongly leached yellow-brown loam.	Inglewood coarse sandy loam (69).	Lo 1960
Lo ₁	Lowgarth soils, strongly rolling phase.	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) comprised of young <i>lapilli showera</i> Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1 (Druce, 1966) E5 and E4. Volcanic ash is > 2m thick.	Level to sloping sites on strongly rolling land, in tephra mantled lowland laharic terrain.	230-340	2050-2260	Similar to Lowgarth soils.	Similar to Lowgarth soils.	Lowgarth soils. Stratford soils, strongly rolling phase.	Well drained.	Pastoral farming, 1A Cropping, 2C Horticulture, 3D Food production, 2 forestry, 1A Urban use, 1	Coarse textures and lower nutrient status due to leaching. Limitations of slope.	Moderately to strongly leached yellow-brown loam.	Inglewood coarse sandy loam (69)	Lo ₁ 970
LoH	Lowgarth hill soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) comprised of young <i>lapilli showera</i> Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1 (Druce, 1966) E5 and E4. Volcanic ash is > 2m thick.	On tephra mantled hilly slopes on the ring plain.	230-275	2050-2260	Similar to Lowgarth soils.	A deep well drained, sandy loam textured soil, with many lithic and pumiceous lapilli. Similar to Lowgarth soils.	Stratford hill soils.	Well drained.	Pastoral farming, 4A Cropping, 4 Horticulture, 4 Food production, 3 Forestry, 4 Urban use, 4	hilly topography restricting the use of agricultural machinery.	Moderately to strongly leached yellow-brown loam.	Inglewood coarse sandy loam (69)	LoH 17

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Kul	Kahul soils	Moderately weathered andesitic volcanic ash, comprised of traces of <i>young lapilli showers</i> , < 250mm thickness of Kaupokonui, Maketawa and Manganui tephiras p2 and p1, (Druce, 1966) on fine textured ashes over laharic debris of Opua and Marea Formations.	Level to very gently sloping sites in flat to easy rolling land in volcanic ash mantled lowland laharic terrain.	210-270	1660-1900	Ap 23cm very dark greyish-brown loam; very friable; moderate fine nut and crumb structure; few lithic (Manganui tephira) and pumiceous lapilli. Bw1 11cm dark brown loam, friable, weak fine nut structure; Bw2 22cm dark yellowish-brown loam; friable; weak coarse blocky structure; scattered lithic and pumiceous lapilli. Bw3 54cm dark yellowish-brown sandy loam; firm; weak coarse blocky structure; pumiceous and lithic lapilli concentrated in a band. 2C dark greyish-brown loamy coarse sand; loose; massive.	A well drained loamy textured soil, derived from volcanic ash, on loose or cemented laharic deposits. Dark coloured topsoils containing traces of <i>young lapilli showers</i> (Kk, Mt and Mn tephiras). Brown to yellowish-brown weakly structured subsoils, which contain pumiceous lapilli and lithic lapilli. The Kk, Mt and Mn tephiras are absent altogether in Eymont soils. Occurs in association with Tipuka and Awatuna soils.	Stratford soils, where volcanic ash > 2m.	Well drained.	Pastoral farming, 1A Cropping, 1B Horticulture, 1A Food production, 1A Forestry, 2A Urban use, 1	Cemented laharic materials, at depths as shallow as 0.40m may restrict deep root development.	Moderately leached yellow-brown loam.	Eymont brown loam (66)	Kul-Tk 180 (Kul >50%)
Tk	Tipoka soils	Moderately weathered andesitic volcanic ash comprised of traces of <i>young lapilli showers</i> < 250mm thickness of Kaupokonui, Maketawa and Manganui tephiras, overlying tephiras p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris of Opua and Marea Formations. The thickness of volcanic ash over laharic debris ranges from 0.50 to 2m.	Depressions in flat to gently undulating land in volcanic ash mantled lowland laharic terrain.	210-270	1660-1900	Ap 18cm very dark brown fine sandy loam; very friable; moderately fine nut and crumb structure; few lithic lapilli (Manganui tephira). Bw 34cm very dark greyish-brown fine sandy loam; friable; weak fine nut structure; few lithic lapilli (Manganui tephira). Bg1 23cm brown loam; friable; weak coarse blocky structure; few yellowish-red mottles; scattered strongly weathered pumiceous lapilli. Bg2 25cm dark yellowish-brown sandy loam; firm; massive to weak coarse blocky structure; common, fine distinct strong brown mottles; strongly weathered pumiceous lapilli concentrated in a band.	Imperfectly drained loamy textured soil derived from between 0.50 and 2m of volcanic ash on laharic debris. Upper horizons are well drained and resemble those of Kahul soils. Lower horizons show the influence of ground water, within 1m of the surface and have pale colours, mottles and concretions. Occurs in association with Kahul and Awatuna soils.	No inclusions noted - mapped only within associations.	Imperfectly drained.	Pastoral farming, 1B Cropping, 1C Horticulture, 1B Food production, 1B Forestry, 2A Urban use, 2	Poor drainage of lower subsoil. Cemented laharic materials at depths as shallow as 0.50m impede drainage in low lying places. Shallow piped drainage may be required to maintain intensive grazing.	Weakly gleyed yellow-brown loam.	Glenn silt loam (100)	Tk-Kul 220

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St	Stratford soils	Moderately weathered andesitic volcanic ash, comprised of Manganui tephra < 250mm in thickness on pumiceous lapilli-bearing ash showers, tephra p2, p1 (Druce, 1966) E5 and E4, on thick ash.	Level or very gently sloping sites on flat to rolling land, in volcanic ash mantled lowland laharic terrain.	120-290	1330-1810	Ap 35cm very dark brown loam; very friable; moderately developed coarse blocky structure breaking to fine crumb; many pumiceous lapilli, rare lithic lapilli (Manganui tephra). Bw1 30cm dark brown sandy loam, friable; weak medium blocky breaking to fine crumb; abundant pumiceous lapilli, occasional lithic lapilli. Bw2 35cm yellowish-brown loam; friable; weak medium blocky structure; scattered pumiceous lapilli.	A deep well drained loamy textured soil. Dark coloured topsoils of loam or silt loam texture and moderately well developed crumb structure overlie paler coloured subsoils of weak blocky structure. The subsoil in Stratford soils is characterised by pumiceous lapilli, which are usually concentrated in distinct bands but may be scattered throughout the profile. The lapilli are weakly weathered in the upper B horizons but become more strongly weathered with depth.	Lowgarth soils. Ngaere soils, where Stratford soils mapped alone.	Well drained.	Pastoral farming, 1A Cropping, 1A Horticulture, 1A Food production, 1A Forestry, 1A Urban use, 1	Potential limitations of nutrients.	Moderately leached yellow-brown loam.	Stratford sandy loam (66b). Stratford sand (6B).	St 7890
St ₁	Stratford soils, strongly rolling phase.	Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1 (Druce, 1966) E5 and E4, on thick ash.	Level to sloping sites on strongly rolling land, in volcanic ash mantled lowland laharic terrain.	120-280	1330-1810	Similar to Stratford soils.	Similar to Stratford soils.	Lowgarth soils, strongly rolling phase.	Well drained.	Pastoral farming, 1A Cropping, 2C Horticulture, 3D Food production, 2 Forestry, 1A Urban use, 1	Potential limitations of nutrients.	Moderately leached yellow-brown loam.	Stratford sandy loam (66b)	St 1640

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StH	Stratford hill soils	Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1 (Orcue, 1966) E5 and E4, on thick ash or sedimentary rocks, silty sandstone deposits.	On volcanic ash mantled hill slopes, on the ring plain and in the dissected hill and steep-land country, east of Eltham.	120-290	1330-1810	Ap 22cm very dark brown silt loam; friable; moderately fine nut structure; few lithic lapilli (Manganui tephra). Bw1 20cm dark brown to brown loam; friable; weakly developed medium nut structure; few to many pumiceous lapilli. Bw2 33cm dark yellowish-brown sandy loam; firm; weak coarse blocky structure; scattered strongly weathered pumiceous lapilli. Bw3 35cm yellowish-brown sandy loam; firm; massive; scattered strongly weathered pumiceous lapilli; rare fragment of underlying silty sandstone.	A well drained loamy textured soil. Dark coloured top-soils of moderately well to strongly developed blocky and nut structure, overlie weakly structured, yellowish-brown subsoils. The profile contains moderately to strongly weathered pumiceous lapilli, which can be scattered or concentrated in bands. The lapilli tend to be more strongly weathered with depth. The release of abundant mafic crystals gives a speckled appearance which is a feature of the lower B horizons. In some cases fragments of the underlying silty sandstone, may be incorporated into the volcanic ash subsoil.	Stratford soils. Lowgarth hill soils. Whangamomona steep-land soils.	Well drained.	Pastoral farming, 4A Cropping, 4 Horticulture, 4 Food production, 3 Forestry, 4 Urban use, 4	Hilly topography, restricting the use of agricultural machinery.	Moderately leached yellow-brown loam.	Stratford sandy loam hill soil (66bH)	StH 1850 StH-St 1690 StH-St ₁ 250 (StH >50%)
Ng	Ngaere soils	Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness on pumiceous lapilli-bearing ash showers tephra p2, p1 (Orcue, 1966) E5 and E4 on thick volcanic ash.	Level or near level sites and in depressions in flat to gently undulating land, in tephra mantled lowland laharic terrain.	150-240	1470-1860	Ap 23cm very dark brown loam; friable; moderate to weak fine nut structure; rare lithic lapilli (Manganui tephra). Bw1 31cm dark brown to brown sandy loam; friable; weak medium nut structure; many pumiceous lapilli. Bw2 28cm brown loam with gritty modification; firm; weak medium and coarse blocky structure; scattered pumiceous lapilli. Bg 18cm strong brown sandy loam to loam; firm; massive; strongly weathered scattered pumiceous lapilli; many distinct yellowish-red mottles.	An imperfectly drained loamy textured soil. Occurs in association with Stratford soils. Upper horizons are well drained and resemble those of Stratford soils. Lower horizons show the influence of ground water, within 1m of the surface and have pale colours, mottles and concretions.	Eltham soils. Localised poorly drained areas.	Imperfectly drained.	Pastoral farming, 1B Cropping, 1C Horticulture, 1B Food production, 1B Forestry, 1B Urban use, 2	Poor drainage of lower sub-soil. Piped drainage may be required to maintain intensive grazing.	Weakly gleyed yellow-brown loam.	Stratford sandy loam (66b)	Ng-St 210 (Ng >50%)

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Stv	Stratford soils, fine topsoil variant.	Moderately weathered andesitic volcanic ash, comprised of strongly weathered tephra, p2 and p1, (Druce, 1966), E5 and E4, on thick volcanic ash.	Level or very gently sloping sites on flat to easy rolling land, on volcanic ash mantled terraces.	90-240	1500-1900	Ap 18cm very dark greyish-brown silt loam; friable; moderately developed fine and very fine nut and crumb structures; few scattered pumiceous lapilli < 10mm in diameter.	A well drained, silt loam over deep, loamy textured soil. Dark topsoils of moderately developed crumb and nut structure overlie yellowish-brown weakly structured subsoils. The upper B horizon is typified by containing scattered strongly weathered, pumiceous lapilli, which average less than 10mm and become a speckled ash in the subsoil.	Stratford soils.	Well drained.	Pastoral farming, 1A Cropping, 1A Horticulture, 1A Food production, 1A Forestry, 1A Urban use, 1	Potential limitations of nutrients.	Moderately leached yellow-brown loam.	New Plymouth black loam (67a).	Stv 1250
GLEYSOILS														
Mw	Mangawhero soils	Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maetawa and Manganui tephra > 250mm in thickness, overlying tephra p2 and p1, (Druce, 1966) on thin (with minor thick) volcanic ash overlying laharic debris. The thickness of volcanic ash over laharic debris ranges from 0.50 to 2m.	Depressions in flat to gently undulating land in tephra mantled upland and lowland laharic terrain.	220-760	1730-3860	Ap 12cm very dark brown loam; very friable; strongly developed fine nut structure; many pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Bg1 14cm dark brown to brown sandy loam; very friable; moderately fine nut structure; few red mottles; many iron coated pumiceous and lithic lapilli (Kk, Mt and Mn tephra). Bg2 27cm light yellowish-brown sandy loam; friable; weak coarse blocky structure; common red mottles; iron oxide concretions; abundant pumiceous and lithic lapilli. Bg3 28cm light yellowish-brown sandy clay loam; firm; massive; many dark greyish-brown mottles; many iron oxide concretions; many pumiceous lapilli. Cr grey, weakly cemented laharic breccia; dark greyish-brown mottles.	A poorly drained loamy textured soil. Upper gravelly horizons derived from Kk, Mt and Mn tephra. Occurs in association with Rowan, Riverlea and Makaka soils. The effect of ground water extends up to and sometimes into topsoils. Subsoils have pale colours, mottles, iron oxide concretions and sometimes vesicular iron oxide pans.	Awatuna soils. A peaty topsoil in some profiles.	Poorly drained.	Pastoral farming, 1B Cropping, 3B Horticulture, 3A Food production, 2 Forestry, 3C Urban use, 2	Poor drainage. Thick iron oxide pans in some profiles may restrict deep root development. Riped drainage would minimise periods of water-logging and reduce poaching of pastures. Mole drains may be a useful secondary treatment.	Gley soil.	Awatuna loam (100a).	Mw-Rv 160 (Mw > 50%) Mw-Mk 160 (Mw > 50%)

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At	Awatuna soils	Moderately weathered andesitic volcanic ash, comprised of traces of young lapilli showers < 250mm in thickness of Kaupokonui, Maketawa and Manganui tephrae, overlying tephrae p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris. The thickness of volcanic ash over laharic debris ranges from 0.60 to 1.50m.	Depressions in flat to gently undulating land in volcanic ash mantled low-land laharic terrain.	210-270	1660-1900	Ap 18cm dark grey to dark greyish-brown silt loam; very friable; strongly developed fine nut and crumb structure; few lithic and pumiceous lapilli. Bg1 17cm brown loam; very friable; weak fine nut structure; few yellowish-red mottles; few concretions. Bg2 40cm light yellowish-brown sandy clay loam; firm; weak coarse blocky structure; many dark reddish-brown mottles; many iron oxide concretions; scattered lithic and pumiceous lapilli. 2C brown to light yellowish-brown loamy coarse sand; loose; massive; abundant reddish-brown mottles; many iron oxide concretions.	A poorly drained loamy textured soil, derived from between 0.60 to 1.50m of volcanic ash on laharic debris. The effect of ground water extends up to and sometimes into topsoils. A few pumiceous and lithic lapilli (Kk, Mt and Mn tephrae) may be found in the A and upper B horizons. The roots are usually iron stained. Subsoils have colours varying from brown to light yellowish-brown. Mottles and iron concretions increase with depth in the profile. Vesicular iron oxide pans may be present at the textural boundary between the andesitic lapilli and laharic debris. Occurs in association with Kahui and Tipoka soils.	Mangawhero series.	Poorly drained.	Pastoral farming, 1B Cropping, 2B Horticulture, 2 Food production, 2 Forestry, 3C Urban use, 2	Poor drainage. Cemented laharic materials at depths as shallow as 0.60m. Piped drainage would minimise period of water-logging and reduce poaching of pastures. Mole drains may be a useful secondary treatment.	Gley soil.	Glenn silt loam (100)	At-Ku1 170
Ok	Okato soils	Weakly weathered andesitic alluvial sands and gravels.	Depressions in alluvial fans, levées and river terraces, within laharic terrain.	120-460	1330-2680	A 24cm very dark greyish-brown to dark greyish-brown silt loam; very friable; moderately developed very fine nut structure. Bg1 18cm dark greyish-brown loam; very friable; weak medium nut structure; few strong brown mottles. Bg2 21cm very dark greyish-brown coarse sand; very friable; weak medium nut structure; few yellowish-red mottles. Cg dark brown silt; loose; single grain; common dark red mottles.	Imperfectly and poorly drained soil derived from similar parent materials to Hangatahua soils. Ground water may cause gleying effects in either the entire subsoil or only the lower subsoil. There can be A/C profiles, with the B horizons absent. Do not receive regular additions of alluvium except where very close to river channels on flood plains.	No inclusions noted - mapped only within soil associations.	Imperfectly and poorly drained.	Pastoral farming, 2B Cropping, 2B Horticulture, 2 Food production, 2 Forestry, 3C Urban use, 3	Coarse textures and poor or imperfect drainage. Piped drainage would minimise period of water-logging and reduce poaching of pastures. Recognised as areas of future liability to flooding.	Gley soil.	Esk (1b)	Ok-Hn 200

Map symbol (1)	Soil name (2)	Parent material (3)	Physiographic position and slope (4)	Elevation range (m) (5)	Mean annual rainfall range (mm) (6)	Brief soil profile description (7)	Characteristic soil and site features (8)	Inclusions and variants (9)	Overall drainage (class) (10)	Soil limitation classes (11)	Limitations for intensive soil use (12)	Soil classification (13)	Soil correlation (NZ Soil Bureau, 1954) (14)	Soil mapping units and area (ha) (15)
INTERGRADE BETWEEN YELLOW-BROWN LOAMS AND RECENT SOILS														
Hn	Hangatahau soils.	Weakly weathered andesitic alluvial sands and gravels.	Flat alluvial fans, levées and river terraces, within lahatic terrain.	120-460	1330-2680	Ap 18cm very dark brown silt loam; very friable; moderately developed medium nut structure; few pumiceous lapilli. Bw1 15cm dark brown sandy loam, very friable; weak medium nut structure; few pumiceous and lithic lapilli. Bw2 32cm dark yellowish-brown loamy sand, very friable; very weak fine crumb structure; scattered pumiceous lapilli. C 40cm very dark greyish-brown fine sand, loose; single grain; few pumiceous lapilli.	Well drained soil derived from alluvium, varying in texture from silt loam to coarse sand. Dark coloured topsoils of moderate or weak nut structure, overlie subsoils of very weak structure, which rest on grey, loose, fine to coarse sands. Soils may or may not contain gravels, stones or boulders. There can be A/C profiles, with the B horizons absent. Do not receive regular additions of alluvium, except where very close to river channels on flood plains.	No inclusions noted - mapped only within soil association.	Well drained.	Pastoral farming, 1A Cropping, 1A,2A Horticulture, 2 Food production, 1A,2 Forestry, 1A,2A Urban use, 3	Coarse textures and a tendency to dry out in summer. Recognised as areas of future liability to inundation by debris flows.	Inter-grade between yellow-brown loams and recent soils.	Esk (1b)	Hn-Dk 493 (Hn > 50%)
RECENT SOILS														
Tah	Tahurangi soils.	Thin volcanic ash (Tahurangi Formation) on older volcanic ashes.	Upper slopes of Mt. Egmont. Generally on ridge crests and plateaus.	760-1100	3000-4500	Ah 8cm dark greyish-brown fine sandy loam; very friable; weak fine crumb structure; (Tahurangi Formation). Cs 16cm dark brown loamy coarse sand; very friable; weak crumb structure few to many iron coated lithic and pumiceous lapilli (Burrell Formation - Punihō Lapilli). Cu gravels and sands with dark reddish-brown coatings of iron oxide.	Very strongly leached soil with thin, dark sandy loam topsoils of weak crumb structure over older, coarse-textured volcanic materials.	No inclusions noted.	Moderately well drained.	Pastoral farming, 7 Cropping, 7 Horticulture, 4 Food production, 3 Forestry, 6 Urban use, 5	Extremes of climate at very high elevations.	Very strongly leached iron illuvial recent soil.	Mountain soils.	Tah-TahH 460
TahH	Tahurangi hill soils.	Thin volcanic ash (Tahurangi Formation) on older volcanic ashes.	On hilly slopes of Mt. Egmont.	760-1100	3000-4500	Similar to Tahurangi soils.	Very strongly leached soil with thin, dark sandy loam topsoils of weak crumb structure over older, coarse-textured volcanic materials.	No inclusions noted.	Moderately well drained.	Pastoral farming, 7 Cropping, 7 Horticulture, 4 Food production, 3 Forestry, 6 Urban use, 5	Extremes of climate at very high elevations.	Very strongly leached, iron illuvial recent soil.	Mountain soils.	Tah - TahH

Map Symbol (1)	Soil name (2)	Parent material (3)	Physiographic position and slope (4)	Elevation range (m) (5)	Mean annual rainfall range (mm) (6)	Brief soil profile description (7)	Characteristic soil and site features (8)	Inclusions and variants (9)	Overall drainage (class) (10)	Soil limitation classes (11)	Limitations for intensive soil use (12)	Soil classification (13)	Soil correlation (NZ Soil Bureau, 1954) (14)	Soil mapping units and area (ha) (15)
LITHOSOLS AND SKELETAL SOILS														
S	Unnamed subalpine steepland soils.	Recent volcanic ashes, colluvium	Upper slopes of Mt. Egnont above forest zone.	1100-1525	4000-6000	Not examined	Formed under subalpine scrub, herbfield and tussock.	Not examined	Moderately well drained.	Pastoral use, 7 Cropping, 7 Horticulture, 4 Food production, 3 Forestry, 7 Urban use, 5	Extremes of climate at very high elevations.	Lithosols and Skeletosols	Mountain soils.	5 210
A1	Unnamed alpine steepland soils.	Solid rock and scree.	Uppermost slopes of Mt. Egnont.	1525-2518	6000-8000	Not examined	Very little or no vegetation cover.	Not examined	Moderately well drained.	Pastoral use, 7 Cropping, 7 Horticulture, 4 Food production, 3 Forestry, 7 Urban use, 5	Extremes of climate at very high elevations.	Lithosols and skeletosols	Mountain soils.	A1 200
ORGANIC SOILS														
E1	Eltham soils.	Woody peat with inter-bedded andesitic tephra layers.	Level sites in flat land on the edge of the volcanic ring plain.	210-220	1620-1890	Ap 20cm dark reddish-brown peaty loam; friable; strong fine crumb and nut structure. Bu 2cm pumiceous lapilli band, averaging 1mm in diameter (Kk, and Mt tephra). Oh1 8cm dark reddish-brown peat; common charcoal fragments; many dusky red wood fragments > 10mm; structureless. Bh1 22cm dark brown peat, with distinct band of lithic lapilli (Mn tephra) friable; structureless. Oh2 13cm very dark brown humic loam; friable; structureless; many wood fragments; moderately to strongly decomposed. Bh2 35cm dark brown humic loam with lithic and pumiceous lapilli (p2, Druce, 1966) occurring in pockets; friable; structureless. Oh3 40cm brownish-black peat, friable; structureless.	A poorly drained peat with interbedded thin andesitic tephra layers. A dark reddish-brown to dark brown topsoil, with silt loam to peaty loam texture and strongly developed nut structure. The subsoil tends to be very dark brown to black, becoming a dark reddish-brown, structureless peat, with depth. The distribution of pumiceous and lithic lapilli is irregular and can be concentrated in a band or pocket. Pumiceous lapilli can be 1mm or less, and impart a gritty modification and speckled appearance. The distinctive lithic-rich Manganui tephra has been identified at depths varying from 0.30 to 0.70m. Pumiceous lapilli become strongly weathered with depth and can be greater than 20mm in diameter. Partly decomposed fragments of wood, twigs and fibres are a feature throughout the profile, and are concentrated at approximately 0.90m. The water-table usually occurs just below 1m but it can be deeper or as shallow as 0.60m.	Ngaere soils.	Poorly drained.	Pastoral farming, 3C Cropping, 2B Horticulture, 2 Food production, 1B Forestry, 3C Urban use, 3	Poor drainage instability, and presence of timber. Surface drainage i.e. bedding and box drains, would minimise periods of water-logging.	Organic soil.	Plako peaty loam and loamy peat (108)	E1 2670

Map symbol (1)	Soil name (2)	Parent material (3)	Physiographic position and slope (4)	Elevation range (m) (5)	Mean annual rainfall range (mm) (6)	Brief soil profile description (7)	Characteristic soil and site features (8)	Inclusions and variants (9)	Overall drainage (class) (10)	Soil limitation classes (11)	Limitations for intensive soil use (12)	Soil classification (13)	Soil correlation (NZ Soil Bureau, 1954) (14)	Soil mapping units and area (ha) (15)
STEEPLAND SOILS RELATED TO YELLOW-BROWN EARTHS														
Wg5	Whangamomona steepland soils.	Quartzo-feldspathic moderately silty consolidated silty sandstone the dominant lithology. Subdominant lithologies include weakly consolidated sandstone, hard sandstone, silty mudstone and varying amounts of volcanic ash. Occasional outcrops of shelly limestone also occur.	On steep and very steep slopes in dissected Tertiary sedimentary hill and steepland country.	120-490	1500-1900	A 24cm brown fine sandy loam; friable; strong to moderately developed fine nut structure; many silty sandstone fragments averaging 10cm in diameter.	A shallow imperfectly drained sandy loam-textured soil, derived from silty sandstone. Dark greyish-brown to brown topsoils, with strong to moderately well developed fine nut structure, overlies thin light yellowish-brown to brownish yellow subsoils. Mottles can be a feature of the subsoil and increase with depth. Fragments of silty sandstone may be present throughout the profile and there can be a sharp and distinct boundary to the moderately consolidated silty sandstone.	Stratford soils, fine topsoil variant. Stratford hill soils. Whangamomona soils ridge phase. Whangamomona soils eroded slope phase. Whangamomona soils accumulation slop phase. Tahora steepland soils.	Moderately well drained.	Pastoral farming, 6 Cropping, 6 Horticulture, 4 Food production, 3 Forestry, 6 Urban use, 5	Limitations of slope and liability to erosion.	Steepland soil related to yellow-brown earth.	Whangamomona complex (116a) Whangamomona silt loam (116)	Wg5 6000
						Bw 17cm light yellowish-brown to brownish-yellow sandy loam; friable; weakly developed fine nut structure; few yellowish-red discolorations along root channels.								
						C/B light yellowish-brown with strong brown distinct, coarse mottles; moderately consolidated silty sandstone.								

APPENDIX VSOIL LIMITATIONS FOR USESOIL RATINGS FOR LAND USE

In this section the soils of Eltham County are classified according to the kind and severity of soil limitations for pastoral, cropping, horticultural, forestry and urban uses and also according to their value for food production in terms of the Town and Country Planning Act 1977 (Tables V-1 - V-6).

The wide range of soils present differ markedly in their capability and potential for different types of land use.

Since land use depends on socio-economic factors, as well as the physical properties of land, these classifications must not be regarded as direct recommendations for any specific use. Any specific use for a particular property should be checked by field examination.

In the survey most of the mapping units are soil associations comprising different soil units. Since the units within an association may each have very different limitations for certain land uses, rating of mapping units is impractical and it is the component members that have been rated.

In order to rate part of an association for any land use, it is necessary to determine in the field the relative extent of the individual members within that part of the association, and apply ratings to the individual members so identified.

The tables indicate that although a considerable number of the soils have only slight limitations of drainage and moderate nutrient requirements for a wide range of uses, several of the soils have severe limitations, which restrict production and use.

On the lowland laharic terrain, river flats and terraces, the limitations for a wide range of uses are affected by laharic debris at a shallow depth, which impedes soil drainage and root development.

Nutrient deficiencies, slope and erosion may also be limiting.

In the case of the upland laharc terrain, subalpine, alpine and steepland terrain, elevation and adverse climatic conditions restrict or preclude agricultural and horticultural land use.

Small scale, very generalised inset maps showing ratings for value for food production and limitations for cropping are shown in Figures V-1 and V-2.

Table V-1 Soil limitations for pastoral use

Soils are classified using the system of Gibbs (1963), as modified by Aitken et al., (1978), except that an extra class (7) has been added.

Class 1	- Soils of flat and rolling land with slight soil limitations to pastoral use.
1A	- Limitations of nutrient deficiencies. Stratford soils; Stratford soils, fine topsoil variant; Stratford soils, strongly rolling phase; Lowgarth soils; Lowgarth soils, strongly rolling phase; Hangatahua soils; Riverlea soils; Kahui soils; Rowan soils (below 460m).
1B	- Limitations of drainage and nutrients. Ngaere soils; Tipoka soils; Makaka soils; Awatuna soils; Mangawhero soils.
Class 2	- Soils of flat and rolling land with moderate soil limitations to potential pastoral use.
2A	- Limitations of insufficient moisture and, to a lesser extent, erosion and moderate nutrient deficiencies. Not present in this survey.
2B	- Limitations of coarse texture, and/or poor drainage. Okato soils.
Class 3	- Soils of flat and rolling land with severe limitations to pastoral use.
3A	- Limitations of salinity with coarse texture and erosion potential. Not present in this survey.
3B	- Limitations of subsoil pans and drainage. Not present in this survey.

- 3C - Limitations of excessive moisture or shrinkage.
Eltham soils.
- 3D - Limitations of elevation, with cool wet climate.
Rowan soils (above 460m elevation).
- 3E - Limitations of frequent dryness, nutrients and susceptibility to wind erosion.
Not present in this survey.
- Class 4 - Soils of hilly land with slight to moderate limitations for pastoral use.
- 4A - Limitations of nutrients.
Stratford hill soils; Lowgarth hill soils; Rowan hill soils.
- Class 5 - Soils of steep land with moderate to severe soil limitations for pastoral use.
Not present in this survey.
- Class 6 - Soils of moderately steep, moderately steep to steep, and steep land with severe to very severe soil limitations for pastoral use.
Limitations of low to very low nutrient status and susceptibility to severe erosion.
Whangamomona steepland soils.
- Class 7 - Soils of high elevation on Mt. Egmont unsuitable for pastoral use.
Tahurangi hill soils; Tahurangi soils; unnamed subalpine soils; unnamed alpine soils.

Table V-2Soil limitations for cropping

The classification follows that of Cutler (1967) as modified by Aitken *et al.*, (1978). As with the classification for horticultural crops it is a generalised scheme and the limitations may be less severe for some crops than others.

- Class 1 - Soils of flat and easy rolling land with minimal to slight soil limitations for crop production.

- Class 1A - Limitations of minimal nutrient deficiencies. These are soils which can be cultivated for most of the year and are suitable for a wide range of crops.
- Stratford soils; Hangatahua soils (in part); Stratford soils, fine topsoil variant.
- 1B - Limitations of medium to high nutrient requirements.
- Kahui soils; Riverlea soils; Lowgarth soils.
- 1C - Slight limitations of imperfect to poor drainage. These soils require some drainage before they can be cropped successfully and the period during the year when they can be cultivated is somewhat restricted.
- Ngaere soils; Tipoka soils; Makaka soils; (below 320m).
- Class 2 - Soils of flat and rolling land with moderate soil limitations for crop production.
- 2A - Limitations of insufficient moisture. These soils are shallow and stony and irrigation is necessary for cropping.
- Hangatahua soils (in part).
- 2B - Limitations of poor drainage and compact subsoils. These soils are not as versatile as those of Class 1 and cropping is largely restricted to annual cropping of cereals and field crops in rotation with pasture.
- Awatuna soils; Okato soils; Eltham soils.
- 2C - Limitations of slope.
- Stratford soils, strongly rolling phase; Lowgarth soils, strongly rolling phase.
- Class 3 - Soils of flat and rolling land with severe soil limitations for crop production.
- 3A - Limitations of excessive drainage and susceptibility to flooding. Some cropping could be done on the deeper soils but the risk of crop loss is high.
- Not present in this survey.
- 3B - Limitations of medium to high altitudes and of wet low lying land which is not easily drained.
- Rowan soils; Mangawhero soils; Makaka soils (between 460-320m elevation).
- Class 4 - Soils of hilly land with moderate to severe limitations for crop production.
- Limitations of slope, shallow profiles and minor risk of erosion.
- Stratford hill soils; Lowgarth hill soils; Rowan hill soils.

- Class 5 - Soils of moderately steep land with severe limitations for crop production.
Not present in this survey.
- Class 6 - Soils of moderately steep to steep, and steep land on which cultivation is precluded owing to the slope, nutrient deficiencies, shallow profiles over hard parent rock, and the major risk of erosion.
Whangamomona steepland soils.
- Class 7 - Soils of high altitude on Mt. Egmont, unsuitable for cropping.
Tahurangi soils; Tahurangi hill soils; unnamed subalpine soils; unnamed alpine soils.

Table V-3 Soil limitations for Horticultural use (after Cowie,1974)

- Class 1 - Soils of flat land with minimal to slight soil limitations for horticultural crops.
- 1A - Soils with minimal soil limitations. The soils are deep, friable and well drained and are suitable for a wide range of horticultural crops.
Stratford soils; Stratford soils, fine topsoil variant; Kahui soils.
- 1B - Soils with slight limitations of imperfect drainage. This limitation could restrict the range of horticultural crops grown. Some crops could be adversely affected in wet years and the period when the soil could be cultivated could be reduced.
Ngaere soils; Tipoka soils.
- Class 2 - Soils of flat land with moderate soil limitations of poor drainage and/or coarse texture for horticultural crops. The choice of horticultural crops is limited and the period during which the soils can be cultivated is restricted even after artificial drainage has been carried out. These soils are best suited for annual cropping.
Okato soils; Awatuna soils; Hangatahua soils; Lowgarth soils; Riverlea soils; Makaka soils; Eltham soils.
- Class 3 - Soils of flat and rolling land with severe soil limitations for horticultural crops.
- 3A - Soils with limitations of poor drainage and poor physical structure.
Mangawhero soils.

- Class 3B - Soils with limitations of excessive drainage and stoniness.
Not present in this survey.
- 3C - Limitations of liability to frequent flooding.
Not present in this survey.
- 3D - Soils with limitations of slope.
Stratford soils, strongly rolling phase; Lowgarth soils, strongly rolling phase.
- Class 4 - Soils of hilly and stepland unsuitable for horticultural crops.
Rowan soils; Rowan hill soils; Stratford hill soils; Lowgarth hill soils; Whangamomona stepland soils; Tahurangi soils; Tahurangi hill soils; unnamed subalpine soils; unnamed alpine soils.

Table V-4Value of soils for Food Production

Soils are classified using the system of Cowie (1974). A high value for food production implies that the intrinsic physical and chemical properties of the soil enable it to produce sustained high yields of food (i.e. crops, horticultural produce and animal products), regardless of the economic climate or the standard and kind of use being made of the soil at the time the classification is made.

- Class 1 - Soils of high actual or potential value for food production.
- 1A - Soils of high actual value for food production. Soils are deep, well drained and friable; limitations are mainly nutrient deficiencies.
Stratford soils; Stratford soils, fine topsoil variant; Kahui soils; Lowgarth soils; Hangatahua soils (in part); Riverlea soils.
- 1B - Soils have a limitation of imperfect to poor natural drainage which can be readily overcome with artificial drainage, though they will be slightly less versatile soils than those of class 1A.
Ngaere soils; Tipoka soils; Makaka soils (in part); Eltham soils.
- Class 2 - Soils with moderate actual or potential value for food production. Limitations include poor drainage, shallowness of profiles, coarseness of texture, more intensive leaching

at intermediate elevations leading to lower nutrient status, their occurrence on the sides of laharic mounds making cultivation difficult, soils at intermediate elevations.

Stratford soils, strongly rolling phase; Lowgarth soils, strongly rolling phase; Rowan soils (below 460m elevation); Makaka soils (in part); Mangawhero soils; Hangatahua soils(in part); Okato soils; Awatuna soils.

- Class 3 - Soils of low actual or potential value for food production. Limitations include liability to river flooding or lahars, slope and elevation. The soils are considered unsuitable for the production of food crops.

Tahurangi soils; Tahurangi hill soils; Stratford hill soils; Lowgarth hill soils; Rowan soils (above 460m elevation); Rowan hill soils; Whangamomona steep-land soils; unnamed subalpine soils; unnamed alpine soils.

Table V-5 Soil limitations for Forestry

Soils are classified using the system of Cutler (1967) with modifications by Aitken et al., (1978).

- Class 1 - Soils of flat and rolling land with slight limitations to forestry.

- 1A - Soils with no significant limitations to forest growth.

Stratford soils; Stratford soils, strongly rolling phase; Stratford soils, fine topsoil variant; Lowgarth soils; Lowgarth soils, strongly rolling phase; Hangatahua soils (in part).

- 1B - Soils with slight limitations of soil drainage which may limit the establishment of some species.

Ngaere soils.

- Class 2 - Soils of flat and rolling land with moderate limitations to forest growth.

- 2A - Soils with limitations of insufficient moisture and a subsoil pan of cemented or lithified laharic materials restricting rooting depths; some soils also have perched water-tables over the lahar in wet seasons further restricting rooting development.

Makaka soils; Tipoka soils; Rowan (below 460m elevation); Kahui soils; Riverlea soils; Hangatahua soils (in part).

- Class 2B - Soils with limitations of coarse sandy texture.
Not present in this survey.
- 2C - Soils with limitations of altitude.
Rowan soils (above 460m).
- Class 3 - Soils of flat, rolling and hilly land with severe soil limitations to forest growth.
- 3A - Soils with limitations of insufficient moisture and exposure to salt laden winds.
Not present in this survey.
- 3B - Soils with shallow and stony profiles*.
Hangatahua soils (in part).
- 3C - Soils with poor drainage.
Eltham soils; Okato soils; Awatuna soils; Mangawhero soils.
- Class 4 - Soils of moderately steep and moderately steep to steep land, with slight soil limitations to forest growth.
Stratford hill soils; Lowgarth hill soils; Rowan hill soils.
- Class 5 - Soils of moderately steep, moderately steep to steep and steep land with moderate soil limitations to forest growth.
Not present in this survey.
- Class 6 - Soils of moderately steep, moderately steep to steep, and steep land with severe to very severe soil limitations to forest growth.

The limitations are mainly those of nutrient deficiencies, low soil temperatures, shallow profiles underlain by hard parent rock and susceptibility to erosion.

Tahurangi hill soils; Tahurangi soils; Whangamomona steepland soils.
- Class 7 - Soils of high altitude on Mt. Egmont, unsuitable for forest growth.

Unnamed subalpine soils; unnamed alpine soils.

*The phrase "and insufficient moisture" added by Cutler to the definition of this group is deleted here. Shallow profiles are considered a severe limitation here.

Table V-6 Limitations for Urban Use (after Cowie, 1974)

Class 1	<p>- Soils of flat and rolling land with minimal to slight soil limitations for urban use.</p> <p>Stratford soils; Stratford soils, fine topsoil variant; Stratford soils, strongly rolling phase; Riverlea soils; Kahui soils; Rowan soils; Lowgarth soils; Lowgarth soils, strongly rolling phase.</p>
Class 2	<p>- Soils of flat and rolling land with moderate soil limitations for urban use.</p> <p>Limitations of poor or imperfect drainage.</p> <p>Ngaere soils; Makaka soils; Tipoka soils; Awatuna soils; Mangawhero soils.</p>
Class 3	<p>- Soils of flat land with severe limitations for urban use.</p> <p>Limitation of poor subsurface foundation materials.</p> <p>Eltham soils.</p> <p>Limitation of liability to river flooding or debris flows.</p> <p>Hangatahua soils; Okato soils.</p>
Class 4	<p>- Soils of hilly land with moderate soil limitations for urban use.</p> <p>Limitations of slope and erosion.</p> <p>Rowan hill soils; Stratford hill soils; Lowgarth hill soils.</p>
Class 5	<p>- Soils of steep land with severe soil limitations for urban use.</p> <p>Limitations of slope and erosion.</p> <p>Whangamomona steepland soils; Taurangi soils; Taurangi hill soils; unnamed subalpine soils; unnamed alpine soils.</p>

EROSION

In the lowland laharc terrain there is no significant present erosion nor is any potential erosion, under pastoral use, predicted. There is slight streambank erosion mainly along the Mangawhero, Kaipokonui and Kapuni Streams (NWSCO,1979). In the upland laharc terrain between 1,100-220m although there is no significant present erosion, moderately

severe erosion involving earth slip and slump is predicted under pastoral use (NWSCO, 1977). It is important that the present vegetation cover within the upland laharic terrain, above 460m, remains undisturbed, since the high precipitation could initiate severe erosion.

Within the subalpine steepland associated with Mt. Egmont, severe erosion is prevalent on steep slopes above streams and on the sides of gorges. The alpine steepland is susceptible to snow and ice avalanches. Soils of both subalpine and alpine steepland should be regarded with caution if used for recreational purposes.

Erosion is evident in the steepland terrain in the east of the County and is mainly moderate to slight earth slip and soil slip. The soils have moderate to severe potential erosion involving earth slip, sheet and slump erosion (NWSCO,1977). The hill soils have a slight to moderate potential erosion severity, involving earth slip and slump erosion under pastoral use.

POTENTIAL NATURAL HAZARDS

A small scale generalised map (Figure V-3) indicates that the area adjacent to the Kaupokonui Stream is of potential risk from flooding or from being overwhelmed by future lahars, in the event of a future eruption of Mt. Egmont.

- 1 - Mainly soils of flat to rolling land with slight limitations for cropping use. (CLASS 1)
- 2 - Mainly soils of flat to rolling land with moderate limitations for cropping use. (CLASS 2)
- 3 - Mainly soils of flat to rolling land with severe limitations for cropping use. (CLASS 3)
- 4 - Mainly soils of hilly land with moderate to severe limitations for cropping use (CLASS 4)
- Soils unsuitable for cropping

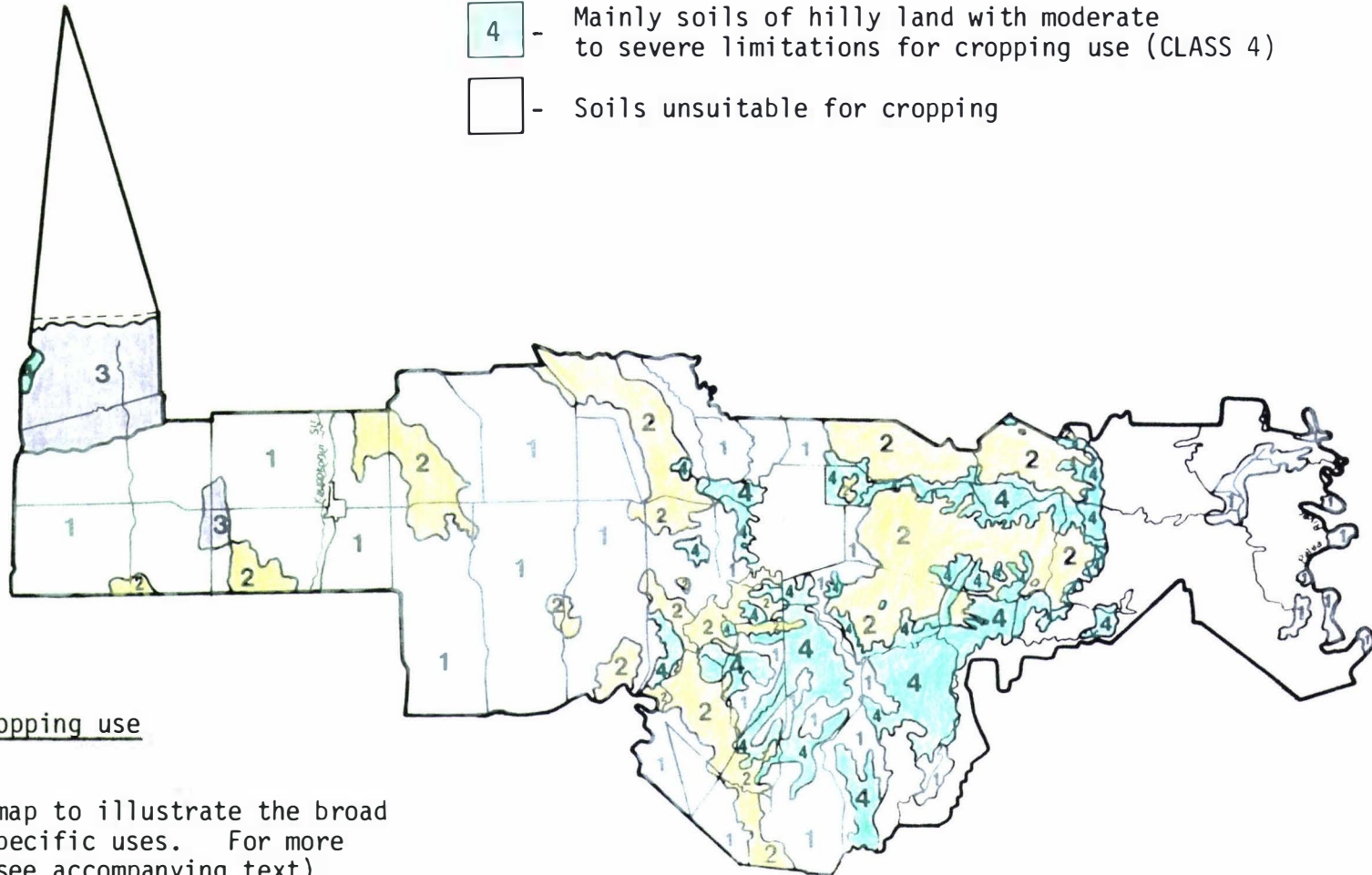


Figure V-1

Soil limitations for cropping use

(This is a generalised map to illustrate the broad pattern of soils for specific uses. For more detailed information, see accompanying text).

1 - Soils of high actual or potential value for food production

2 - Soils of moderate actual or potential value for food production

3 - Soils of low actual or potential value for food production

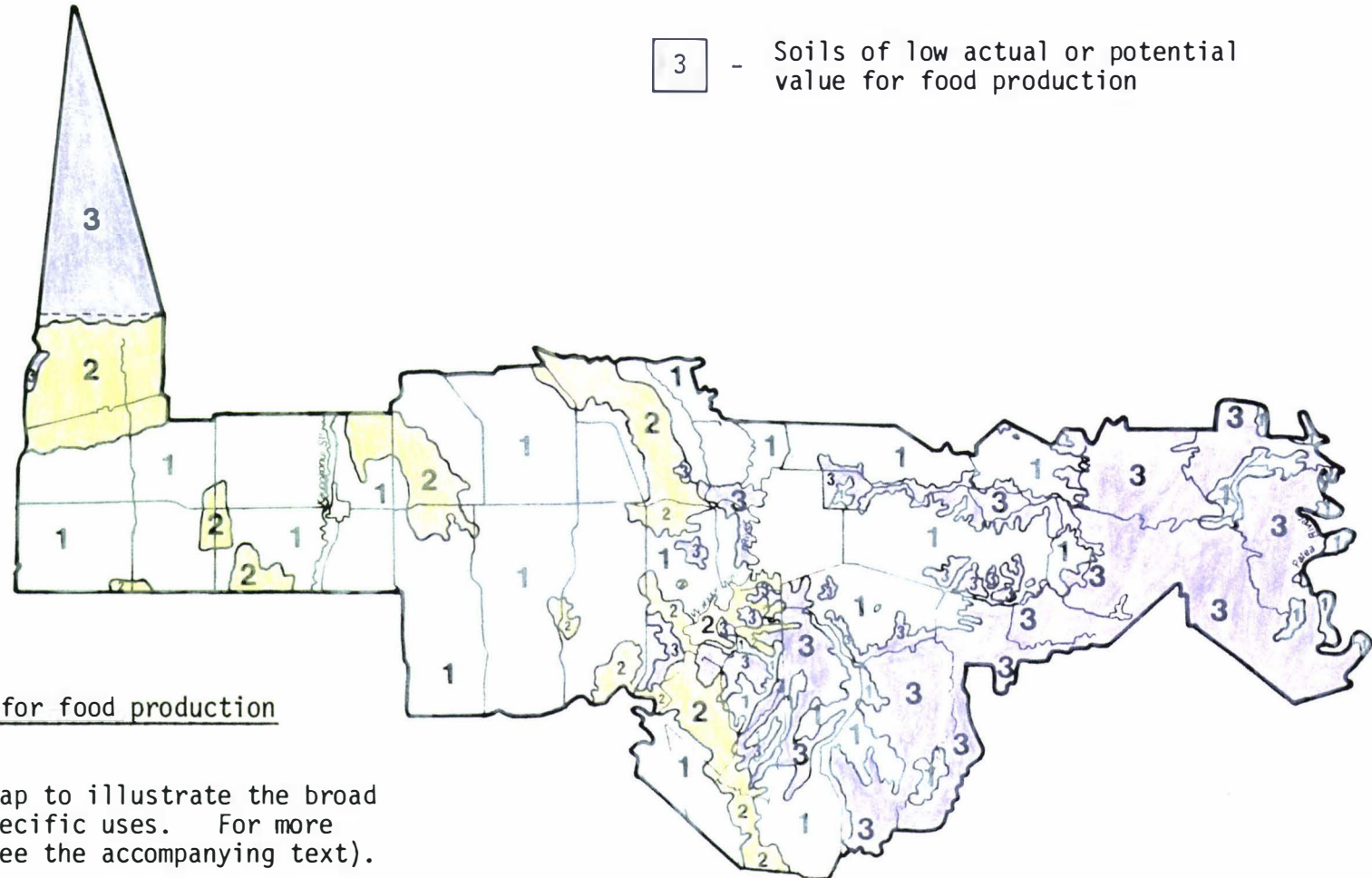



Figure V-2

Classification of soils for food production

(This is a generalised map to illustrate the broad pattern of soils for specific uses. For more detailed information, see the accompanying text).

 - Area covered by recent alluvium, debris flow and mudflow deposits.

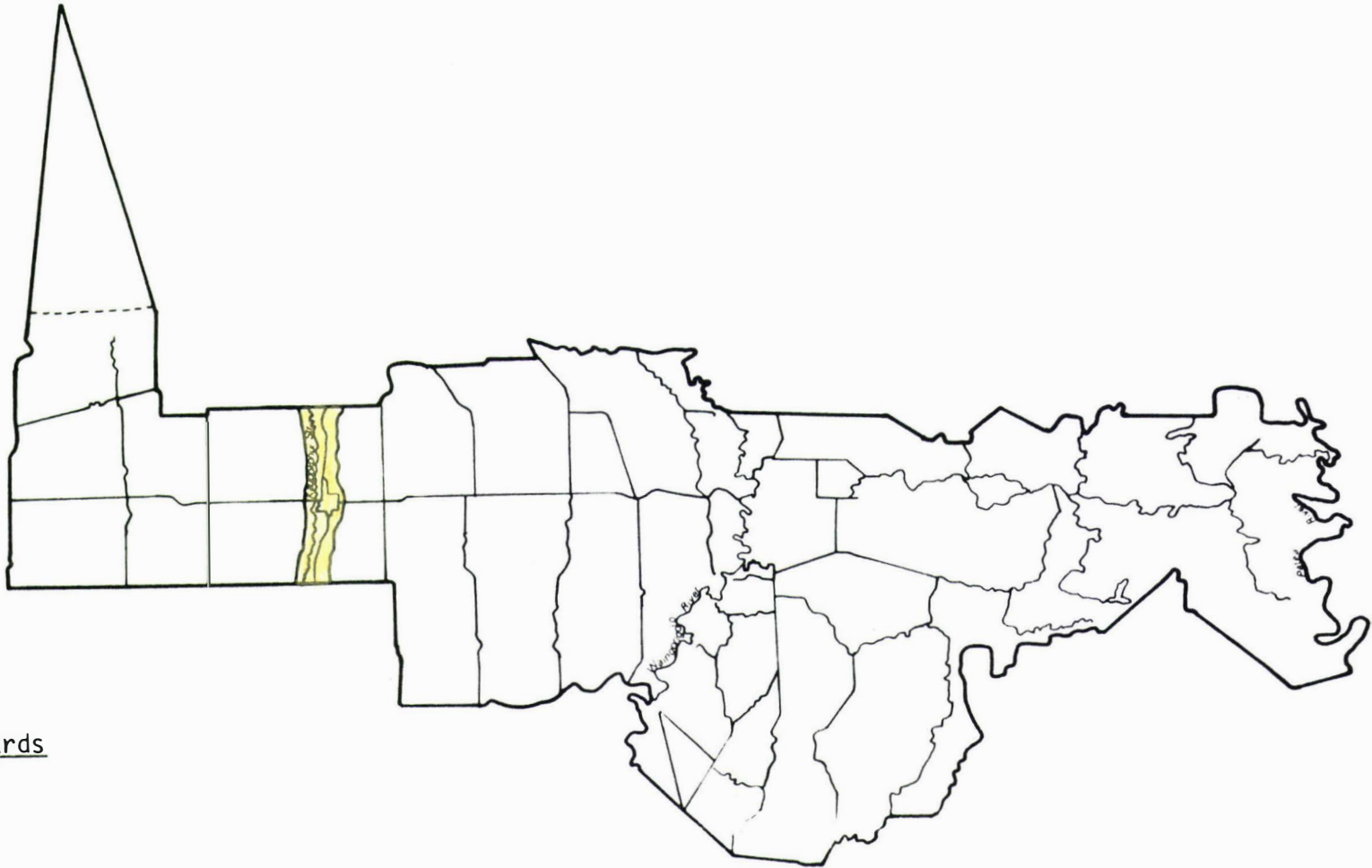


Figure V-3.

Potential natural hazards

SOIL TAXONOMIC UNIT SHEETS

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APPENDIX VI

The soil taxonomic unit descriptions act as an important source of information for correlation and reference. Each taxonomic unit recognised and named in the soil survey of Eltham County is described.

The first part of the descriptions deals mainly with reference and classification data for the unit.

The second part of the descriptions covers the site and environmental characteristics of the unit, such as parent material, landform, vegetation and climate. The next part covers morphological details of the soil, and features which distinguish it from closely related soils are explained.

Finally, the soil is defined in terms of a modal profile description.

EXPLANATION OF HEADINGS USED IN TAXONOMIC UNIT DESCRIPTIONS

1. REFERENCE - The history of the soil name is given, with details of earlier surveys in which the soil was identified. Where applicable, a redefinition of the series is given. Where a new series has been created, the original "4-mile" set (N.Z. Soil Bureau, 1954), in which it was included is given, together with reasons for its separation from the original set.
2. SYMBOLS OF MAPPING UNITS - The symbols of the mapping unit where the taxonomic unit is dominant and subdominant is given.
3. CLASSIFICATION - The classification of the soil is given in:
 1. New Zealand Genetic Soil Classification (Taylor and Pohlen, 1970).
 2. Soil Taxonomy (a) to subgroup level according to U.S. Soil Taxonomy (Soil Survey Staff, 1975), and
(b) to family level according to the 1978 Andisol Proposal of Soil Taxonomy (Smith, 1978).
4. GEOGRAPHICAL DISTRIBUTION - The known geographic occurrence of the soil, within the County, is given in general terms.
5. PARENT MATERIAL - The parent material is the weathered unconsolidated material from which the soil has been formed.

6. LANDFORM - This indicates the position in which the soil occurs in the landscape.
7. SLOPE CLASS - Slope is given in terms of slope classes defined by Taylor and Pohlen (1970). In this survey rolling has been split into two classes, with the break at 12° and the moderately steep and moderately steep to steep classes have been combined to form a hilly class.

	Flat
	Flat to gently undulating
Rolling	{ Easy rolling Strongly rolling
Hilly	{ Moderately steep Moderately steep to steep Steep Very steep

8. VEGETATION AND LAND USE - The original pre-European vegetation is given, together with the present vegetation and major land uses.
9. RANGE OF ELEVATION - The range of elevation, in metres, over which the soil unit occurs in this survey.
10. RAINFALL RANGE - The geographic range of mean annual rainfall under which the soil occurs in this survey (R. Aldridge, pers. comm.).
11. SOIL MOISTURE CLASS - The soil moisture class, in terms of both Soil Taxonomy and Soil Survey Method (Taylor and Pohlen, 1970) is given. The aquic moisture regime implies a reducing regime that is virtually free of dissolved oxygen because the soil is saturated by ground-water or by water of the capillary fringe. The udic moisture regime implies that in most years the soil moisture control section is not dry in any part for as long as 90 days (cumulative). The perudic moisture regime is when precipitation exceeds evapotranspiration in all months of most years. The Hygrous moisture class is when the soil on the average does not reach wilting point for any month and is above field capacity for the greater part of the year. The Hydrous moisture class is when the soil on the average is above field capacity for all months of the year and is continuously above field capacity and over-wet for long periods.

12. MEAN ANNUAL AIR TEMPERATURE - This gives the mean annual air temperature under which the soil occurs in this survey (N.Z. Meteorological Service, 1983).
13. SOIL TEMPERATURE REGIME - The soil temperature regime is given in terms of Soil Taxonomy.
All soils have a mesic soil temperature regime in which the mean annual soil temperature is 8°C or higher but lower than 15°C .
14. SOIL DRAINAGE CLASS - The overall drainage class in terms of those given by Taylor and Pohlen (1970). The class refers to natural drainage conditions and, for some soils, artificial drainage may raise the drainage class given by one or more classes.
15. PERMEABILITY - Given in terms of the seven classes defined in the United States Soil Survey Manual (Soil Survey Staff, 1951, p.168).
16. FLOODING - Flooding is given in terms of frequency of flooding (return interval) and the duration that floodwaters are likely to remain on the land.
17. EROSION - Severity and type of erosion of the taxonomic unit under the major present and potential land uses is given. Degree of erosion is given in relative terms of nil, slight, moderate, severe and very severe.
18. CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT - Indicates the soil morphological and environmental features which are characteristic of the soil and which distinguish it from other soils.
19. SIMILAR SOILS AND DISTINGUISHING FEATURES - Lists soils which are similar and/or related to the taxonomic unit being described. Key morphological and environmental features which distinguish the soils are given.
20. LABORATORY NUMBERS - Lists N.Z. Soil Bureau laboratory numbers for samples within survey area.
21. TYPIFYING PROFILE - This is given as a detailed profile description of the type profile or modal profile, which is characteristic of the taxonomic unit. Location of the site and all relevant site information is given. The profile number on the aerial photo is also given to aid relocation. In many cases the typifying profile is also the site from which samples have been taken for chemical analyses.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: AWATUNA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by Grange and Taylor (1934) in a DSIR Internal Report to include poorly drained soils, derived mainly from volcanic debris deposited by streams.

Included by N.Z. Soil Bureau (1954) in Awatuna set, which consisted of gley soils of moderate natural drainage derived from "Egmont and Stratford Ash". Area mapped in this survey was previously mapped in Glenn set by N.Z. Soil Bureau (1954).

In Waimate West County, Campbell and Wilde (1970) described Awatuna sandy loam, as poorly drained to imperfectly drained soil, formed on flood plains from alluvium of volcanic origin. The parent material being mainly coarse textured, with a thin coating of "Stratford Ash" in places.

In Egmont County, the Awatuna soil was redefined by R.W.P. Palmer et al., (1981) to include poorly drained gley soils, derived from between 0.60 and 1.50m of volcanic ash, on laharc materials.

In Eltham County, the Awatuna soil has < 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras, overlying tephras p2 and p1, (Druce, 1966) on fine textured ashes over laharc debris.

SYMBOLS OF MAPPING UNITS:

- (a) Taxonomic unit dominant At-Kui, At-Tk
 (b) Taxonomic unit sub-dominant -

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Gley soil
2. Soil Taxonomy (a): Haplic Andaquept
 (b): Typic Haplaquand (medial, mesic)

GEOGRAPHICAL DISTRIBUTION:

West of Kaponga above boundary with Waimate West County

PARENT MATERIAL:

Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers*, of < 250mm thickness, Kaupokonui, Maketawa and Manganui tephras, overlying tephras p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris.

LANDFORM:

Volcanic ash mantled lowland laharic terrain

SLOPE CLASS:

Flat to gently undulating, in depressions

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's. Now ryegrass clover pastures used mainly for dairying.

RANGE OF ELEVATION: 210-270m

MEAN ANNUAL
RAINFALL RANGE: 1660-1900mm

SOIL MOISTURE CLASS: Aquic
Hydrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Poorly drained

PERMEABILITY: Slow

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

Very dark greyish-brown to grey silt loam to sandy loam topsoils, with a strong to weakly developed nutty and crumb structure, overlies weakly structured B horizons. A few pumiceous and lithic lapilli, Kapokonui, Maketawa and Managanui tephras, may be found in the A and upper B horizons. The roots are usually iron stained.

The B horizons are all gleyed and have colours varying from brown to light yellowish-brown, with dark reddish-brown to yellowish-red mottles, which increase from few faint to many distinct, with depth. Concretions may also be a feature of the profile and similarly increase with depth. The mottles and concretions tend to be associated with the presence of lithic and pumiceous lapilli, which can be concentrated in distinct bands or scattered. The concretions can be cemented together to form an indurated, vesicular iron oxide pan, at the textural boundary, between the andesitic lapilli and laharic deposits. The thickness of volcanic ash over laharic debris ranges from 0.60 to 1.50m.

The water-table in Awatuna series is often less than one metre from the surface.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Mangawhero series differs from Awatuna series in having > 250mm thickness of *young lapilli showers* Kaupokonui, Maketawa and Manganui tephras in the upper horizons.

Tipoka series is derived from similar parent materials but differs from Awatuna series in having one or more non-gleyed B horizons above gleyed B horizons.

LABORATORY NUMBERS: Not sampled.

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Awatuna series
PROFILE NO: 305
SITE LOCATION: Lower Rowan Road, 2km south from crossroads with Eltham Road. Sandbrook's property. Paddock at end of race, adjacent to Waimate West County boundary, below patch of bush.
 N119/705442

SITE INFORMATION

LANDFORM: Volcanic ash mantled lowland laharic terrain
TOPOGRAPHY: Depression in flat land
SLOPE: 1⁰
ASPECT: East
ELEVATION: 230m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers*, < 250mm thickness of Kaupokonui, Maketawa and Manganui tephras, overlying tephras p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris.
SITE VEGETATION: Ryegrass and clover, Juncus spp.
LAND USE: Pasture
DRAINAGE: Poorly drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-18 cm
 Ap dark grey to dark greyish-brown (10YR 4/1-4/2) silt loam, with few gravels (Manganui tephra); friable; slightly plastic; non sticky; strongly developed fine nut structure; many roots; iron stained, dark reddish-brown (5YR 3/4) distinct irregular boundary,

- 18-35 cm
Bg1
brown (10YR 5/3) loam, with strongly weathered pumiceous lapilli; friable; slightly plastic; non sticky; moderately well to weakly developed fine nutty structure; many roots; few distinct yellowish-red (5YR 4/8) mottles; many yellowish-red (5YR 4/8) mottles; many yellowish-red (5YR 4/6) soft concretions averaging 10mm; indistinct boundary,
- 35-75 cm
Bg2
light yellowish-brown (10YR 6/4) sandy clay loam, with strongly weathered pumiceous lapilli, concentrated in a band together with many dark reddish-brown (5YR 2.5/2) hard concretions; firm. slightly plastic; sticky; weakly developed coarse and medium blocky structure; few roots; many distinct dark reddish-brown (5YR 3/4) mottles; distinct boundary,
- 75+
2C
brown to light yellowish-brown (10YR 5/3-6/4) loamy coarse sand, with many dark reddish-brown (5YR 2.5/2) hard concretions; loose; massive; many distinct dark reddish-brown (5YR 3/4) mottles.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: ELTHAM SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by Grange L.I., Taylor, N.H. 1933. Field-work on soils of Western Taranaki Annual Report N.Z. D.S.I.R. 1932-33, pp 3-5.

The area mapped in this survey was previously mapped in Piako set by N.Z. Soil Bureau (1954).

Redefined by Aitken *et al.*, (1978) as a moderately developed organic soil, derived from a lowmoor, woody peat, with interbedded thin andesitic tephra layers. This definition followed in this survey.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant E1
 (b) Taxonomic unit subdominant -

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Organic soil
 2. Soil Taxonomy Fibric Terric Medisaprist

GEOGRAPHICAL DISTRIBUTION:

Drained swamp east of Eltham

PARENT MATERIAL:

Woody peat with interbedded tephra layers

LANDFORM:

Flat land on the edge of the volcanic ring plain

SLOPE CLASS:

Flat

VEGETATION AND LAND USE:

In the past the dominant trees were silver pine (Podocarpus dacrydioides), manuka (Leptospermum scorparium), pukatea (Laurelia novae-zelandiae), rimu (Dacrydium cupressinum), tawa (Beilschmiedia tawa), rata (Metrosideros robusta), and miro (Podocarpus ferrugineus). The swamp plant raupo (Typha orientalis) grew in abundance. As the bush was felled the second growth came in with great stands of poroporo (Solanum aviculare).

RANGE OF ELEVATION: 210-220m

MEAN ANNUAL RAINFALL RANGE: 1620-1890mm

SOIL MOISTURE CLASS: Aquic
Hydrous

MEAN ANNUAL AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Poor drainage

PERMEABILITY: Rapid

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A dark reddish-brown to dark brown topsoil with silt loam to peaty loam texture and strongly developed nutty structure. The roots are usually concentrated in the topsoil and are often iron stained. Pumiceous lapilli 1mm or less can be concentrated in a band or pocket and impart a gritty modification and speckled appearance.

The subsoil tends to be very dark brown to black becoming a dark reddish-brown, structureless peat with depth.

The distribution of pumiceous and lithic lapilli is irregular and can be concentrated in a band or pocket. Pumiceous lapilli can be greater than 20mm in diameter and become strongly weathered with depth. The distinctive lithic-rich Manganui tephra (c. 3,300 years B.P.) has been identified at a depth of approximately 0.60-0.70m and results in a gravelly horizon.

Partly decomposed fragments of wood, twigs and fibres are a feature throughout the profile and are concentrated at approximately 0.90m.

The water-table usually occurs just below one metre but it can be deeper or as shallow as 0.60m.

LABORATORY NUMBERS: SB 9704 A-G

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Eltham series
PROFILE NO.: 303
SITE LOCATION: Maata Road, 1.5km down from junction with Rawhitiroa and Sangster Roads. Kaiser's property. Paddock adjacent to Maata Road, 17m east of road
 N119/944455

SITE INFORMATION

LANDFORM: Flat land on the edge of the volcanic ring plain
TOPOGRAPHY: Flat
SLOPE: Near level
ASPECT: South-west
ELEVATION: 200m
PARENT MATERIAL: Woody peat, with interbedded tephra layers
SITE VEGETATION: Ryegrass pasture, Plantago spp.
LAND USE: Dairy pasture
DRAINAGE: Poor drainage
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9704 A-G

PROFILE DESCRIPTION

0-20 cm Ap	dark reddish-brown (5YR 2.5/2) peaty loam; friable; strongly developed fine crumb and nutty structure; abundant very fine roots; distinct boundary,
20-22 cm Bu	a 20mm irregular tephra band (Kaupokonui and Maketawa tephra), averaging 1mm in diameter,
22-30 cm Oh1	dark reddish-brown (5YR 3/2) peat; common charcoal fragments; many dusky red (2.5YR 3/2) wood fragments greater than 10mm; structureless; many very fine roots; irregular distinct boundary.

- 30-52 cm
Bh1 dark brown (7.5YR 3/2) humic loam with gravelly band of Manganui tephra; friable; structureless; distinct, irregular boundary,
- 52-65 cm
Oh2 very dark brown (10YR 2/2) gritty peat; many moderately to strongly decomposed wood fragments; friable; structureless; few very fine roots; distinct wavy boundary,
- 65-100 cm
Bh2 dark brown (7.5YR 3/2) humic loam with gravels and pumiceous lapilli (p2, (Druce, 1966)) occurring in pockets; friable; structureless; distinct, irregular boundary,
- 100-140 cm
Oh3 brownish-black (5YR 2.5/1) peat; friable; structureless.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: HANGATAHUA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by Grange, L.I., Taylor, N.H., 1933. Field-work on soils of Western Taranaki Annual Report N.Z. D.S.I.R. 1932-33 pp 3-5 to include all the soils derived from volcanic material deposited by streams flowing from Mt. Egmont.

Hangatahua soils were described in Waimate West County by Campbell and Wilde (1970) as well drained and well drained to somewhat excessively drained soils, derived from volcanic alluvium on flat land.

In Stratford County, they were described by Aitken *et al.*, (1978) as well drained soils derived from alluvium, free from flooding and were considered to show enough profile development to be classified as weakly weathered yellow-brown loams.

In Egmont County R.W.P. Palmer *et al.*, (1981) defined the Hangatahua series as a well drained, weakly weathered intergrade between yellow-brown loams and recent soils, developed on alluvium of Hangatahua Gravels and Maero Debris Flows. It was also described as non-accumulating and quite extensive areas were mapped, in contrast with Stratford County, where the area mapped separately as Hangatahua soils is small.

In Eltham County this concept is followed and Hangatahua is defined as a well drained soil, which is an intergrade between yellow-brown loams and recent soils, developed on andesitic alluvium.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant Hn
 (b) Taxonomic unit subdominant Ok-Hn

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Intergrade between yellow-brown loams and recent soils
2. Soil Taxonomy (a): Typic Vitrandept
 (b): Typic Vitrudand (ashy, mesic)

GEOGRAPHICAL DISTRIBUTION:

Adjacent to many stream channels in Eltham County, particularly in catchments such as the Otakeho, Mangawhero, Mangawheroiti, and Kapuni streams. Extensive area along the Kaipokonui Stream.

PARENT MATERIAL:

Weakly weathered andesitic alluvial sands and gravels.

The deposits vary in texture from fine to coarse sand and may be gravelly, stony or bouldary. There is no volcanic ash cover.

LANDFORM:

Alluvial fans and levées and river terraces, within laharic terrain.

SLOPE CLASS:

Flat to gently undulating.

VEGETATION AND LAND USE:

Originally rimu-rata forest. Now pasture grasses.

The major land use is dairying with minor sheep and beef cattle.

RANGE OF ELEVATION: 120-460m

MEAN ANNUAL
RAINFALL RANGE: 1330-2680mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid

FLOODING:

Do not receive regular additions of alluvium.
Recognised as areas of future liability to inundation by debris flows.

EROSION:

According to N.Z. Land Resource Inventory Worksheet N119 (NWSC0,1979) slight streambank erosion exists along Mangawhero, Kaupokonui and Kapuni Streams.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A black to dark brown topsoil, with moderately well developed nutty and crumb structures. Textures are variable and range from silt loam to fine loamy sand. The B horizons have dark greyish-brown to yellowish-brown colours, with either weakly developed structures or are single grained and structureless.

The C horizons are very dark to dark greyish-brown, fine to coarse sands, which may be loose or firm.

Gravel and stones are usually present and increase in concentration with depth. Bounders may also occur.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Okato series differs from Hangatahua in having gleyed horizons, within one metre of the surface.

LABORATORY NUMBERS: SB 9702 A-E

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Hangatahua series
PROFILE NO: 256
SITE LOCATION: Manaia Road, 2.5km south of Kaponga. Hurcombe's property. Across Kaupokonui Stream and tributary. Second paddock, on north side of race, 6m from hedge.
 N119/718445

SITE INFORMATION

LANDFORM: River terrace within laharic terrain
TOPOGRAPHY: Flat land
SLOPE: Near level
ASPECT: South-west
ELEVATION: 200m
PARENT MATERIAL: Weakly weathered andesitic alluvial sands and gravels < 1000 years old.
SITE VEGETATION: Ryegrass and clover pasture
LAND USE: Pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9702 A-E

PROFILE DESCRIPTION

0-18 cm Ap	very dark brown (10YR 2/2) silt loam, with few moderately weathered pumiceous lapilli, averaging 10-20mm in diameter; slightly sticky; slightly plastic; moderately fine nutty structure; firm penetration; abundant very fine roots; distinct irregular boundary,
18-33 cm Bw1	dark brown (10YR 3/3) sandy loam, with few scattered pumiceous and lithic lapilli averaging less than 20mm in diameter; friable; non sticky; non plastic; weak fine crumb structure; firm penetration; many very fine roots and few medium roots; indistinct irregular boundary,

- 33-65 cm
Bw2 dark yellowish-brown (10YR 3/4) sandy loam, with scattered strongly weathered pumiceous lapilli, less than 20mm in diameter; friable; non plastic; non sticky; weakly developed crumb structure; soft penetration; common roots; distinct wavy boundary,
- 65-105 cm
C very dark greyish-brown (2.5YR 3/2) fine sand, with scattered strongly weathered pumiceous lapilli, up to 20mm in diameter; single grain; stiff penetration; distinct irregular boundary,
- 105+ cm dark brown (10YR 3/3) gritty loam, with abundant strongly weathered, yellowish-red (5YR 5/6) iron stained pumiceous lapilli; friable; slightly sticky; slightly plastic; weakly developed blocky structure; stiff penetration.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: KAHUI SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by N.Z. Soil Bureau (1954). Kahui set included a variety of soils which were more strongly leached than Egmont or Stratford soils, and were derived from "Egmont and Stratford Ash" on laharic debris.

The area mapped in this survey was previously mapped in Egmont and Glenn sets by N.Z. Soil Bureau (1954).

Kahui series was more closely defined by R.W.P. Palmer et al., in "Soils of Egmont County" (1981) as a moderately to strongly leached, well drained soil formed from between 0.40 and 2m of volcanic ash on laharic debris above 165m elevation.

This definition followed but in Eltham County Kahui series is a moderately leached, well drained soil formed from < 250mm thickness of *young lapilli showers*, Kapokonui, Maketawa and Manganui tephtras, overlying tephtras p2 and p1, (Druce, 1966) on fine textured ashes, over laharic debris of Opuia and Warea Formations.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant Kui-Tk
- (b) Taxonomic unit subdominant Tk-Kui, At-Kui

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Moderately leached yellow-brown loam
2. Soil Taxonomy (a): Typic Dystrandept
 (b): Typic Hapludand (medial, mesic)

GEOGRAPHICAL DISTRIBUTION:

West of Kaponga above boundary with Waimate West County.

PARENT MATERIAL:

Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers*, < 250mm thickness of Kaupokonui, Maketawa and Manganui tephtras, overlying tephtras p2 and p1, (Druce, 1966) on fine textured ashes over laharic debris of Opuia and Warea Formations.

LANDFORM:

Volcanic ash mantled lowland laharic terrain.

SLOPE CLASS:

Flat to easy rolling.

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's. Now ryegrass clover pastures used mainly for dairying.

RANGE OF ELEVATION: 210-270m

MEAN ANNUAL RAINFALL RANGE: 1660-1900mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to dark brown loam to silt loam topsoil overlies brown to yellowish-brown weakly structured B horizons.

There are traces of *young lapilli showers* in the upper part of the profile. Moderately weathered scattered pumiceous and lithic lapilli occur in the lower B horizons and become more strongly weathered with depth.

A band of strongly weathered pumiceous lapilli, concentrated just above one metre is a characteristic feature of Kahui soils.

The thickness of volcanic ash over laharic debris varies and is greater than one metre in the profiles examined.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Riverlea series differs from Kahui series in having > 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras in the upper horizons.

Rowan series differs from Kahui series in being strongly leached, with illuvial coatings on lapilli and ped surfaces. There is > 250mm thickness of *young lapilli showers* in Rowan series.

Stratford series differs from Kahui series in being found in volcanic ash > 2metres thick.

Egmont series differs from Kahui series in its finer textured topsoil and absence of *young lapilli showers*, Kapokonui, Maketawa and Manganui tephras.

Lowgarth series differs from Kahui series in being moderately to strongly leached and in having > 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras, in the upper horizons. Lowgarth series also differs from Kahui series in being found in thicker (not less than 2m) volcanic ash. It may be mapped extensively using the soil series as the mapping unit, whereas Kahui series is mapped in association with other soils.

LABORATORY NUMBERS: Not sampled.

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Kahui series
PROFILE NO: 76
SITE LOCATION: Auroa Road. Last farm before Waimate West County boundary. Steffert's property. End of race, south of Macrocarpas.
 N118/644442

SITE INFORMATION

LANDFORM: Volcanic ash mantled lowland laharic terrain
TOPOGRAPHY: Flat land
SLOPE: 1°
ASPECT: West
ELEVATION: 230m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers* < 250mm thickness of Kaupokonui, Maketawa and Manganui tephtras, overlying tephtras p2 and p1, (Druce, 1966) on fine textured ashes over laharic debris of Warea Formation
SITE VEGETATION: Ryegrass and white clover
LAND USE: Pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-23 cm
 Ap very dark greyish-brown (10YR 3/2) loam with few gravels (Manganui tephra); moderately weak; non sticky; slightly plastic; moderately developed fine and very fine nutty and crumb structure; many roots; distinct irregular boundary,

- 23-34 cm
Bw1 dark brown (10YR 3/3) loam with occasional gravel (Manganui tephra); moderately weak; slightly sticky; slightly plastic; moderate to weakly developed coarse blocky breaking to fine nutty structure; many roots; indistinct irregular boundary,
- 34-56 cm
Bw2 dark yellowish-brown (10YR 4/4) loam with moderately weathered pumiceous lapilli; moderately weak; weakly developed coarse structure; slightly sticky; slightly plastic; few roots; diffuse boundary,
- 56-110 cm
Bw3 dark yellowish-brown (10YR 4/6) sandy loam with strongly weathered pumiceous lapilli and lithic lapilli at 0.56m, scattered, and at 0.75m to greater than 1.10m concentrated in a band; moderately firm; non sticky; non plastic; weakly developed coarse blocky structure; few roots.

SLOPE CLASS:

Flat to strongly rolling and hilly

VEGETATION AND LAND USE:

Originally rimu-rata forest cleared in the early 1900's. Now ryegrass clover pasture used mainly for dairying.

RANGE OF ELEVATION: 230-340m

MEAN ANNUAL
RAINFALL RANGE: 2050-2260mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid - moderate

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to dark brown topsoil with well developed nutty structure, over weakly structured, dark yellowish-brown to yellowish-brown B horizons.

The topsoil and upper B horizon of Lowgarth soils are characterised by containing abundant lithic lapilli of the Manganui tephra, which produces a gravelly and gritty modification to the sandy loam to loam texture.

The lower B horizons are of softer penetration and finer texture, varying from sandy clay loam to loam. Many concentrated to few scattered pumiceous lapilli are present and become more strongly weathered with depth.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Rowan series differs from Lowgarth series in being found at higher elevations and is strongly leached, with iron illuvial coatings on ped surfaces and lapilli.

Stratford series differs from Lowgarth series in having < 250mm thickness of

young lapilli showers, Kaupokonui, Maketawa and Manganui tephras and so lacks a gravelly topsoil and upper B horizon.

Kahui series differs from Lowgarth series in being moderately leached and in having < 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras present in the upper horizons.

LABORATORY NUMBERS: SB 9706 A-D

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Lowgarth series
PROFILE NO: 212
SITE LOCATION: Lower Hastings Road, 1km below Lowgarth Hall.
 Sulzberger's property. First paddock up from gully,
 north side of race, 5m from hedge.
 N119/796515

SITE INFORMATION

LANDFORM: Tephra mantled lowland laharic terrain
TOPOGRAPHY: Crest of gently sloping lahar mound
SLOPE: 5°
ASPECT: South-west
ELEVATION: 300m
PARENT MATERIAL: Moderately weathered andesitic lapilli (c.3,300 years B.P.) comprised of *young lapilli showers*, Kaupokonui, Maketawa and Manganui > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966), E5 and E4.
SITE VEGETATION: Ryegrass and clover
LAND USE: Dairy pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Remains of Rata stump at ½m
LABORATORY NUMBERS: SB 9706 A-D

PROFILE DESCRIPTION

0-23 cm
 Ap dark brown (7.5YR 3/2) gritty loam, with abundant gravels (Manganui tephra); very friable; non sticky; non plastic; moderately developed fine nutty and crumb structure; firm penetration; many fine roots; distinct wavy boundary,

- 23-52 cm
Bw1 dark yellowish-brown (10YR 3/4) sandy loam, with abundant gravels (Manganui tephra); friable; non sticky; non plastic; weak crumb structure; firm penetration; many fine roots; distinct wavy boundary,
- 52-92 cm
Bw2 yellowish-brown (10YR 5/4) sandy clay loam, with many, moderately weathered pumiceous lapilli, averaging 20mm in diameter; friable; slightly sticky; slightly plastic; weak coarse blocky structure; soft penetration; few roots; diffuse boundary,
- 92+ cm yellowish-brown (10YR 5/6) sandy clay loam with abundant strongly weathered, pumiceous lapilli; few iron stained lithic lapilli; friable; slightly sticky; slightly plastic; weak, coarse blocky structure; soft penetration.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: MAKAKA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

New taxonomic unit introduced in this soil survey. Area mapped in this survey previously mapped in Stratford, Egmont, Awatuna, Kahui, Inglewood and Glenn sets by N.Z. Soil Bureau (1954). Now separated out as an imperfectly drained, weakly gleyed soil formed in *young lapilli showers*, Kaipokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966) on laharic debris.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant Mk-Rc, Mk-Mw
 (b) Taxonomic unit subdominant Rc-Mk, Mw-Mk, Rv-Mk

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Weakly gleyed yellow-brown loam
 2. Soil Taxonomy (a): Aquic Vitrandept
 (b): Aquic Hapludand (medial, medial-skeletal, mesic)

GEOGRAPHICAL DISTRIBUTION:

Area west of Kaponga to Awatuna.

PARENT MATERIAL:

Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaipokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966) on thin (with minor thick) volcanic ash overlying laharic debris.

LANDFORM:

Tephra mantled upland and lowland laharic terrain.

SLOPE CLASS:

Flat to gently undulating land.

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's.
Now ryegrass clover pastures used mainly for dairying.

RANGE OF ELEVATION: 220-760m

MEAN ANNUAL
RAINFALL RANGE: 1730-3860mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6⁰C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Imperfectly drained

PERMEABILITY: Moderately slow

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to dark brown topsoil, with moderately developed nutty and crumb structures overlies one or two non-gleyed horizons. The non-gleyed horizons are dark brown or brown in colour and are usually gravelly due to the presence of the Manganui tephra (c. 3,300 years B.P.).

The lower B horizons are gleyed and vary from dark greyish-brown to yellowish-brown in colour, with red to dark reddish-brown mottles, which are usually associated with the moderately to strongly weathered pumiceous lapilli, scattered or concentrated in bands.

Concretions can be present and concentrated with the pumiceous lapilli bands. An iron pan can occur at the textural break with the laharic debris. The thickness of volcanic ash over laharic debris ranges from 0.60 to 2m.

The water-table can be just above 1m, in the profile.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Tipoka series differs from Makaka series in having less than 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras in the upper horizons.

LABORATORY NUMBERS: SB 9703 A-E

AUTHOR: A.M. Franks

DATE: 1982

TYPIFYING PROFILE

SOIL NAME: Makaka series
PROFILE NO: 12
SITE LOCATION: Upper Mangawhero Road. Moore's property. Near western boundary of farm, 20m north of race.
 N119/653504

SITE INFORMATION

LANDFORM: Tephra mantled upland lahric terrain
TOPOGRAPHY: Very gently sloping interfluve
SLOPE: 3⁰
ASPECT: South-east
ELEVATION: 458m
PARENT MATERIAL: Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1 (Druce, 1966) on thin volcanic ash overlying lahric debris.
SITE VEGETATION: Ryegrass and clover
LAND USE: Dairy pasture
DRAINAGE: Imperfectly drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9703 A-E

PROFILE DESCRIPTION

0-15 cm
 Ap dark brown (7.5YR 3/2) gritty loam, with weakly weathered pumiceous lapilli, dark reddish-brown (2.5YR 3/4) iron coatings present; common gravels (Manganui tephra) also iron stained; friable; non sticky; non plastic; moderately fine nut structure; firm penetration; abundant red (2.5YR 4/6) iron stained very fine roots; distinct wavy boundary,

- 15-28 cm
BA
very dark greyish-brown (10YR 3/2) sandy loam, with abundant iron stained gravels (Manganui tephra), with few, weakly weathered pumiceous lapilli; friable; non plastic; non sticky; strongly developed medium nut structure; abundant very fine roots, slightly iron stained; distinct irregular boundary,
- 28-58 cm
BW
brown (10YR 4/3) gritty loam, with few strongly weathered pumiceous lapilli; discontinuous dark grey (10YR 4/1) lithic tuff at approx. 0.47 to 0.49m; friable; slightly sticky; slightly plastic; weak medium blocky structure; firm penetration; many very fine roots; diffuse boundary,
- 58-84 cm
Bg1
dark yellowish-brown (10YR 4/4) gritty loam; firm slightly sticky; slightly plastic; weak coarse blocky structure; firm penetration; many, medium distinct dark greyish-brown (2.5YR 3/6) iron concretions; Andesite stone approx. 0.2m diameter; few very fine roots; indistinct wavy boundary,
- 84-108 cm
Bg2
yellowish-brown (10YR 5/4-5/6) sandy clay loam, with band of moderately weathered, iron stained pumiceous lapilli; firm; non sticky; non plastic; weak blocky structure; firm penetration; few, fine faint dark greyish-brown (10YR 4/2) mottles; few very fine roots; distinct wavy boundary,
- 108+ cm
laharic debris containing stones and occasional boulders.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: MANGAWHERO SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

New taxonomic unit introduced in this soil survey. Area mapped in this survey previously mapped in Egmont, Awatuna, Stratford, Kahui, Inglewood and Glenn sets by N.Z. Soil Bureau (1954). Now separated out as poorly drained soils, formed in *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966) on laharic debris. The closest correlation is with Awatuna set.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant Mw-Mk, Mw-Rv
 (b) Taxonomic unit subdominant Mk-Mw, Rc-Mw, Rv-Mw

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Gley soil
2. Soil Taxonomy
 - (a): Typic Andaquept
 - (b): Typic Vitraquand (ashy, ashy-skeletal, mesic)

GEOGRAPHICAL DISTRIBUTION:

Area west of Kaponga to Awatuna

PARENT MATERIAL:

Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966) on thin (with minor thick) volcanic ash, overlying laharic debris.

LANDFORM:

Tephra mantled upland and lowland laharic terrain.

SLOPE CLASS:

Flat to gently undulating, in depressions.

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's and mid 1900's near 460m.

Now ryegrass clover pastures used mainly for dairying.

Juncus spp. + browntop (Agrostis tenuis), between 336-460m, used for sheep and beef cattle.

RANGE OF ELEVATION: 220-760m

MEAN ANNUAL RAINFALL RANGE: 1730-3860mm

SOIL MOISTURE CLASS: Aquic
Hydrous

MEAN ANNUAL AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE: Poorly drained

PERMEABILITY: Slow

FLOODING: Nil

EROSION:

Occurs in two erosion zones on Sheet 7 of Erosion Map of New Zealand (NWSCO,1977). Up to about 500m elevation no significant present erosion is indicated and no significant potential erosion under pastoral use is predicted. Above this there is no significant present erosion but a moderate potential erosion severity under pastoral use is predicted, involving earth slip and slump erosion.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

Very dark greyish-brown to very dark brown loam to silt loam topsoils, with a strong to moderately well developed structure, overlies weakly structured B horizons.

The B horizons are all gleyed and have colours varying from yellowish-brown to pale brown with dark reddish-brown to red mottles, which increase from

few to faint to many distinct, with depth. Concretions may also be a feature of the profile and similarly increase with depth. The mottles and concretions tend to be associated with the presence of lithic and pumiceous lapilli, which can be concentrated in distinct bands, or scattered. The Manganui tephra is usually concentrated in the upper gleyed horizons, with its discontinuous dark grey (10YR 4/1) lithic tuff. The lithic lapilli and lithic tuff are heavily iron stained.

The concretions can be cemented together to form an indurated, vesicular iron oxide pan, at the textural boundary, between the andesitic lapilli and laharic deposits. The thickness of volcanic ash over laharic debris ranges from 0.50 to 2m.

The water-table in Mangawhero soils is often less than one metre from the surface.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Makaka series differs from Mangawhero in having one or more non-gleyed B horizons above gleyed B horizons.

Awatuna series differs from Mangawhero series in having < 250mm thickness of *young lapilli showers*, Kapokonui, Maketawa and Manganui tephra in the upper horizons.

LABORATORY NUMBERS: 9709 A-G

AUTHOR: A.M. Franks

DATE: 1982

TYPIFYING PROFILE

SOIL NAME: Mangawhero series
PROFILE NO: 4
SITE LOCATION: Upper Mangawhero Road. Moore's property.
 Near western boundary of farm, northern end of
 paddock, 15m south of ditch.
 N119/652505

SITE INFORMATION

LANDFORM: Tephra mantled upland laharic terrain
TOPOGRAPHY: Very gently sloping interfluvium
SLOPE: Near level
ASPECT: South-west
ELEVATION: 458m
PARENT MATERIAL: Moderately weathered andesitic lapilli (c. 3,300
 years B.P.) namely Kaupokonui, Maketawa and Manganui
 tephras > 250mm in thickness, overlying tephras p2
 and p1, (Druce, 1966) on volcanic ash overlying
 laharic debris.
SITE VEGETATION: Ryegrass and clover
LAND USE: Dairy pasture
DRAINAGE: Poorly drained. Lateral seepage at approximately 0.90m.
MOISTURE CONDITIONS: Moist
DISTURBANCE: Nil
LABORATORY NUMBERS: 9709 A-G

PROFILE DESCRIPTION

0-9 cm dark brown (7.5YR 3/2) silt loam; friable; slightly
 Ap sticky; slightly plastic; weak very fine crumb
 structure; soft penetration; abundant very fine roots,
 iron stained, dark red (2.5YR 3/6); distinct wavy
 boundary,

- 9-17 cm
Bg1 dark reddish-brown (5YR 2.5/2) with dusky red (2.5YR 3/2) iron coatings; gritty loam, with few iron stained gravels (Manganui tephra); very friable; non plastic; non sticky; moderately fine nut structure; firm penetration; abundant very fine iron stained roots; wavy distinct boundary,
- 17-34 cm
Bg2 very dark brown (10YR 3/2) sandy loam, with abundant iron stained gravels (Manganui tephra); many moderately weathered pumiceous lapilli up to 30mm, also iron coated; friable; non sticky; non plastic; weak coarse blocky structure; firm to stiff penetration; many, medium, distinct dark greyish-brown (2.5Y 3/2) mottles; many very fine roots; distinct wavy boundary,
- 34-53 cm
Bg3 Manganui gravels concentrated in a band, iron coated and averaging less than 20mm in diameter; structureless; slightly cemented; stiff penetration; (loamy sand where Manganui tephra pockets); few very fine roots; sharp wavy boundary,
- 53-67 cm
Bg4 two lithic tuff bands; upper band very dark grey (5Y 3/1) with dark reddish-brown (5YR 3/2) iron staining; lower band olive grey (5Y 4/1) with yellowish-red (5YR 4/6) iron staining. Bands average 30mm, separated by 60mm dark yellowish-brown (10YR 3/4) sandy clay loam; friable; slightly sticky; moderately plastic; weak coarse blocky structure; firm penetration; many medium distinct dark greyish-brown 10YR 4/2 mottles; dusky red (2.5YR 3/2) iron coatings on old root channels; few very fine roots; distinct wavy boundary,
- 62-82 cm
Bg5 dark yellowish-brown (10YR 4/6) sandy clay loam, traces of strongly weathered pumiceous lapilli; friable; slightly sticky; moderately plastic; very weak coarse blocky structure; firm penetration; many medium distinct dark greyish-brown (2.5Y 4/2) mottles; few, prominent black (10YR 2/1) humus coatings; abundant yellowish-red (5YR 4/6) concretions, less than 10mm in diameter; sharp irregular boundary,
- 82+ cm
2C grey (5Y 5/1) weakly cemented laharic breccia; dark greyish-brown (2.5Y 4/2) medium distinct mottles.

SOIL TAXONOMIC UNIT DESCRIPTIONSSOIL NAME: NGAERE SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

New soil series, introduced in this survey to include imperfectly drained, weakly gleyed soils formed in thick volcanic ash, with Manganui tephra being < 250mm in thickness and the tephra p2 and p1 (Druce, 1966) present as a distinct band of pumiceous lapilli, with tephra E5 and E4 present, less than 1m from the surface. Included in Stratford set by N.Z. Soil Bureau (1954).

SYMBOLS OF MAPPING UNITS WHERE:

- | | | |
|-----|----------------------------|-------|
| (a) | Taxonomic unit dominant | Ng-St |
| (b) | Taxonomic unit subdominant | - |

CLASSIFICATION:

- | | | |
|----|------------------------------------|--|
| 1. | N.Z. Genetic Classification (1970) | Weakly gleyed yellow-brown loam |
| 2. | Soil Taxonomy | (a): Aquic Dystrandept
(b): Aquic Hapludand (medial, mesic) |

GEOGRAPHICAL DISTRIBUTION:

Occurs near Eltham township, adjacent to the Eltham swamp.

PARENT MATERIAL:

Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1, (Druce, 1966) E5 and E4 on thick volcanic ash.

LANDFORM:

Volcanic ash mantled lowland laharic terrain.

SLOPE CLASS:

Flat to gently undulating.

VEGETATION AND LAND USE:

Originally rimu-rata forest, cleared in the early 1900's.
Now ryegrass clover pasture used mainly for dairying.

ELEVATION RANGE: 150-240m

MEAN ANNUAL
RAINFALL RANGE: 1470-1860mm

MEAN ANNUAL
AIR TEMPERATURE: 11.6⁰C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Imperfectly drained

SOIL MOISTURE CLASS: Udic
Hygrous

PERMEABILITY: Moderately slow

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES

Ngaere soils are characterised by very dark brown to dark brown loam top-soils, with moderately well developed nutty structure. There may be one or two non-gleyed horizons above the lower gleyed B horizons. The poorly drained variant has all its B horizons gleyed.

The upper B horizons vary from dark reddish-brown to brown weathered sandy loam to loam while the lower B horizons range from strong brown to reddish-brown to yellowish-brown in colour, with dark reddish-brown to yellowish-red mottles. These gleyed features tend to be associated with the moderately to strongly weathered pumiceous lapilli, present either scattered or concentrated in a band.

Iron concretions are a feature of Ngaere soils, with few to many concretions usually associated with the pumiceous lapilli and an iron pan can sometimes occur.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Stratford series differs from Ngaere series in being well drained and so lacks gleyed features.

LABORATORY NUMBERS: Not sampled

AUTHOR: A.M. Franks .

DATE: 1982

TYPIFYING PROFILE

SOIL NAME: Ngaere series
PROFILE NO: 228
SITE LOCATION: Mangawhero Road. 1.4km from junction with Mountain Road. Shaw's property. Paddock containing barn, near end of property.
 N119/883447

SITE INFORMATION

LANDFORM: Volcanic ash mantled lowland laharic terrain
TOPOGRAPHY: Slight depression on undulating land
SLOPE: Near level
ASPECT: South
ELEVATION: 183m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1, (Druce, 1966) E5 and E4 on thick volcanic ash.
SITE VEGETATION: Ryegrass, clover, Plantago spp. Juncus spp.
LAND USE: Pasture
DRAINAGE: Imperfectly drained
MOISTURE CONDITIONS: Moist
EROSION Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-23 cm
 Ap very dark brown (10YR 2/2) loam, with rare gravel (Manganui tephra); moderately weak; non sticky; non plastic; mod-weakly developed fine nutty structure; many roots; distinct irregular boundary,

- 23-54 cm
Bw1
dark brown-brown (10YR 4/3) sandy loam, with many moderately weathered pumiceous lapilli; moderately weak; non sticky; non plastic; weakly developed medium nutty structure; many roots; distinct wavy boundary,
- 54-82 cm
Bw2
brown (7.5YR 4/4) gritty loam, with strongly weathered scattered pumiceous lapilli; moderately firm; slightly sticky; slightly plastic; weak medium and coarse blocky structure; common roots; distinct irregular boundary,
- 82-100 cm
Bg1
strong brown (7.5YR 5/6) sandy loam to loam, with strongly weathered, scattered pumiceous lapilli; moderately firm; non sticky; non plastic; massive; few roots; many, distinct yellowish-red (5YR 4/6) mottles.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: OKATO SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by R.W.P. Palmer et al., in Soils of Egmont County (1981).

Okato soils were separated out by R.W.P. Palmer et al., to include imperfectly and poorly drained soils from recent alluvium. This definition followed in Eltham County.

SYMBOLS OF MAPPING UNITS WHERE:

- | | | |
|-----|----------------------------|-------|
| (a) | Taxonomic unit dominant | Ok |
| (b) | Taxonomic unit subdominant | Hn-Ok |

CLASSIFICATION:

- | | | |
|----|------------------------------------|--|
| 1. | N.Z. Genetic Classification (1970) | Gley soil |
| 2. | Soil Taxonomy | (a): Haplic Andaquept
(b): Entic Vitraquand (ashy, mesic) |

GEOGRAPHICAL DISTRIBUTION:

Adjacent to several stream channels in Eltham County. Extensive in catchments of Otakeho, Dunns, Waingongoro, Kaupokonui, Mangawhero, and Mangawheroiti streams.

PARENT MATERIAL:

Weakly weathered andesitic alluvial sands and gravels.

The deposits vary in texture from loamy sand to coarse sand and may be stony or gravelly and occasionally have boulders. There is no volcanic ash cover.

LANDFORM:

Alluvial fans and levées and river terraces.

SLOPE CLASS:

Flat to gently undulating.

VEGETATION AND LAND USE:

In the past mainly rimu-rata forest. Now ryegrass clover pastures used chiefly for dairying, with minor grazing of sheep and beef cattle.

RANGE OF ELEVATION: 120-460m

MEAN ANNUAL RAINFALL RANGE: 1330-2680mm

MOISTURE CLASS: Udic
Hydrous

MEAN ANNUAL AIR TEMPERATURE 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Imperfectly and poorly drained

PERMEABILITY: Moderately slow to slow

FLOODING:

Do not receive regular additions of alluvium; recognised as areas of future liability to inundation by debris flows.

EROSION:

According to N.Z. Land Resource Inventory Worksheet N119 (NWSCQ,1979) slight streambank erosion occurs along the Mangawhero, Kaupokonui and Kapuni streams.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

The A horizons have dark reddish-brown, dark brown to black colours, with moderate to weakly developed nutty and crumb structures and iron stained roots. The textures vary from silt loam to loamy sand.

A thin non-gleyed B horizon may be present above gleyed B horizons. In poorly drained profiles, the B horizons are all gleyed and vary in colour from dark greyish-brown to dark yellowish-brown. Strong brown to dark red mottles increase and become more prominent with depth.

The B horizons are very weak and either have a weakly developed structure or are single grained and structureless. The textures vary from silt loam to sandy loam and there may be pockets or bands of sand in the profile.

The C horizons are gleyed, with many mottles and vary in texture from silt to coarse sand.

Gravel and stones may be present and tend to increase with depth so that horizons become gravelly or stony.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Hangatahua series differs from Okato series in being well drained.

LABORATORY NUMBERS: Not sampled

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Okato series
PROFILE NO: 204
SITE LOCATION: Lower Stuart Road, adjacent to Waingongoro River.
 Kreger's property.
 N119/857459

SITE INFORMATION

LANDFORM: Levée
TOPOGRAPHY: Slight depression
SLOPE: 1°
ASPECT: North-east
ELEVATION: 183m
PARENT MATERIAL: Weakly weathered andesitic alluvial sands and gravel.
 There is no volcanic ash cover
SITE VEGETATION: Ryegrass and Juncus spp.
LAND USE: Dairy pasture
DRAINAGE: Poorly drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-24 cm A	very dark greyish-brown to dark greyish-brown (10YR 3/2-4/2) silt loam; very weak; non sticky; slightly plastic; weak fine and very fine nutty structure; many iron stained roots; distinct irregular boundary,
24-42 cm Bg1	dark greyish-brown (2.5YR 4/2) loam; very weak; non sticky; non plastic; weak medium nutty structure; many iron stained roots; few distinct fine strong brown (7.5YR 5.8) mottles; distinct wavy boundary,

- 42-63 cm
Bg2 very dark greyish-brown (2.5Y 3/2) coarse sand; non sticky; non plastic; single grain; common roots; few, distinct medium yellowish-red (5YR 4/6) mottles; distinct wavy boundary,
- 63-100 cm
Cg dark brown (7.5YR 3/2) silt; non sticky; non plastic; few roots; structureless; common, distinct medium dark red (2.5YR 3/6) mottles.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: RIVERLEA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

New taxonomic unit introduced in this soil survey. Area mapped in this survey previously mapped in Stratford, Egmont, Awatuna, Kahui and Glenn sets by N.Z. Soil Bureau (1954). Now separated out as well drained soils, formed in *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness, overlying tephras p2 and p1, (Druce, 1966) on laharic debris.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant Rv-Mk, Rv-Mw
 (b) Taxonomic unit subdominant Mk-Rv, Mw-Rv

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Moderately to strongly leached yellow-brown loam
 2. Soil Taxonomy (a): Mollic Vitrandept
 (b): Typic Hapludand (medial, medial-skeletal, mesic)

GEOGRAPHICAL DISTRIBUTION:

Extensive area west of Kaponga to Awatuna

PARENT MATERIAL:

Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness overlying tephras p2 and p1, (Druce, 1966) on thin (with minor thick) volcanic ash, overlying laharic debris.

LANDFORM:

Tephra mantled lowland laharic terrain.

SLOPE CLASS:

Flat to easy rolling.

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's.
Now ryegrass clover pasture used mainly for dairying.

RANGE OF ELEVATION: 220-310m

MEAN ANNUAL
RAINFALL RANGE: 1730-2060mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY CLASS: Moderately rapid

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to very dark brown loam to sandy loam topsoil, with moderately well developed fine nutty and crumb structure, overlies dark yellowish-brown to yellowish-brown, weakly structured B horizons.

Lithic and pumiceous lapilli are a characteristic feature of Riverlea soils, with Kaupokonui, Maketawa and Manganui tephra concentrated in the A and upper B horizon. The lithic tuff may be present as a 10-30mm discontinuous band, in the subsoil. Lithic and pumiceous lapilli occur scattered or concentrated in bands, in the lower B horizons and become more strongly weathered with depth.

The thickness of volcanic ash over laharic debris ranges from 0.70 to 2m.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Rowan series: differs from Riverlea series in being more strongly leached with dark reddish-brown (5YR or 2.5YR) illuvial coatings on lapilli and ped surfaces. Kaupokonui and Maketawa tephras are present as a distinct band in the topsoil.

Stratford series: differs from Riverlea in being found in thicker (not less than 2m) of volcanic ash, with < 250mm thickness of Manganui tephra. In the upper B horizons the tephras p2 and p1 (Druce, 1966) are present in concentration. It may be mapped extensively using the soil series as the mapping unit, whereas Riverlea series is mapped in association with other soils.

Kahui series: differs from Riverlea in having < 250 thickness of Manganui tephra in the upper horizons.

Lowgarth series: differs from Riverlea in being found in thicker (not less than 2m) volcanic ash. It may be mapped extensively using the soil series as the mapping unit, whereas Riverlea series is mapped in association with other soils.

LABORATORY NUMBERS: SB 9705 A-D

AUTHOR: A.M.Franks

DATE: 1982

TYPIFYING PROFILE

SOIL NAME: Riverlea series
PROFILE NO: 106
SITE LOCATION: Lower Mangawhero Road, 1km south from Riverlea. Gardner's property. Across Mangawhero stream, on a slight dip in far corner of paddock, 10m from hedge, north boundary,
 N119/674449

SITE INFORMATION

LANDFORM: Tephra mantled lowland laharic terrain
TOPOGRAPHY: Gently sloping
SLOPE: 4^o
ASPECT: South-west
ELEVATION: 225m
PARENT MATERIAL: Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephras > 250mm in thickness overlying tephras p2 and p1, (Druce, 1966) on volcanic ash, overlying laharic debris.

SITE VEGETATION: Ryegrass and clover

LAND USE: Dairy pasture

DRAINAGE: Well drained

MOISTURE CONDITIONS: Moist

EROSION: Nil

DISTURBANCE: Nil

LABORATORY NUMBERS: SB 9705 A-D

PROFILE DESCRIPTION

0-21 cm
 Ap very dark greyish-brown (10YR 3/2) gritty loam, with abundant gravels (Manganui tephra); very friable; non sticky; non plastic; moderately developed coarse blocky, breaking to fine nutty structure; firm penetration; abundant very fine roots; indistinct, irregular boundary,

- 21-34 cm
BA dark brown (10YR 3/3) sandy loam, with many gravels (Manganui tephra) concentrated in the upper part of horizon; friable; non sticky; non plastic; moderately developed fine crumb and nut structure; firm penetration; many very fine roots; indistinct wavy boundary,
- 34-83 cm
Bw1 dark brown (10YR 4/3) gritty loam, with rare gravels and pumiceous lapilli concentrated in lower horizon, moderately to strongly weathered averaging 50mm in diameter; friable; slightly sticky; slightly plastic; moderately coarse blocky breaking to fine crumb structure; firm penetration; common very fine roots; indistinct wavy boundary,
- 83-118 cm
Bw2 dark yellowish-brown (10YR 4/4-4/6) sandy clay loam; slightly sticky; moderately plastic; weak blocky structure; stiff penetration; few very fine roots; sharp wavy boundary,
- 118+ cm dark greyish-brown (2.5Y 4/2) laharic debris, weakly cemented; yellowish-red (5YR 4/6) iron coatings.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: ROWAN SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by Aitken *et al.*, (1978) Soils of Stratford County N.I. N.Z. Soil Survey Report 42. Rowan soils included soils derived from a lapilli-bearing "unnamed ash" over "Stratford Ash". The area mapped in this survey was previously mapped in Patua, Kahui and Inglewood sets by N.Z. Soil Bureau (1954).

The parent material was defined by R.W.P. Palmer *et al.*, as andesitic, lapilli-bearing volcanic ash on older tephrae, on lahāric sandstone of Warea Formation. This definition followed in this survey, with the tephrae being more rigorously defined.

In Eltham County Rowan series is a well drained, strongly leached soil formed in *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephrae > 250mm in thickness, overlying tephrae p2 and p1 (Druce, 1966) on lahāric debris of Warea Formation (12-15,000 years B.P.).

SYMBOLS OF MAPPING UNITS WHERE:

- | | |
|--------------------------------|--------------|
| (a) Taxonomic unit dominant | Rc-Mk, Rc-Mw |
| (b) Taxonomic unit subdominant | - |

CLASSIFICATION:

- | | |
|---------------------------------------|--|
| 1. N.Z. Genetic Classification (1970) | Strongly leached, iron illuvial yellow-brown loam |
| 2. Soil Taxonomy | (a): Typic Vitrandept
(b): Typic Vitrudand (ashy over medial, ashy-skeletal, mesic) |

GEOGRAPHICAL DISTRIBUTION:

A belt north and south of Opunake Road, in the western area of Eltham County

PARENT MATERIAL:

Moderately weathered andesitic lapilli (c. 3,300 years B.P.) namely Kaupokonui, Maketawa and Manganui tephrae, > 250mm in thickness, overlying tephrae p2 and p1 (Druce, 1966) on thin (with minor thick) volcanic ash, overlying lahāric debris of Warea Formation.

LANDFORM:

Tephra mantled upland lahāric terrain.

SLOPE CLASS:

Flat to hilly.

VEGETATION AND LAND USE:

Within Egmont National Park above 460m rimu-rata/kamahahi forest, progressing to kamahahi dominant to kamahahi-totara forest, with elevation. Used for reserve or recreational purposes. Outside the National Park the original vegetation was rimu-rata forest, which was cleared in the early 1900's and the 1950's, just below 460m. Now pasture used for sheep, dairying and some beef cattle.

RANGE OF ELEVATION: 310-760m

MEAN ANNUAL
RAINFALL RANGE: 2060-3860mm

SOIL MOISTURE CLASS: Perudic
Hydrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6⁰C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid

FLOODING: Nil

EROSION:

Occurs in two erosion zones on Sheet 7 of Erosion Map of New Zealand, (NWSCO, 1977). Up to about 500m elevation, no significant present erosion is indicated and no significant potential erosion under pastoral use is predicted. Above this there is no significant present erosion but a moderate potential erosion severity under pastoral use is predicted, involving earth slip and slump erosion.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

Dark reddish-brown or dark brown, sandy loam topsoils, with moderately well developed nutty structure. Lithic and pumiceous lapilli are characteristic of Rowan series, with 5YR and 2.5YR iron illuvial coatings. The tephras Kaupokonui, Makatawa and Manganui, impart a gravelly modification to the topsoils.

The B horizons range from yellowish-brown to dark brown colours with weak blocky structures and illuvial coatings on ped surfaces and the pumiceous and lithic lapilli, which occur either scattered or concentrated in a band.

Most profiles include a layer of dark grey (10YR 4/1) finely bedded lithic tuff 20-60mm thick. The lithic tuff is estimated to be around 3,300 years B.P. and is found at depths ranging from 0.38 to 0.60m.

The thickness of volcanic ash over laharic debris ranges from 0.80 to greater than 2m.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Lowgarth series differs from a Rowan in being found at lower elevations with rainfall being < 2000mm and is less leached than a Rowan, with no illuvial coatings.

Riverlea series is less leached than a Rowan and illuvial coatings are absent from lapilli and ped surfaces. The *young lapilli showers* are not usually present in any great concentration.

Kahui series differs from a Rowan in being less leached and has < 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras.

LABORATORY NUMBERS: SB 9707 A-D

AUTHOR: A.M.Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Rowan series
PROFILE NO: 1
SITE LOCATION: Upper Mangawhero Road. Keenan's property.
 Paddock below National Park boundary, fourth paddock
 along from ford.
 N119/674526

SITE INFORMATION

LANDFORM: Tephra mantled upland laharic terrain
TOPOGRAPHY: Very gently sloping rise
SLOPE: 5°
ASPECT: South
ELEVATION: 450m
PARENT MATERIAL: Moderately weathered andesitic lapilli (c. 3,300
 years B.P.) namely Kaupokonui, Maketawa and Manganui
 tephras, > 250mm in thickness overlying tephras p2
 and p1, (Druce, 1966) on ash overlying laharic debris
 of Warea Formation.
SITE VEGETATION: Ryegrass and clover
LAND USE: Pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9707 A-D

PROFILE DESCRIPTION

0-30 cm
 A dark reddish-brown (5YR 3/2) gritty loam with
 pumiceous lapilli (Kaupokonui and Maketawa tephras)
 concentrated in lower part of the horizon, moderately
 weathered, averaging 30mm in diameter, with dark
 reddish-brown (2.5YR 3/4) iron cutans; friable;
 non sticky; non plastic; moderately developed fine
 nut structure; soft penetration; abundant very
 fine roots; distinct wavy boundary,

- 30-51 cm
Bs dark yellowish-brown (10YR 3/4) sandy loam with abundant gravels (Manganui tephra) concentrated in the lower part of the horizon; dark red (2.5YR 3/6) cutans; friable; non sticky; non plastic; weakly developed fine nut structure; stiff penetration; many very fine roots; distinct wavy boundary,
- 51-75 cm
Bw1 dark brown (10YR 4/3) gritty loam with scattered strongly weathered pumiceous lapilli, averaging 20mm in diameter; friable; slightly sticky; moderately plastic; weak, medium, blocky structure; firm penetration; few very fine roots; sharp wavy boundary,
- 75-100+ cm
2C thin layer of loamy sand grading to a dark greyish-brown (2.5YR 4/2) coarse sand, with gravels; loose; non sticky; non plastic firm penetration; rare roots.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: STRATFORD SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by Grange, L.I., Taylor, N.H. 1933. Field work on Soils of Western Taranaki D.S.I.R. Annual Report 1932-33 pp 3-5.

The area mapped in this survey was previously mapped in Stratford and New Plymouth sets by N.Z. Soil Bureau (1954).

Redefined by Aitken *et al.*, (1978) Soils of Stratford County N.I. N.Z. Soil Survey Report 42. Stratford soils included soils formed from "Stratford Ash" overlying the older deposits of Egmont Ash and bouldery lahar detritus.

More closely defined in this survey, as a well drained, moderately leached soil formed in thick volcanic ash, with Manganui tephra being < 250mm in thickness and the tephra p2 and p1, (Druce, 1966) present as a distinct band of pumiceous lapilli, with tephra E5 and E4 present, less than 1m from the surface.

SYMBOLS OF MAPPING UNITS WHERE:

- | | | |
|-----|----------------------------|---|
| (a) | Taxonomic unit dominant | St, StH-St, StH-St ₁ , St ₁ |
| (b) | Taxonomic unit subdominant | Ng-St |

CLASSIFICATION:

- | | | |
|----|------------------------------------|--|
| 1. | N.Z. Genetic Classification (1970) | Moderately leached yellow-brown loam |
| 2. | Soil Taxonomy | (a): Entic Dystrandept
(b): Typic Hapludand (medial, mesic) |

GEOGRAPHICAL DISTRIBUTION:

Extensive area east of Kaponga.

PARENT MATERIAL:

Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1, (Druce, 1966) E5 and E4, on thick ash or sedimentary rocks, silty sandstone deposits.

LANDFORM:

Volcanic ash mantled lowland laharic terrain.

SLOPE CLASS:

Flat to strongly rolling and hilly.

VEGETATION AND LAND USE:

Originally rimu-rata forest cleared in the early 1900's. Now pasture used mainly for dairying.

RANGE OF ELEVATION: 120-290m

MEAN ANNUAL
RAINFALL RANGE: 1330-1810mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid - Moderate

FLOODING: Nil

EROSION:

No significant present erosion. In Sheet 7 of Erosion Map of New Zealand (NW5C0,1977). Stratford series hill soils are predicted as having a slight to moderate potential erosion severity, involving earth slip and slump erosion under pastoral use.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to very dark brown coloured topsoil of loam or silt loam texture and moderately well developed crumb structure overlies

paler coloured B horizons.

The subsoil in Stratford soils is characterised by containing pumiceous lapilli, which are usually concentrated in distinct bands but may be scattered throughout the profile. The lapilli are weakly to moderately weathered in the upper B horizons but become more strongly weathered with depth.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Lowgarth series differs from Stratford series in having > 250mm thickness of *young lapilli showers*, Kapokonui, Maketawa and Manganui tephras, which impart a gravelly modification to the upper horizons.

Kahui series differs from Stratford series in being found in volcanic ash < 2m thick, over laharic debris. Kahui series is mapped in association with other soils whereas Stratford covers an extensive area and is mapped as a simple mapping unit either as Stratford soils, Stratford soils, strongly rolling phase or Stratford hill soils.

Egmont series differs from Stratford series in that it does not contain pumiceous lapilli throughout the soil profile and the texture is finer. Egmont series forms under a lower mean annual rainfall range (1100-1600mm).

Ngaere series differs from Stratford series in being imperfectly drained, with one or two non-gleyed but weathered horizons above the gleyed B horizons.

LABORATORY NUMBERS: SB 9708 A-D

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Stratford series
PROFILE NO: 120
SITE LOCATION: Lower Hastings Road, 1.5km from Matapu. Blake's property. Second paddock along from hay barn, centre of paddock.
 N119/797423

SITE INFORMATION

LANDFORM: Volcanic ash mantled lowland laharic terrain.
TOPOGRAPHY: Flat
SLOPE: Near level
ASPECT: South-east
ELEVATION: 175m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of Manganui tephra < 250mm in thickness, on pumiceous lapilli-bearing ash showers, tephra p2, p1 (Druce, 1966) E5 and E4 on thick volcanic ash.
SITE VEGETATION: Ryegrass and clover
LAND USE: Dairy pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9708 A-D

PROFILE DESCRIPTION

0-35 cm
 Ap very dark brown (10YR 2/2) gritty loam, with gravels (Manganui tephra), confined to top 250mm; moderately weathered pumiceous lapilli, averaging 20mm; very friable; slightly sticky; slightly plastic; moderately developed coarse blocky breaking to fine crumb structure; firm penetration; abundant very fine roots; distinct wavy boundary,

- 35-65 cm
Bw1 dark brown (10YR 3/3) sandy loam, with abundant moderately weathered pumiceous lapilli, averaging 20mm in diameter, occasional lithic lapilli; friable; non sticky; non plastic; weak medium blocky breaking to fine crumb structure; firm penetration; common roots; indistinct, wavy boundary,
- 65-100 cm
Bw2 yellowish-brown (10YR 5/4) gritty loam with scattered strongly weathered pumiceous lapilli; friable; slightly sticky; slightly plastic; weakly developed medium blocky structure; firm penetration; few roots.

VEGETATION AND LAND USE:

Originally under podocarp-broadleaf forest, with some areas of beech (Nothofagus spp.)

Present vegetation is grass, used for sheep pasture.

RANGE OF ELEVATION: 90-240m

MEAN ANNUAL RAINFALL RANGE: 1500-1900mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL AIR TEMPERATURE: 11.9⁰C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Well drained

PERMEABILITY: Moderately rapid - Moderate

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

Stratford series fine topsoil variants are characterised by very dark brown coloured topsoils of silt loam texture and moderately well developed crumb structure.

The upper B horizon in a Stratford variant is typified by containing scattered, strongly weathered, pumiceous lapilli, which average less than 10mm, and become a speckled ash in the subsoil. The lower B horizons are yellowish-brown in colour and have a loam to sandy clay loam texture.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Stratford series differs from Stratford variant in having traces of Manganui tephra, with the tephra p2 and p1 (Druce, 1966) present as a

distinct band of pumiceous lapilli with E5 and E4 present less than 1m from the surface.

Ngaere series differs from Stratford variant in being imperfectly drained with one or two non-gleyed but weathered horizons above the gleyed B horizons. Ngaere series has moderately weathered pumiceous lapilli throughout the profile.

Egmont series differs from Stratford variant in forming under a lower mean annual rainfall range (1100-1600mm) and in having a distinct black (10YR 2/1) topsoil.

LABORATORY NUMBERS: SB 9708 A-D

AUTHOR: A.M. Franks

DATE: 1982

TYPIFYING PROFILE

SOIL NAME: Stratford series, fine topsoil variant
PROFILE NO: 339
SITE LOCATION: Mangamingi. Hardwick-Smith's property. End of track, terrace above the Patea River.
 N119/031505

SITE INFORMATION

LANDFORM: Volcanic ash mantled terrace
TOPOGRAPHY: Flat land
SLOPE: 1°
ASPECT: North-east
ELEVATION: 115m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of strongly weathered tephras, p2 and p1, (Druce, 1966), E5 and E4, on thick volcanic ash.
SITE VEGETATION: Ryegrass and clover
LAND USE: Pasture
DRAINAGE: Well drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: SB 9708 A-D

PROFILE DESCRIPTION

0-18 cm A	very dark greyish-brown (10YR 3/2) silt loam; moderately weak; slightly plastic; non sticky; moderately developed fine and very fine nutty and crumb structure; many roots; distinct wavy boundary,
18-42 cm Bw1	dark brown to brown (10YR 4/3) loam, with gritty modification, few scattered pumiceous lapilli, less than 10mm; moderately weak; slightly plastic; slightly sticky; moderately developed fine nutty structure; common roots; indistinct irregular boundary,

42-70 cm
Bw2

yellowish-brown (10YR 5/4) loam, with gritty modification; moderately weak; slightly plastic; slightly sticky; weakly developed coarse blocky structure; few roots; diffuse boundary,

70-100 cm
Bw3

yellowish-brown (10YR 5/4-5/6) sandy clay loam, with speckled appearance due to concentration of mafic crystals; moderately firm; slightly plastic; sticky; massive.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: TIPOKA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by R.W.P. Palmer et al. in "Soils of Egmont County" (1981).

The area mapped in this survey was previously mapped in Glenn and Egmont sets by N.Z. Soil Bureau (1954).

Defined and separated out by R.W.P. Palmer et al., as moderately well drained and imperfectly drained, weakly gleyed soils derived from between 0.60 and 2m of volcanic ash, on laharic materials.

This definition followed but in Eltham County Tipoka series is an imperfectly drained, weakly gleyed soil derived from < 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras, overlying tephras p2 and p1, (Druce, 1966) on fine textured ashes over laharic debris of Opuia and Warea Formations.

SYMBOLS OF MAPPING UNITS WHERE:

- | | | |
|-----|----------------------------|---------------|
| (a) | Taxonomic unit dominant | Tk-Kui |
| (b) | Taxonomic unit subdominant | At-Tk, Kui-Tk |

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Weakly gleyed yellow-brown loam
2. Soil Taxonomy

(a):	Aquic Vitrandept
(b):	Aquic Hapludand (medial, mesic)

GEOGRAPHICAL DISTRIBUTION:

West of Kaponga above boundary with Waimate West County.

PARENT MATERIAL:

Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers* < 250mm in thickness of Kaupokonui, Maketawa and Manganui tephras, overlying tephras p2 and p1, (Druce, 1966) on fine textured ashes over laharic debris of Opuia and Warea Formations.

LANDFORM:

Volcanic ash mantled lowland laharic terrain.

SLOPE CLASS:

Flat to gently undulating land.

VEGETATION AND LAND USE:

Originally rimu-rata forest, which was cleared in the early 1900's. Now ryegrass clover pastures used mainly for dairying.

RANGE OF ELEVATION: 210-270m

MEAN ANNUAL
RAINFALL RANGE: 1660-1900mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL
AIR TEMPERATURE: 11.6°C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Imperfectly drained

PERMEABILITY: Moderately slow

FLOODING: Nil

EROSION: Nil

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A very dark greyish-brown to dark brown topsoil, with moderately developed nutty structure overlies a dark brown non-gleyed B horizon. These horizons contain few scattered pumiceous and lithic lapilli (Kaupokonui, Maketawa and Manganui tephra).

The lower B horizons are gleyed and have brown to light yellowish-brown colours, with red to yellowish-red mottles. These mottles are associated with the strongly weathered pumiceous lapilli, which are scattered or concentrated in the lower part of the profile. Concretions may be present.

The thickness of volcanic ash over laharc debris varies and ranges from 0.50 to 2m.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Makaka series differs from Tipoka series in having > 250mm thickness of *young lapilli showers*, Kaupokonui, Maketawa and Manganui tephras, in the upper horizons.

LABORATORY NUMBERS: Not sampled.

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Tipoka series
PROFILE NO: 96
SITE LOCATION: Auroa Road, 1.3km south from Awatuna. Steffert's property. End of race, paddock adjacent to Waimate West County boundary.
 N118/643445

SITE INFORMATION

LANDFORM: Volcanic ash mantled lowland laharic terrain.
TOPOGRAPHY: Depression
SLOPE: 1^o
ASPECT: -
ELEVATION: 230m
PARENT MATERIAL: Moderately weathered andesitic volcanic ash comprised of traces of *young lapilli showers* < 250mm thickness of Kaupokonui, Maketawa and Manganui tephra, overlying tephra p2 and p1 (Druce, 1966) on fine textured ashes over laharic debris
SITE VEGETATION: Ryegrass and clover
LAND USE: Pasture
DRAINAGE: Imperfectly drained
MOISTURE CONDITIONS: Moist
EROSION: Nil
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-18 cm
 Ap very dark brown (10YR 2/2) fine sandy loam with few gravels (Manganui tephra); moderately weak; non sticky; non plastic; moderately developed to weak fine and very fine nutty structure; many roots; distinct wavy boundary,

- 18-52 cm
Bw1
very dark greyish-brown (10YR 3/2) fine sandy loam with few gravels (Manganui tephra), lithic tuff present; moderately weak; non sticky; non plastic; weak fine and very fine nutty structure; common roots; indistinct boundary,
- 52-75 cm
Bg1
brown (10YR 4/3) loam with scattered strongly weathered, < 10mm pumiceous lapilli; very weak; slightly sticky; slightly plastic; weak coarse blocky structure; few, fine, faint yellowish-red mottles (5YR 5/8); few roots; indistinct boundary,
- 75-100 cm
Bg2
dark yellowish-brown (10YR 4/4) sandy loam with strongly weathered pumiceous lapilli concentrated in a band; moderately weak-moderately firm; massive-weak coarse blocky structure; common, fine distinct strong brown (7.5YR 5/8) mottles.

SOIL TAXONOMIC UNIT SHEETSOIL NAME: WHANGAMOMONA SERIESNAME OF SURVEY: ELTHAM COUNTYREFERENCE:

Introduced by N.Z. Soil Bureau (1954) as Whangamomona silt loam, derived from sandy mudstone and sandstone and Whangamomona complex, derived from mudstone, sandstone, Stratford ash and Egmont ash. The area mapped in this survey was previously mapped in Whangamomona and Moumahaki sets.

In N.Z. Soil Bureau (1968), Whangamomona soils were described as being derived from sandstone and were mapped in association with Mangamahu soils.

Whangamomona soils were more closely defined as being formed from moderately consolidated silty sandstone by Aitken et al., (1978).

This definition followed in this survey.

SYMBOLS OF MAPPING UNITS WHERE:

- (a) Taxonomic unit dominant WgS
 (b) Taxonomic unit subdominant -

CLASSIFICATION:

1. N.Z. Genetic Classification (1970) Steepland soil related to yellow-brown earth
2. Soil Taxonomy Aquic, Typic, Andic Dystrochrepts, clayey-skeletal, mesic

GEOGRAPHICAL DISTRIBUTION:

Extensive area east of Eltham Borough

PARENT MATERIAL:

Quartzo-feldspathic moderately consolidated silty sandstone.

LANDFORM:

Dissected Tertiary sedimentary rock terrain.

SLOPE CLASS:

Steep and very steep

VEGETATION AND LAND USE:

Originally under podocarp-broadleaf forest, with some areas of beech (Nothofagus spp.). The major components of the forest were rimu (Dacrydium cupressinum), matai (Podocarpus spicatus) and totara (Podocarpus totara) with kahikatea (Podocarpus dacrydioides), dominant in lowlying areas.

Present vegetation is some secondary growth of bush and pasture grasses. The species ratstail (Sporobolus capensis) browntop (Agrostis tenuis) and danthonia (Danthonia spp.), tend to prevail. Weeds such as ragwort (Senecio jacobaea), rush (Juncus spp.) and thistle (Cirsium spp.) are common.

Land use is mainly concerned with the production of wool, store-sheep and beef cattle with some areas having intensive sheep farming.

RANGE OF ELEVATION: 120-490m

MEAN ANNUAL RAINFALL RANGE: 1500-1900mm

SOIL MOISTURE CLASS: Udic
Hygrous

MEAN ANNUAL AIR TEMPERATURE: 11.9⁰C

SOIL TEMPERATURE REGIME: Mesic

SOIL DRAINAGE CLASS: Imperfectly drained.

EROSION:

In Sheet 7 of Erosion Map of New Zealand (NWSCO,1977) these soils have moderate to severe potential erosion severity, involving earth slip, sheet and slump erosion.

Present erosion severity is moderate to slight earth slip and soil slip.

CHARACTERISTIC PROFILE FEATURES FOR TAXONOMIC UNIT:

A dark greyish-brown to brown topsoil of fine sandy loam texture, with a strongly to moderately well developed fine nutty structure.

A BA horizon may be present with a weakly developed fine nutty structure. Mottles can be a feature of the subsoil and increase with depth.

Fragments of silty sandstone may be present throughout the profile and there can be a sharp and distinct boundary to the moderately consolidated silty sandstone.

In the ridge phase the transition to parent rock is more gradual. The depth to parent rock is usually shallower than in the ridge phase.

SIMILAR SOILS AND DISTINGUISHING FEATURES:

Tahora series: differs from Whangamomona series in being derived from sandy mudstone, with clay loam texture. Sandy mudstone fragments are present throughout the profile and there is a gradual rather than a sharp transition to the rubbly parent rock.

Moumahaki series: differs from Whangamomona series in being derived from strongly consolidated sandstone, with sandier textures, less strongly developed structures and passes more abruptly into the parent rock.

Tirangi series: differs from Whangamomona series in being derived from sandy siltstone, with silt loam texture.

LABORATORY NUMBERS: Not sampled

AUTHOR: A.M. Franks

DATE: 1982

REPRESENTATIVE PROFILE

SOIL NAME: Whangamomona series
PROFILE NO: 343
SITE LOCATION: Mangamingi, 0.5km west of the Patea River. Hardwick-Smith's property. Profile located on steep site of the valley side, between a spur and the valley floor.

SITE INFORMATION

LANDFORM: Dissected Tertiary sedimentary rock terrain
TOPOGRAPHY: Steep slope
SLOPE: 20⁰
ASPECT: North-east
ELEVATION: 200m
PARENT MATERIAL: Quartzo-feldspathic, moderately consolidated silty sandstone.
SITE VEGETATION: Improved pasture
LAND USE: Pasture
DRAINAGE: Imperfectly drained
MOISTURE CONDITIONS: Moist-dry
EROSION: Slight
DISTURBANCE: Nil
LABORATORY NUMBERS: Not sampled

PROFILE DESCRIPTION

0-24 cm
A brown (10YR 5/3) fine sandy loam with many silty sandstone fragments, averaging 10mm in diameter; friable; strong to moderately developed fine nutty structure; soft penetration; many roots; distinct irregular boundary,

24-41 cm
B_w light yellowish-brown to brownish-yellow (10YR 6/4-6/6) sandy loam; friable; weakly developed fine nutty structure; soft penetration; few yellowish-red (5YR 5/8) discolorations along root channels;

common roots; distinct wavy boundary,

on
C/B

light yellowish-brown (2.5Y 6/4) with strong brown (7.5YR 5/8) distinct, coarse mottles; moderately consolidated silty sandstone.

- Yellow-brown loams and gley soils
 - Intergrade between yellow-brown loams and recent soils
 - Recent soils from volcanic ash
- Lithosols and skeletal soils
 - Organic soils
 - Steepland soils related to yellow-brown loams

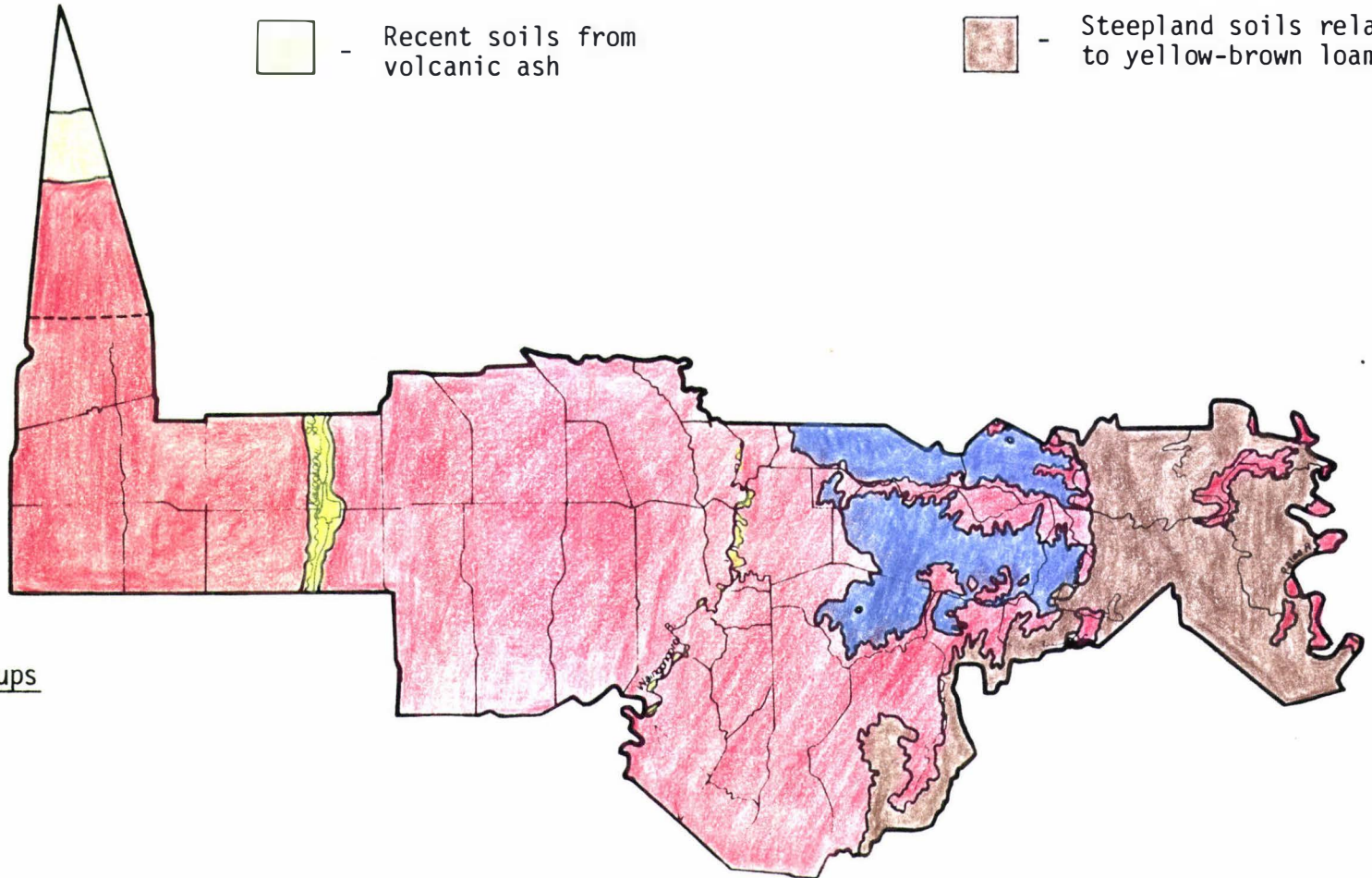


Figure VII- 1 Soil groups

-  - >2m. Volcanic Ash
-  - 1-2m.
-  - 0.1-1m.
-  - < 0.1m.
-  - Peat

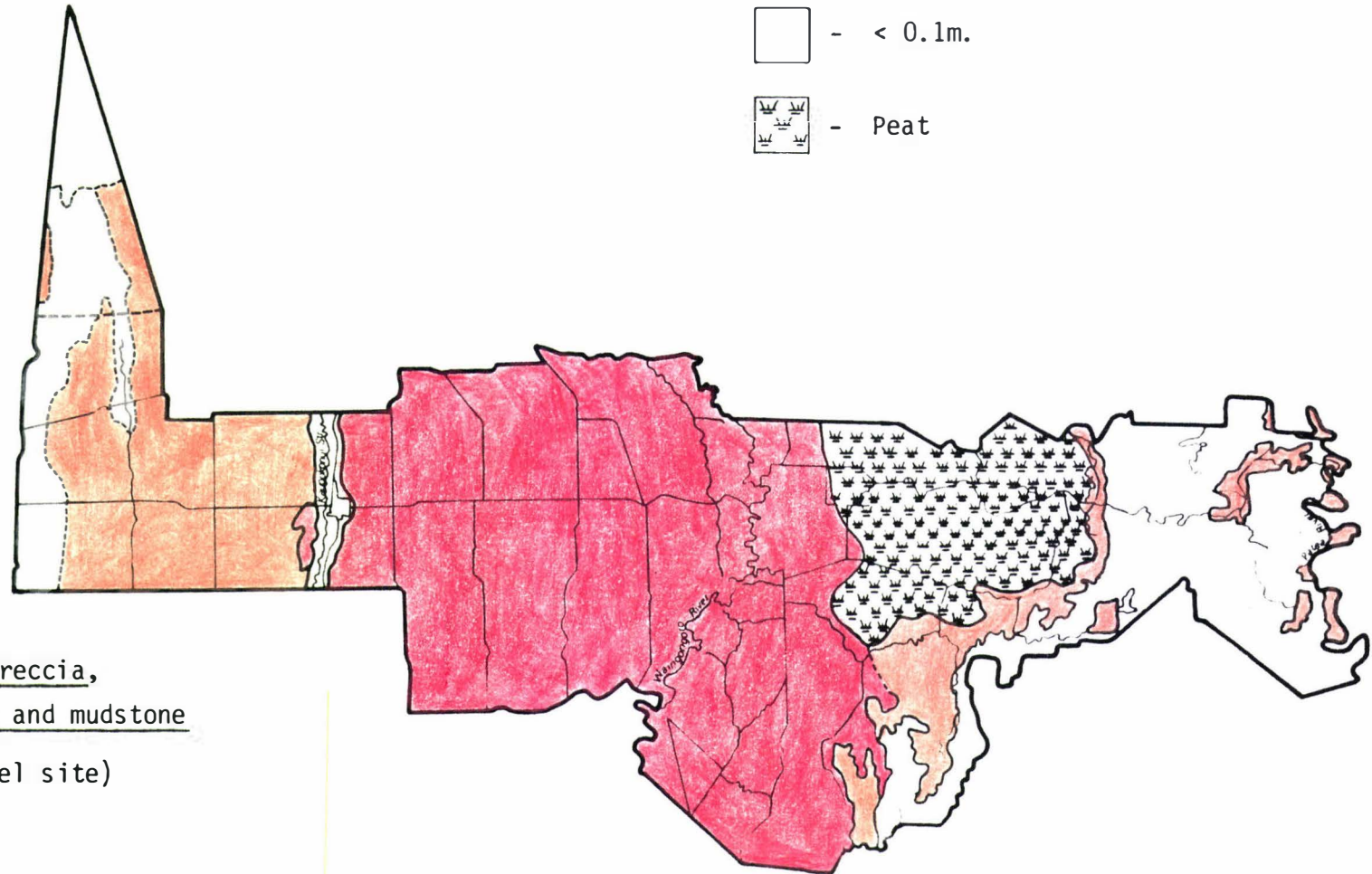


Figure VII- 2
Volcanic ash depth to breccia,
conglomerate, sandstone and mudstone
 (average depth on a level site)

Figure VII- 3

Rainfall Isohyets

From N.Z. Meteorological Service mean annual rainfall maps.

(Based on Rainfall Normals 1941-1970 published in N.Z. Meteorological Service Miscellaneous Publications 145 and supplement).

