LATE QUATERNARY POLLEN STRATIGRAPHY, GEOLOGY AND SOILS OF AN AREA NEAR GREYTOWN.

A thesis presented in partial fulfilment of
the requirements for the Degree of
Master of Science at
Massey University.

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ABSTRACT.

In the southern Wairarapa Valley there are extensive gravel fans, built by the Tauherenikau, Waiohine, and Waingawa Rivers. The fans form the Waiohine Surface which is lapped by a complex of Holocene fluvial, lacustrine and estuarine deposits. At the toe of the fans, peat deposits have accumulated over early Holocene sediments.

This study involved;

a) detailed mapping of the Quaternary deposits and soils and,

b) analysis of pollen stratigraphy from continuous peat deposits in an area south of Greytown, in order to establish the Late Quaternary vegetative and environmental changes in the area.

Detailed mapping showed that the c.6,000 years B.P. Holocene high sea level did not encroach the area as was previously believed. After the formation of the Waiohine Surface c.10,000 years B.P., the Waiohine and possibly Tauherenikau Rivers infilled the area with aggradational gravels and sands. At c.8,500 years B.P. these river systems left the area and, peat deposits began accumulating soon after.

The pollen spectrum, dated from c.8,500 years B.P. at the base, to c.5,500 years B.P. at the surface showed that the vegetation in the area suffered little change during the period of peat accumulation. Substantial areas of shrub, herbaceous and swamp communities existed in the valley, in addition to a *Dacrydium cupressinum* dominated podocarp-hardwood forest. Stands of *Dacrycarpus dacrydioides* were prominent on many wetter sites. A podocarp-hardwood complex, with areas of *Nothofagus* existed in the adjacent ranges.

Climatic deterioration may have caused the rise in *Nothofagus* at the expense of the podocarps after 6,000 years B.P. The steady decline of *D. dacrydioides* with respect to *D. cupressinum* between 6,000 years B.P. and 5,000 years B.P. however, is a result of local drying around the bog. Fluctuations in vegetation are not of sufficient magnitude to justify the use of pollen zones.

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CHAPTER ONE

INTRODUCTION.

1.1 OBJECTIVES.

The objective of the present study was to elucidate the spatial and temporal Late Quaternary stratigraphy of an area south of Greytown. Specific objectives were:

(1) To map the distribution of peat deposits and analyse their pollen stratigraphy.

(2) To map the distribution of other Late Quaternary deposits in order to

(a) Locate the edge of the Ohakean Waiohine Surface.

and (b) Date the abandonment of the area by the Waiohine River

(3) Produce a Quaternary geology map, and soil map of the area at a scale of 1:25,000.

1.2 THE STUDY AREA.

The study area is located just south of Greytown (fig 1.0a), bordered on the east by the Otukura Stream and Te Maire Ridge, and on the west by Phillips Line, Pharazyns Road and Moroa Road. The area is approximately 4700 hectares extending from Greytown southward 10km to State Highway 53.

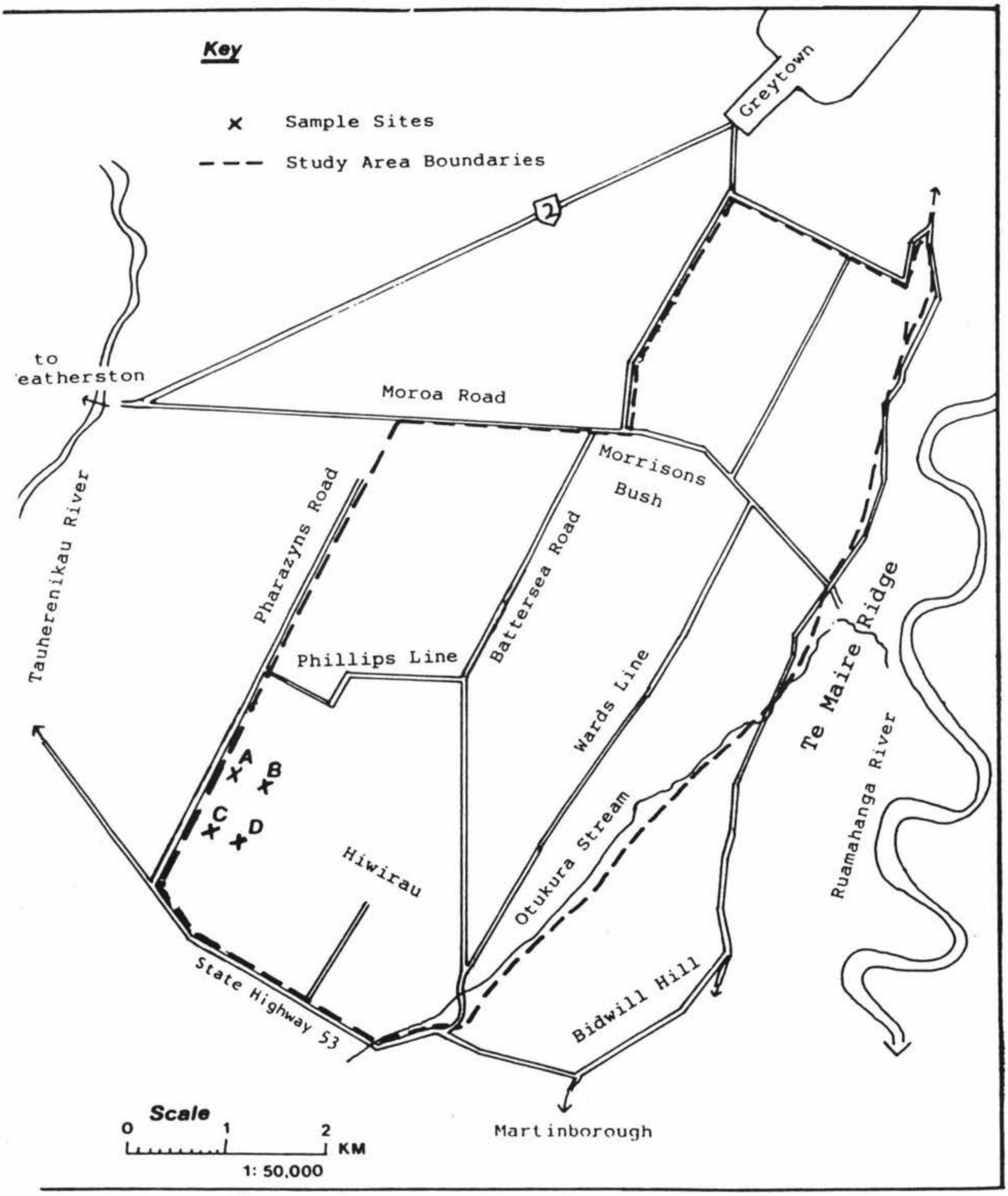


Figure 1·0a Map showing study area, surrounding roads, major waterways, & pollen sampling sites.

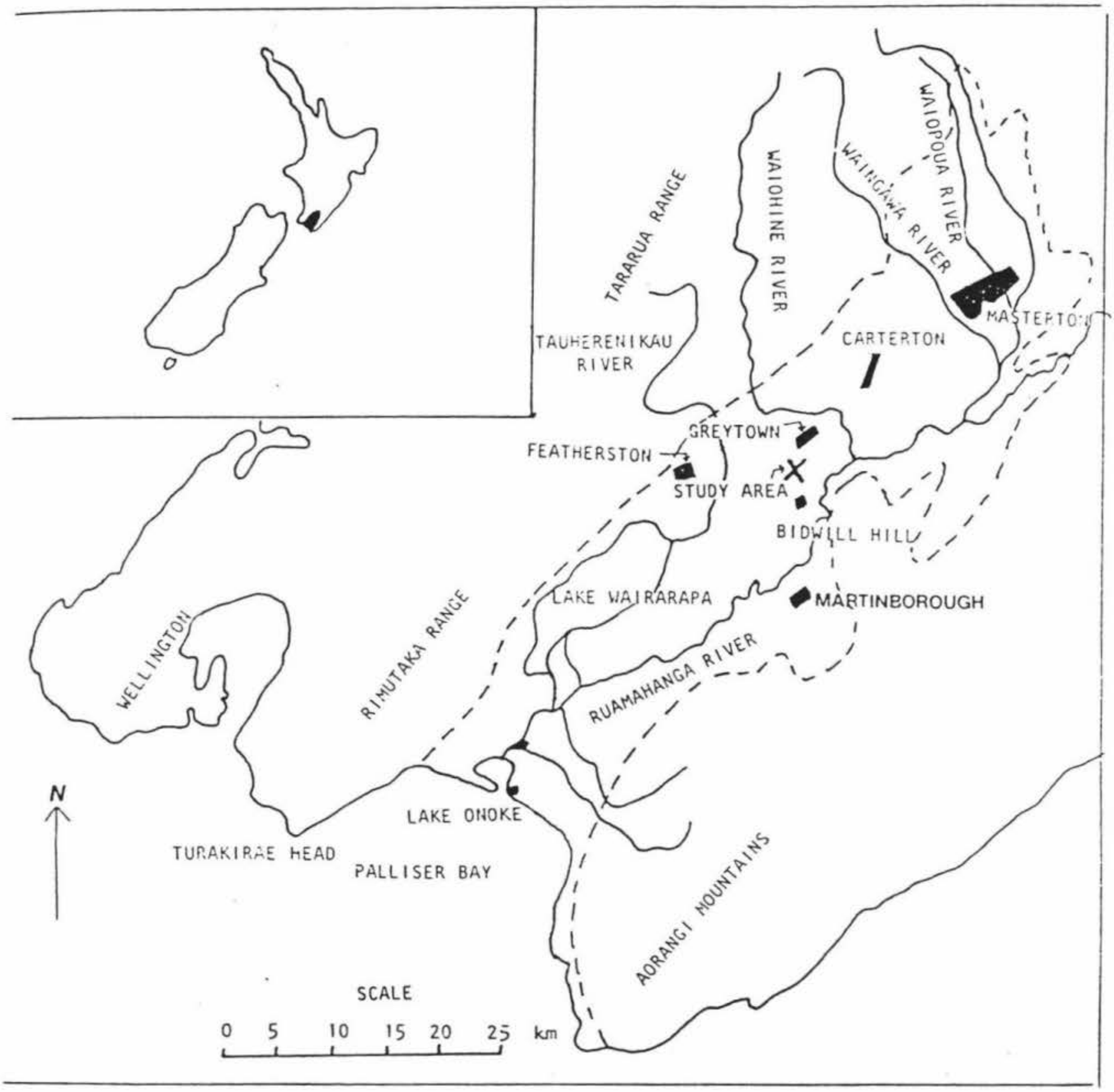


FIGURE 1.0b Locality map of the Study Area showing the extent of Wairarapa Valley (bounded by the broken line), towns, lakes, and rivers mentioned in the text.

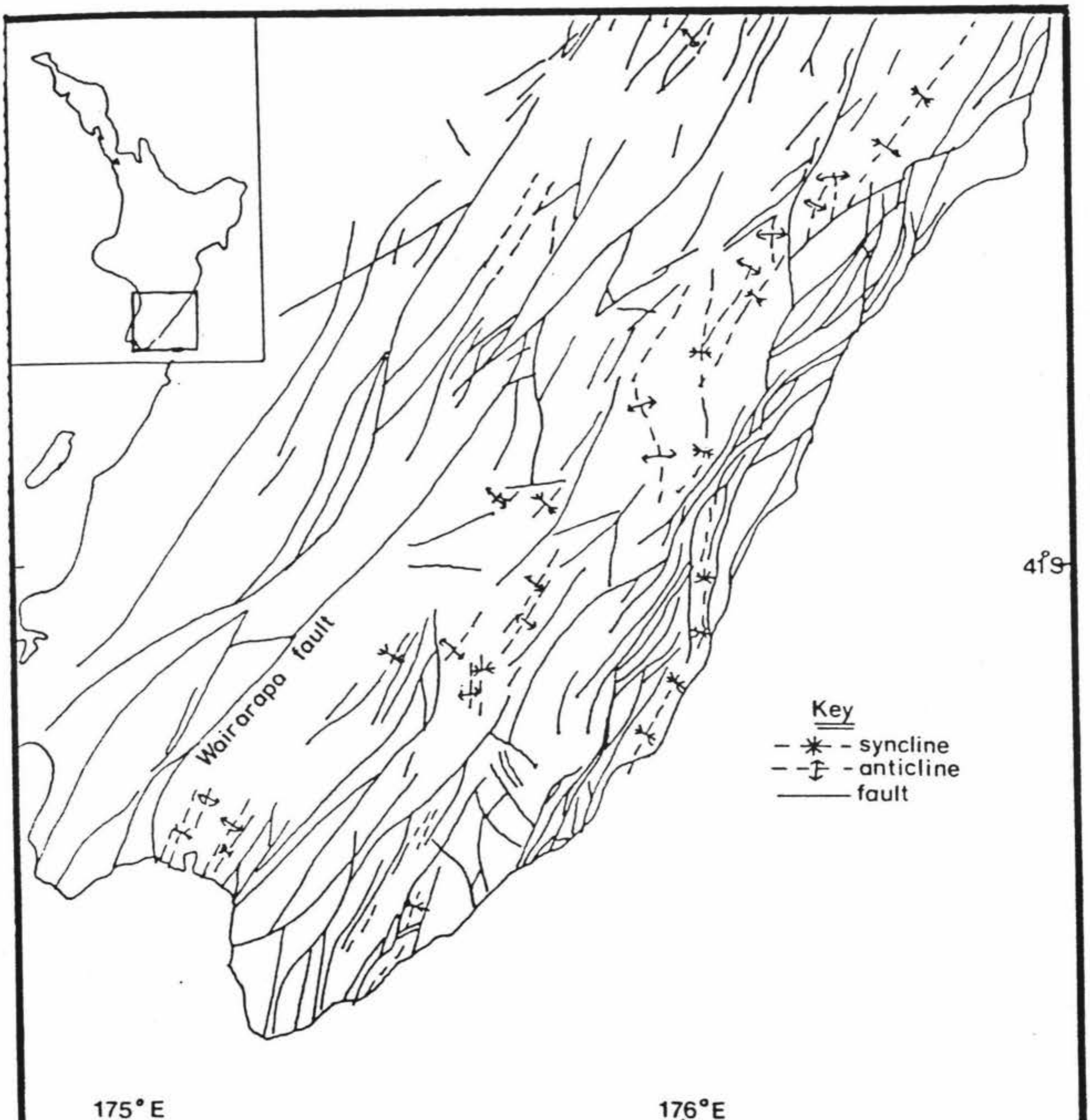


Figure 1.1

A map of the major foldings and faulting in Wairarapa Valley showing the NE-SW structural trend. The Wairara[illegible] Fault which extends the western side of lower Wairarapa Valley at the base of the Rimutaka-Tararua Ranges.

1.3 GEOLOGY OF THE WAIRARAPA REGION.

1.3.1 INTRODUCTION.

Wairarapa Valley is a structural depression approximately 77 km ong, and up to 20 km wide (Kamp and Vucetich 1982). The Valley is ounded by the Rimutaka and Tararua Ranges to the west and the Aorangi id Maungaraki Ranges to the east (fig 1.0b). The ranges consist of olifted highly folded and faulted Mesozoic greywackes and argillites iich reach a height of 1500m. Between the ranges these basement rocks e downfaulted and covered by a sequence of Cenozoic sedimentary ocks up to 3000m thick (Hicks and Woodward, 1975). Sedimentary tterns and erosion cycles, responding primarily to fluctuations in imate and sea level have since infilled the valley forming the latively flat plains of Wairarapa Valley.

The valley is situated within an active tectonic belt (Ghani 978) which has resulted in extensive transcurrent faulting and olding. The many faults and folds form a pattern of lineations riking SSW-NNE through the valley. The most important fault is the iirarapa Fault which extends along the base of the Rimutaka-Tararua inges (fig 1.1).

1.3.2 UPLIFT.

In Wairarapa, marine benches flank the present coast and extend ome 42km around the Ruamahanga valley (Ghani, 1974). King (1930) oted these uplifted marine shoreline features, but gave no heights. iter work by Ghani (1974;1978) detailed a sequence of four Last iterglacial marine benches, preserved as a consequence of uplift. iese marine benches, named the Eparaima Marine Benches (individual nches lettered EA, EB, EC, and ED from youngest to oldest) record gh eustatic sea levels at c.80, 84, 100, and 125kyr B.P. (fig 1.2). llman (1969) studied a lower, fifth marine bench of Holocene age, ie Turakirae Marine Bench.

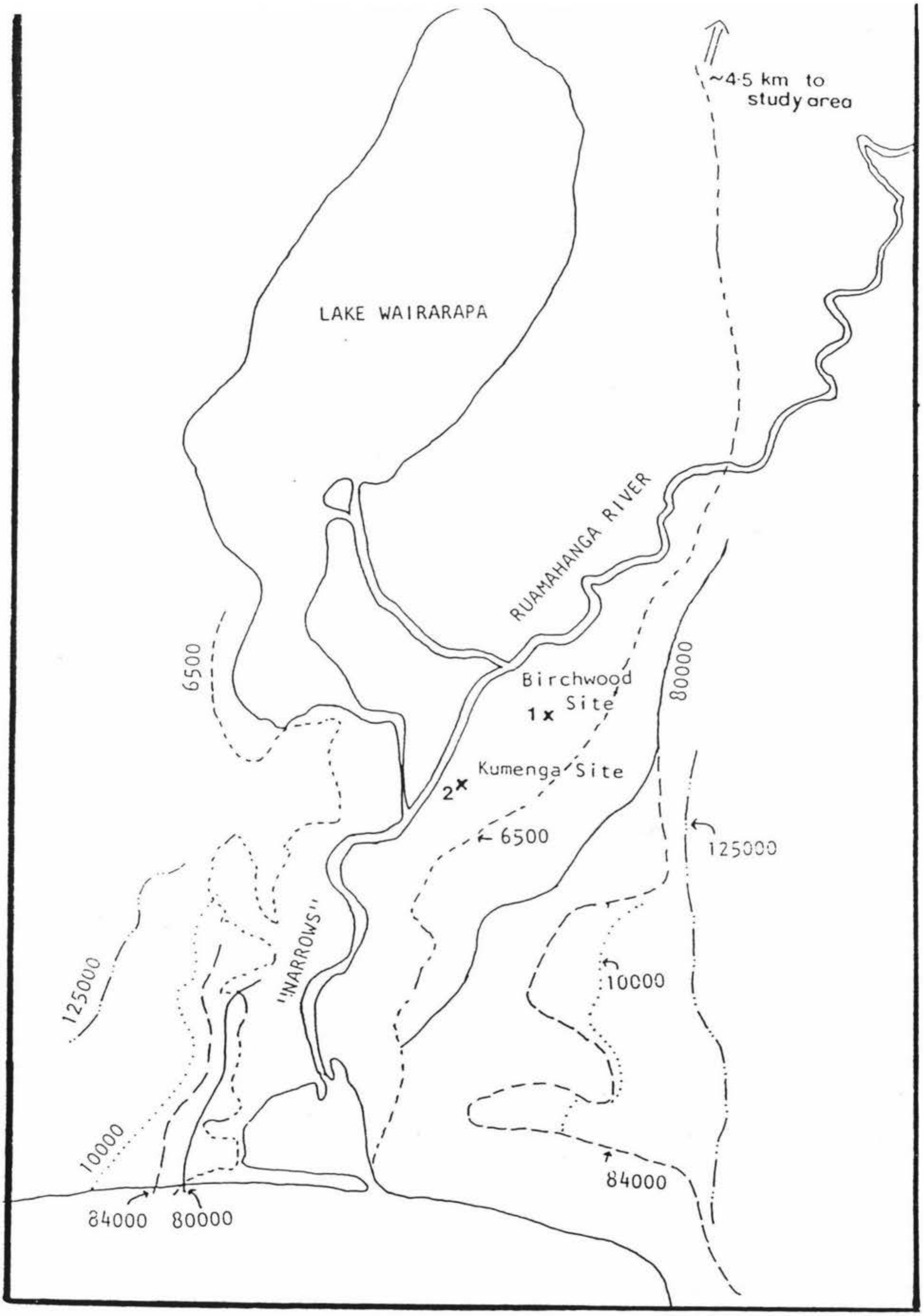


FIGURE 1.2 Map showing the Eparaima Marine Benches and Holocene High Sea Level Shoreline around Wairarapa Valley (from Palmer 1982)

Note: 1 & 2 show the locations of Birchwood Site (1) and Kumenga Site (2) for Figure 1.3

At Turakirae Head, (where the bench is best exposed) seven stranded beach ridges have formed on the Turakirae Marine Bench recording Holocene sea level fluctuations, (Wellman, 1969; 1972; Ghani, 1972; 1978; Bagnall, 1975; Stevens, 1969). The oldest and the highest Holocene shoreline, thought to be 6,500 years B.P. (Wellman, 1969; 1972; Palmer, 1982; Singh, 1971) can be traced around most of the west coast of Lake Wairarapa (Palmer, 1982) (fig 1.2). Each of the raised beach ridges is thought to have been uplifted during a major earthquake, the youngest being uplifted by approximately 2.5m (Wellman, 1969) in the 1855 earthquake. Wellman (1969) calculated an average positive uplift rate of 1.41mm/yr for the ridges. The youngest ridge was stranded after an uplift of approximately 2.5 m during the 1855 earthquake (Stevens, 1969).

Using the heights of the Last Interglacial, and Holocene benches Ghani (1974; 1978) defined a pattern of folds and faults which he could trace inland. He found that on the marine benches the anticlines are growing at a rate of 0.75mm/yr to 4.0mm/yr and the synclines at 0.5mm/yr to 2.2mm/yr. He also calculated uplift rates in the axial ranges (using summit heights) to be from 3 - 8mm/yr. For the Bidwill Hill anticline, a maximum uplift rate of 1.1mm/yr was calculated.

The thick sedimentary deposits overlying the Last Interglacial marine benches in the central valley have prevented uplift rates being calculated. However, Ghani (1978) does suggest that valley uplift could range down to zero.

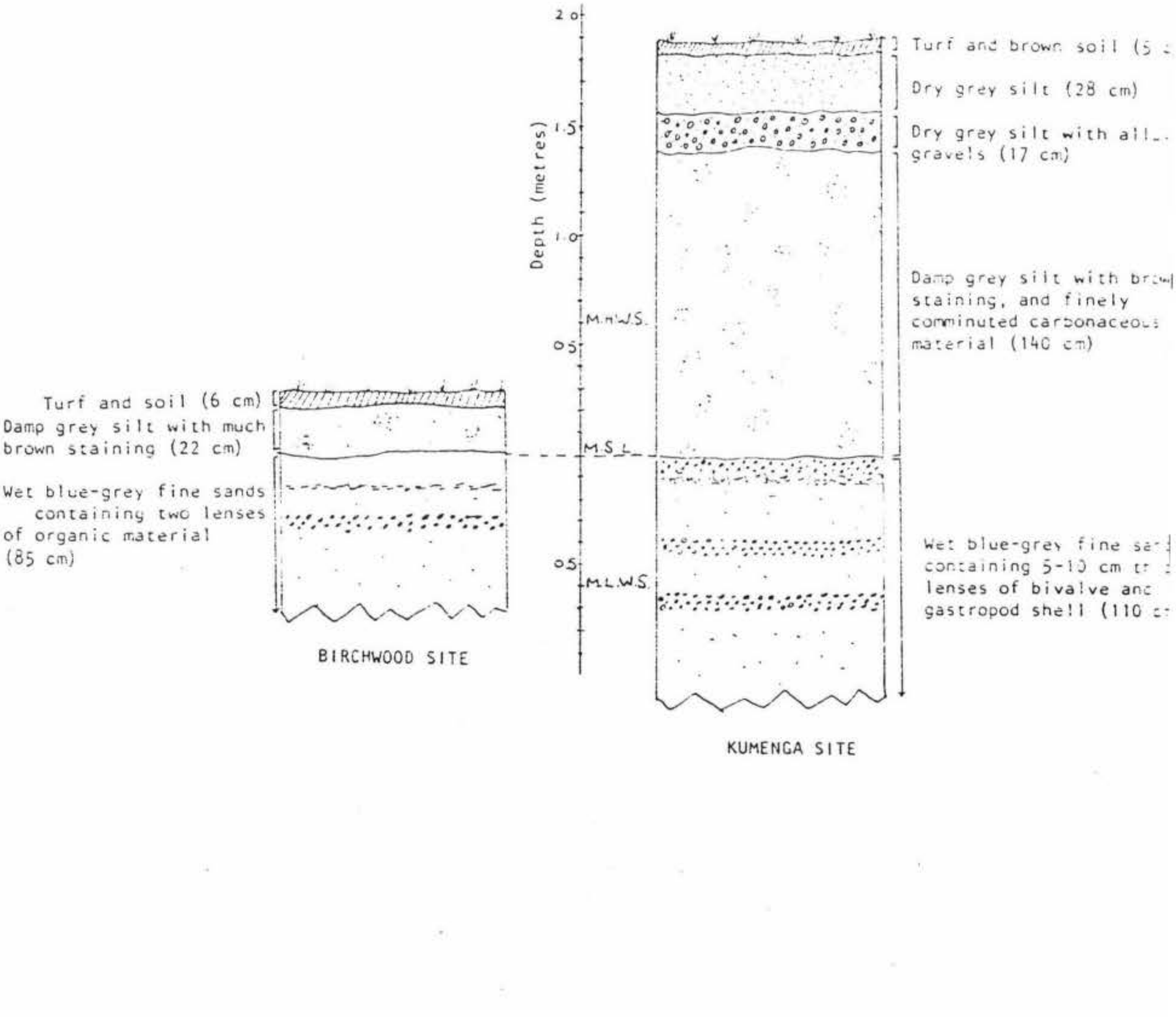
Marine shells dated at 3,470 $\pm$ 50 years B.P. (NZ1634) found at present mean sea level in the valley near Pirinoa (Leach and Anderson, 1974) suggest little uplift has occured in the valley since the Last Glaciation. Ghani (1978) surmises that his calculated rates have been similar for the past 0.2M years, but that previous uplift rates were slower.

1.3.3 LATE QUATERNARY DEPOSITS OF THE LOWER WAIRARAPA.

At the time of the high sea level (c.6,500 years B.P.) southern Wairarapa Valley to within 5km of Greytown and Featherston was thought to have been an estuary (Palmer, 1982; Leach and Anderson, 1974). Following extensive public works Leach and Anderson (1974) investigated two sites in the Kumenga area, south west of Lake Wairarapa in order to establish if, and for what period, estuarine conditions prevailed in the area. Uniform stratigraphy was observable for about 20m each side of the two sites with two estuarine shell lenses occuring at similar levels (fig 1.3). The lower shell lens is radiocarbon dated at 4,600 ± 60 years B.P. (NZ3107) and the upper shell bed is 3470 ± 50 years B.P. (NZ1634). Immediately above the upper bed are fresh water sediments. Leach and Anderson (1974) and Leach (1984) suggest that the estuary existed long before the earliest shell material dated here, because the shell lenses are embedded in marine sands which extend down both sections. In the upper lens there are many closed pairs of *Mactra evata*, a shellfish common in brackish waters mostly near river mouths (Powell, 1961). The presence of small gastropod shells which have not been filled with sediment is further evidence that the death of the shell bed was very abrupt. Leach and Anderson (1974) proposed that rapid shoreline retreat, or a sudden change in environment probably occurred at 3,500 years B.P. causing the shellfish mortality. The surface of the marine sands and shell lenses is at present mean sea level.

The seaward entrance to the valley is very narrow, and a gravel bar has developed across the channel, forming the "Narrows". (fig 1.2). This bar is now about 7m above mean sea level and at least 5m higher than the Holocene beach ridges within the valley (Ghani, 1974). Leach and Anderson (1974) suggest that continual development of the bar restricted the seaward outlet of the estuary until a sufficiently severe flooding episode caused sedimentation to close the Narrows. The salinity of the estuary would have been drastically reduced as fresh

FIGURE 1.3 Profiles showing Estuarine Shell Beds from two sites in the Kumenga Area, (Leach and Anderson 1974). (see figure 1.2 for location of sites)



water continued to feed into the lake, causing the sudden death of the shell beds. The change to fresh water sedimentation and lacustrine conditions in the lake is therefore dated at about 3,500 years B.P.

The blocking of the Narrows and subsequent flooding of Lake Wairarapa and surrounds was a problem until 1964 when the Wairarapa Catchment Board developed the Lower Waiarapa Valley Development Scheme which has kept Lake Onoke water levels constant, and opened the Narrows when nesessary.

The marine and estuarine deposits overlap Waiohine Surface deposits described by Vella (1963) as poorly sorted fluvial aggradational sands and gravels, (the equivalent of the 'Rosebank Surface' in the upper Wairarapa Valley). The Waiohine Surface is part of a composite fan built by the Waiohine, Tauherenikau, and Waingawa Rivers (fig 1.0b) during the Ohakean. The surface of the fan is considered to have an age of c.10,000 years B.P.(Palmer, 1982), since there is very little loess on the surface and it appears to be of similar age to the top of the Ohakean loess dated at 9450 years B.P. in the Rangitikei area (Milne and Smalley, 1979).

The contact between the Waiohine gravels and the Holocene deposits forms an arc from just south of Greytown to near the northwest shore of Lake Wairarapa (Vella, 1963; Palmer, 1982). North of Featherston, and nearer the apices of the fans the rivers are presently downcutting into the Waiohine Surface, but are beyond the toe of the fan.

1.4 CLIMATE.

Wairarapa Valley has a humid temperate climate. The highest mean annual rainfall (1600mm) falls in the north, and the lowest, 800mm around Masterton and Martinborough (N.Z. Met. S. Misc. Pub. 145) (fig 1.4). In the ranges to the west, rainfall is up to 6,500 mm/yr and in the Aorangi Range, rainfall can exceed 1400mm annually. There is, therefore, a steep rainfall gradient from west to east (table 1.6 and fig 1.5).

Temperatures in the valley vary from 8°C in the winter months, to 18°C in December and January, with an average annual temperature of approximately 12.5°C, (N.Z. Met. S. Misc. Pub. 183), (table 1.7).

The Tararua Ranges are notorious for the persistance and strength of winds (N.Z. Forest Service, 1977) which have a dramatic effect on the climate in the valley. The predominant wind direction in the valley during the summer is from the north-west, creating a warm fohn-type wind which provides a rainshadow area over the central and southern parts of the valley producing dry hot summers (Tomlinson, 1976; Cowie and Money, 1965). Winters are frosty, cold, and wet. This highly seasonal weather pattern is the result of the change to winds from the south and south-west during winter, bringing lower temperatures and a higher precipitation.

Table 1.6: Monthly and annual rainfall (mm) normals (1941 - 1970):
(from N.Z. Met. S. Misc. Pub. 145 and 175)

month / station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	m.a.r.
Ngapotoki	86	86	127	114	188	183	178	173	117	107	86	97	1542
Greytown	79	66	86	81	114	117	119	104	91	91	81	86	1115
Feather/ ston.	94	86	102	99	130	137	132	122	109	109	99	107	1326
Morrisons Bush	69	58	74	69	94	99	99	86	79	79	71	74	951
Mangahao Upper	226	231	198	206	272	305	274	267	257	310	279	269	3094
Pahiatua	94	86	84	94	114	140	124	114	104	132	107	124	964
Masterton*	64	62	73	80	102	100	106	94	79	78	71	73	982

* Data from N. Z. Met. S. Misc. Pub 180, (for 1884 - 1982).

Location of stations used in Tables 1.6 and 1.7 are shown in Appendix 4 (a).

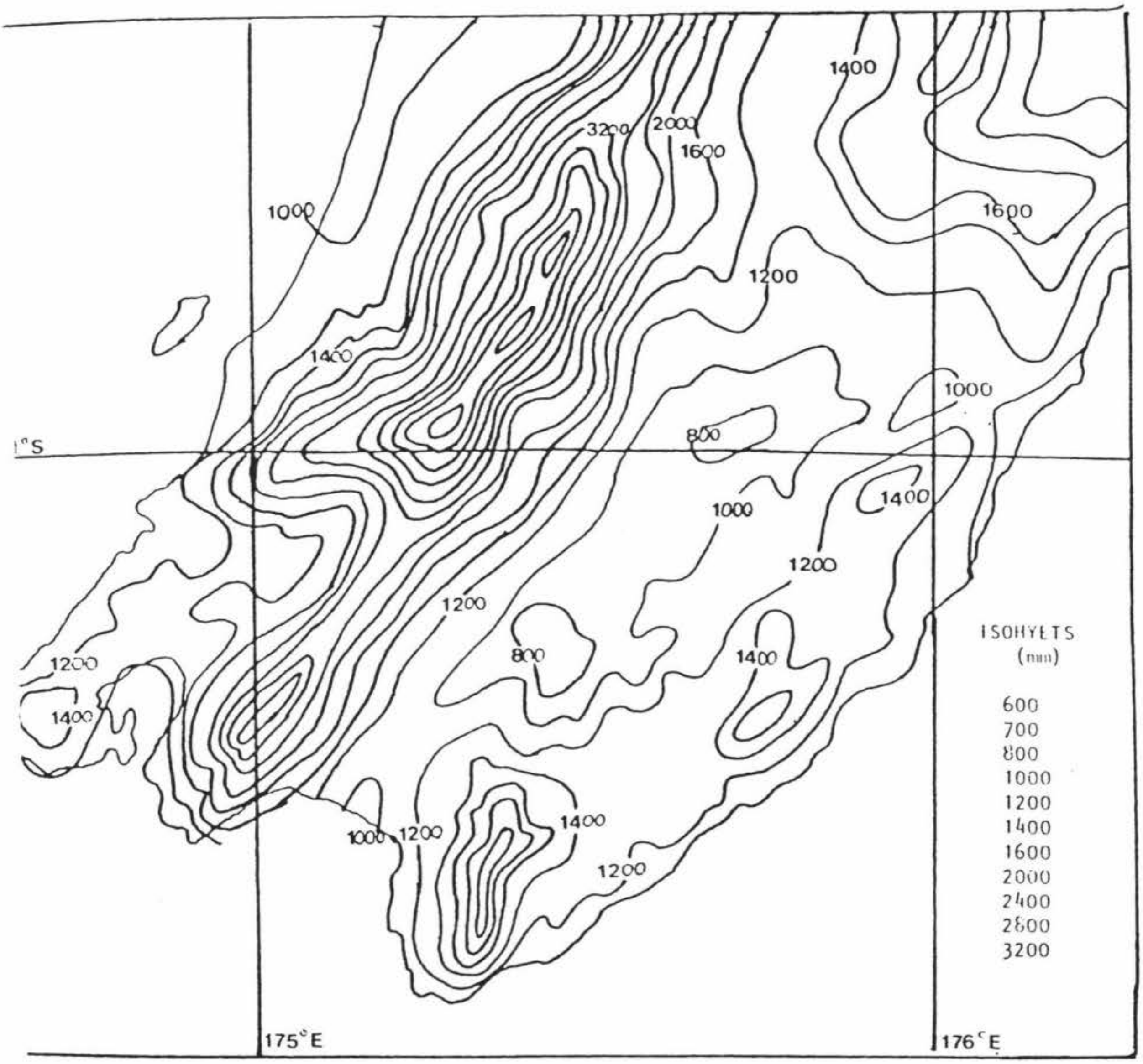
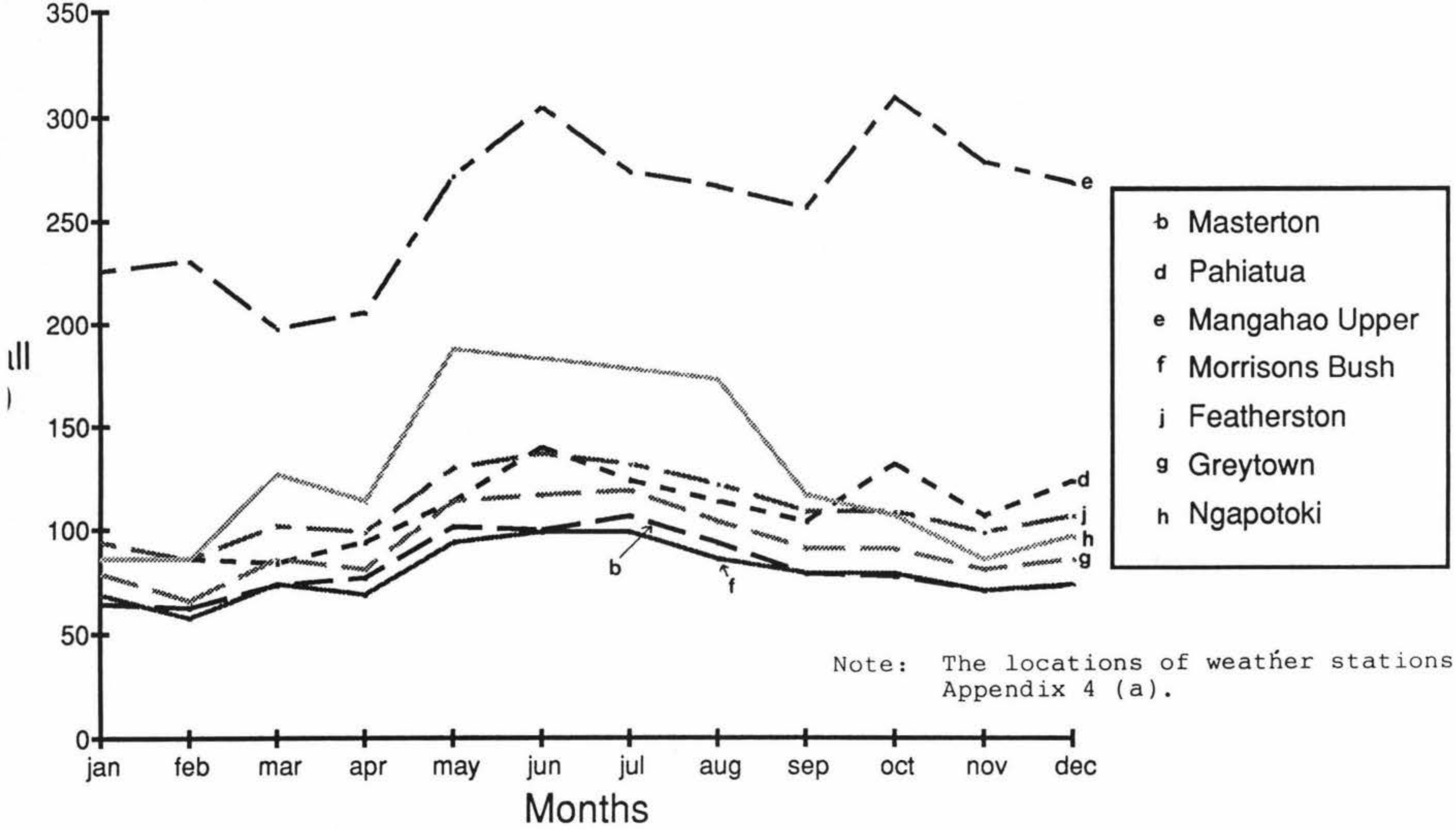


FIGURE 1.4 Mean annual rainfall (mm) 1941 - 1970.
(From: N.Z. Met. S. Misc. Pub. 145, and 155(11)

Figure 1.5. Graph of monthly rainfall normals
(from table 1.6)



Note: The locations of weather stations shown in Appendix 4 (a).

Table 1.7: Temperature normals (°C), mean daily temperatures (1951 - 1980):

(N.Z. Met. S. Misc. Pub. 183)

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	m.a.t.
station													
Pahiatua	17	17	16	13	10	8	7	8	10	12	14	15	12.2
Masterton	17	18	16	13	10	8	7	8	10	12	14	16	12.4
Gladstone	17	17	16	13	10	8	7	8	10	12	14	15	12.2
Cape Palliser	18	18	17	15	13	11	10	10	12	14	15	17	14.0

Location of stations used in Tables 1.6 and 1.7 are shown in Appendix 4 (a).

1.5 SOILS OF THE WAIRARAPA REGION.

Very little detailed work on the soils of lower Wairarapa has been published. The soils of the Greytown area have been mapped by Cowie and Money (1965) at a scale of 1:15,840, and an interim soil map of Wairarapa Valley was mapped at a scale of 1:126,720 by Gibbs *et al.* (1975).

The soil pattern in lower Wairarapa Valley can be outlined in terms of three physiographic regions with an overriding rainfall effect (Gibbs *et al.*, 1975). On the western mountains, (the Rimutaka and Tararua Ranges) where rainfall is high (1500 - 5000 mm/yr) yellow-brown earths and associated steepland soils have developed on Jurassic-Triassic greywacke-argillite parent materials.

The soils of the ranges and higher country on the eastern side of the valley are dominantly yellow-brown earths, and yellow-grey earths together with intergrades and related steepland soils. Their distribution relates primarily to rainfall patterns in the area. Where rainfall exceeds 1150 mm/yr yellow-brown earths form (Taylor and Pohlen, 1968) with the yellow-grey earths and related soils found where rainfall is less than 1150 mm/yr. However yellow-grey earths have developed in the higher rainfall areas where parent materials are sandier. This has created a patchy distribution of yellow-grey earths on the eastern ranges, (Vincent, 1984).

Soils on the loess blanketed river terraces, marine benches and downlands of the central and eastern parts of the valley are all yellow-grey earths. These surfaces are thought to be erosional remnants, being at an elevation where they were unaffected by following alluvial depositional cycles.

On lower flatter surfaces in the central valley the stony free-draining soils of the Waiohine Surface are classified as intergrades between yellow-brown loams and yellow-brown earths (Griffiths, 1975). These soils are shallow, friable, well drained soils prone to excessive drainage.

At the toe of the extensive aggradation fans of the Waiohine Surface, gley and organic soils have developed. These soils are very poorly drained and strongly mottled.

Recent and gley recent soils are found on the fresh alluvium accumulating on present river flood plains and around Lake Wairarapa, the latter where the water table is high for long periods during the year.

The soil pattern is summarised in diagrammatic form in figure 1.6.

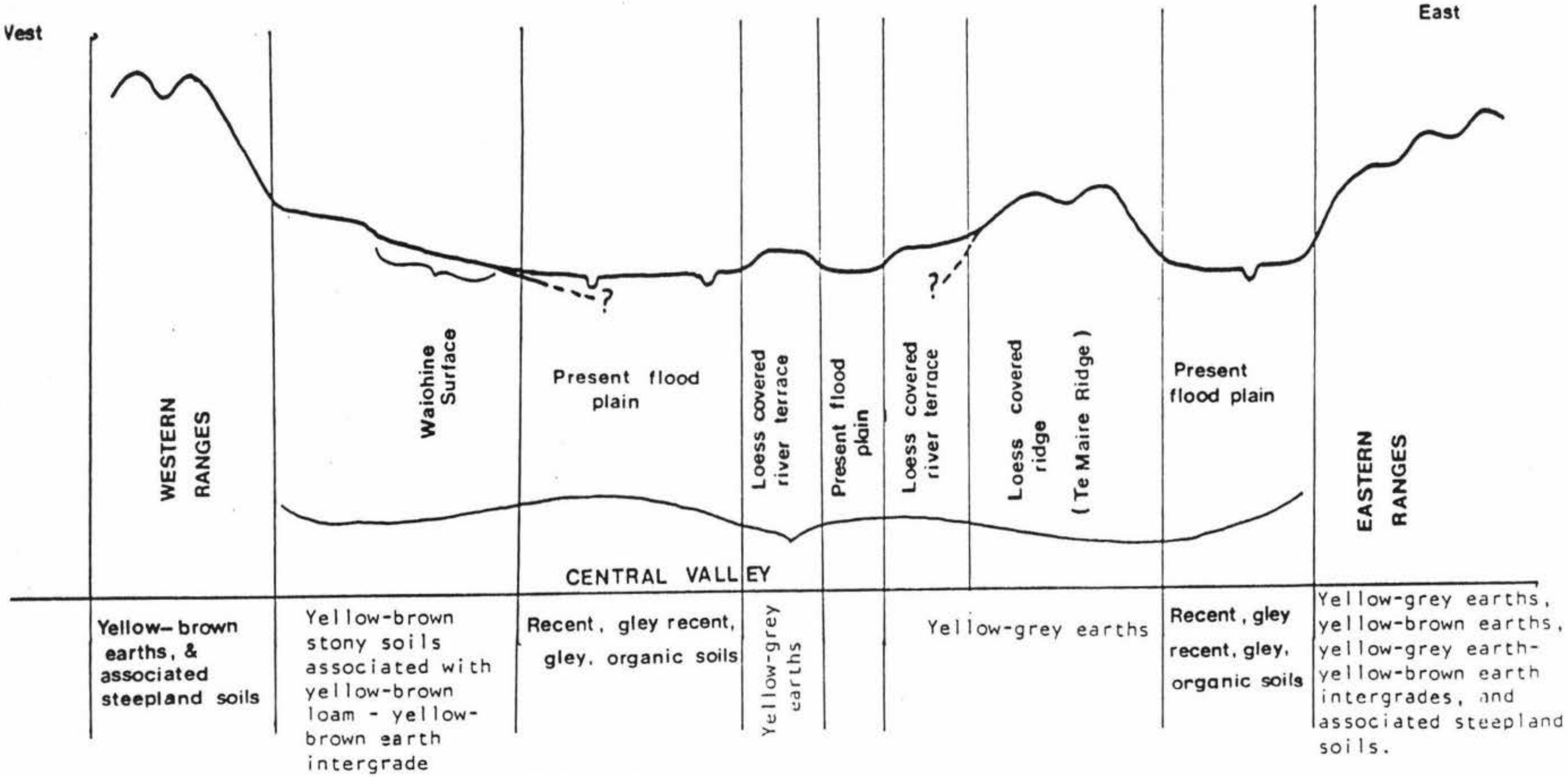


FIGURE 1.6 Diagrammatic representation of soil pattern across central Wairarapa Valley and adjacent ranges.

1.6 VEGETATION OF THE WAIRARAPA REGION, PAST AND PRESENT.

In Wairarapa Valley there is now no indigenous grassland or shrubland but several hundred hectares of modified lowland podocarp forest remain. Information has been collected from previous records and observations from the early settlers of the area (albeit meagre), and from fossil and plant fragments and pollens (Leach and Anderson, 1974).

South of Woodville there are 20 scenic reserves (fig 1.7) with a collective area of 2,212 hectares (Wassilieff *et al.*, 1986), together with reserves in the Tararua, Rimutaka and Aorangi ranges, and Mt Bruce State Reserve. From these reserves the former vegetation pattern in the valley and surrounds prior to human interence has been pieced together.

1.6.1 VEGETATION OF THE RANGES.

Tararua Range.

The Tararua and Rimutaka ranges are covered with indigenous forest which has, in many places, been modified by fire, introduced pests, milling and erosion.

The wide range of local climates has produced an extremely complex forest with greatest variety occuring on the foothills and deep valleys at altitudes below 450m, (New Zealand Forest Service, 1977).

Beech (*Nothofagus* spp.) is widespread in the central and southern Tararuas, but absent in the north (New Zealand Forest Service, 1977). Where beech is present there is a general altitudinal sequence from lowland podocarp-tawa or podocarp-kamahi forest, to montane podocarp-beech forest and then sub-alpine pure beech forest (mostly red beech

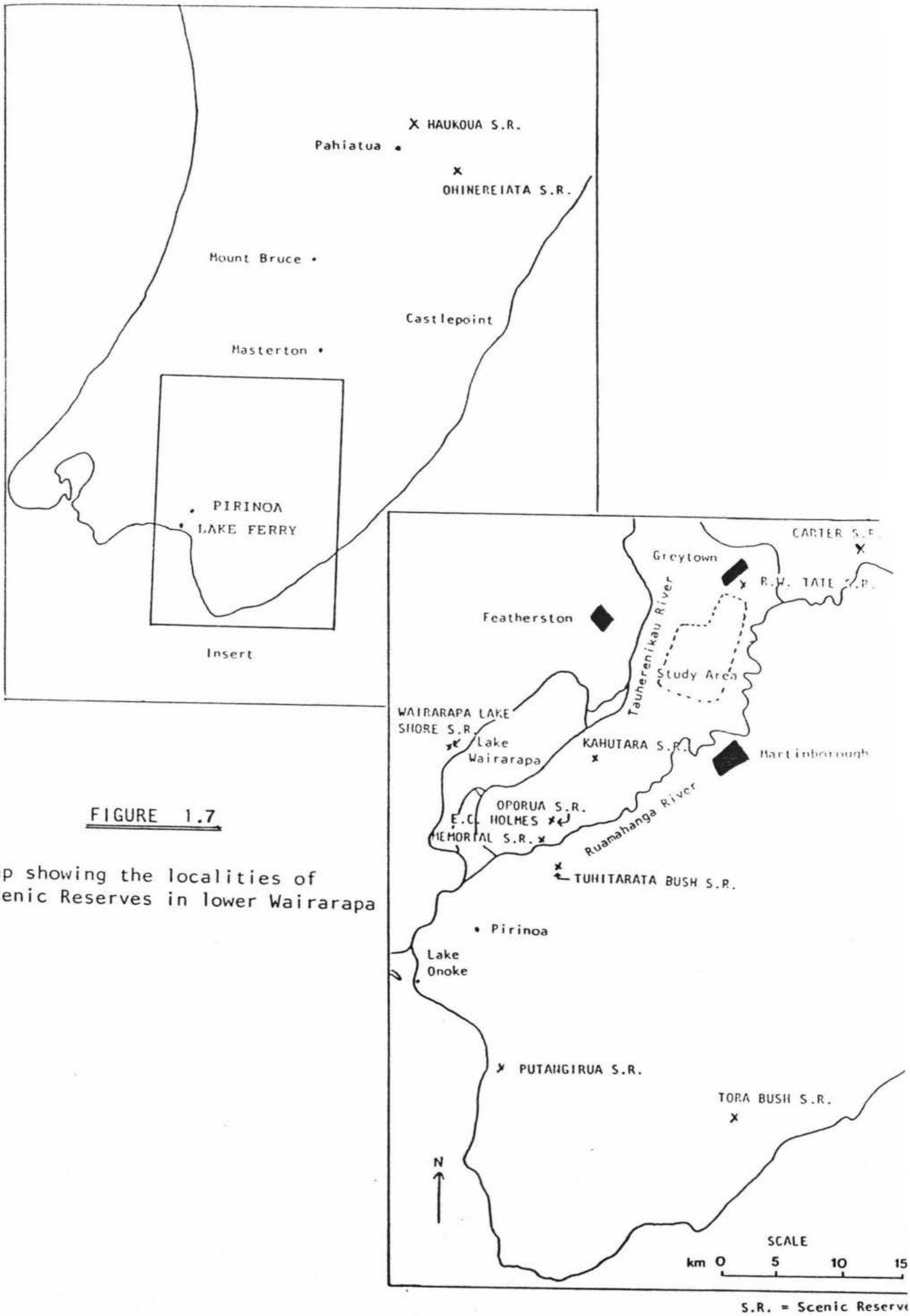


FIGURE 1.7

Map showing the localities of Scenic Reserves in lower Wairarapa

Nothofagus fusca, and silver beech *N. menziesii* with lesser amounts of black beech *N. solandri*). Podocarp species are dominated by rimu, (*Dacrydium cupressinum*) and miro (*Prumnopitys ferruginea*), with Hall's totara (*Podocarpus hallii*) and matai (*Prumnopitys taxifolia*) as subdominant species (Franklin, 1965). Rimu-kamahi forests prevail to lower altitudes further north where beech does not occur.

The treeline over most of the range is at an altitude of 1100 - 1220m (New Zealand Forest Service, 1977). The sub-alpine scrublands above are dominated by leatherwood (*Brachyglottis elagnifolia*) with alpine grasslands dominated by *Chionochla* spp. extending to the ridge tops.

Aorangi Range.

Forest also covers most of the Aorangi Ranges in the southeast. The forest can be grouped into four different types; mahoe-hinau-rewarewa forest on the stable sites up to about 600m, black beech forest on the drier exposed slopes to 500m, red beech forest between 400m and 600m and silver beech along the ridges above 600m (Wardle, 1967). Where burning, erosion and browsing have modified the vegetation, kanuka (*Leptospermum kunzia*) and other shrubby vegetation prevail with subalpine scrub and tussock replacing beech forest on the higher slopes.

1.6.2 VEGETATION IN THE VALLEY.

Past Vegetation

The vegetation of Wairarapa Valley was characterised by variety (Hill, 1962, 1963), being a patchwork of grass, swamp and scrublands as well as forest (fig 1.8). After crossing the Ruamahanga River and heading south in 1842, New Zealand Company surveyors, C. Kettle and A. Wills described the vegetation as; "large tracts of grazing land

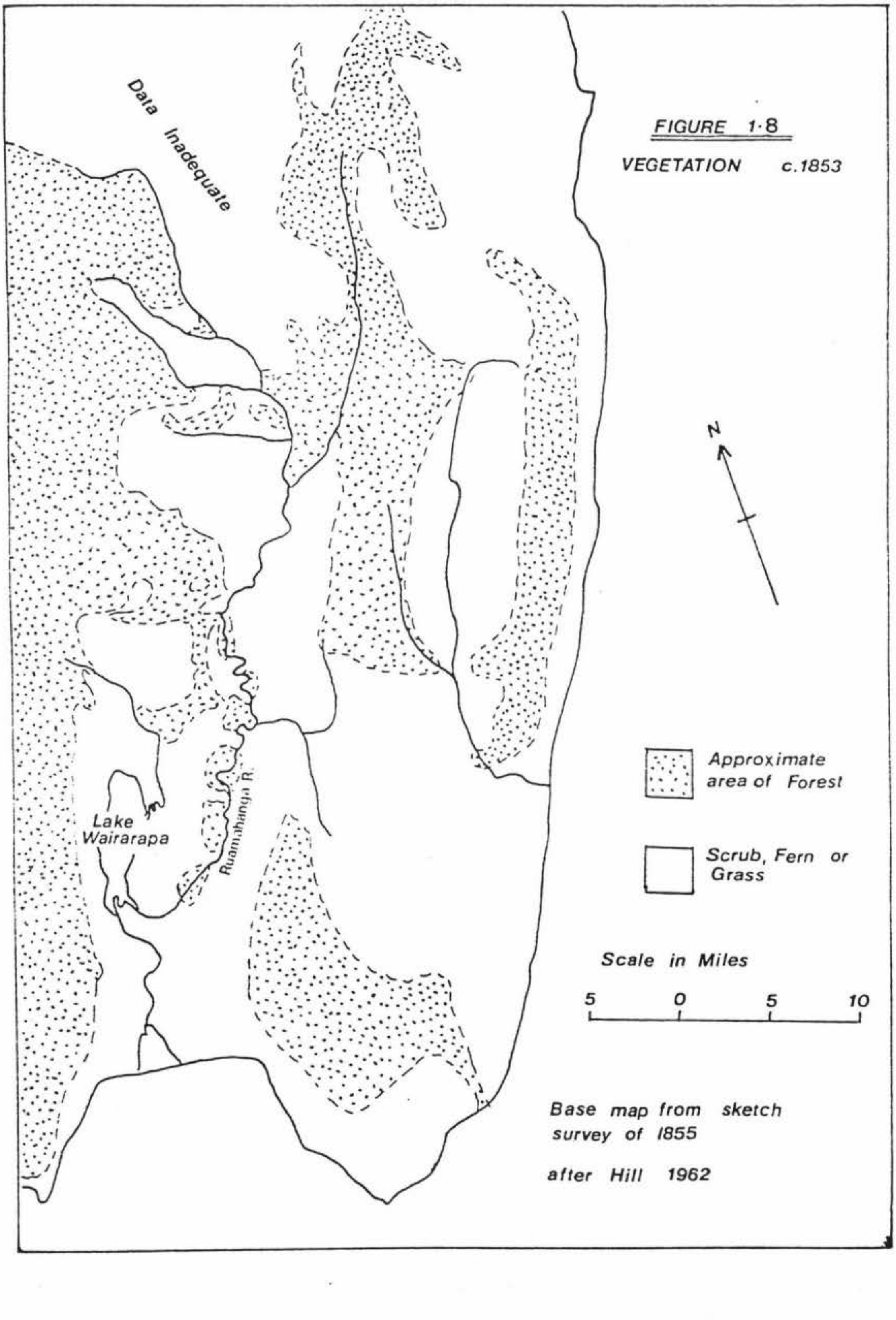


FIGURE 1·8
VEGETATION c.1853
Data Inadequate
N
Lake Wairarapa
Ruamahanga R.
Approximate area of Forest
Scrub, Fern or Grass
Scale in Miles
5
0
5
10
Base map from sketch survey of 1855
after Hill 1962

interspersed with groves of trees, stretched to the distance of 12 miles or the whole width of the valley" (cited from Bagnall, 1954). Another report made by R. Stokes in 1841 as he viewed the lower Wairarapa Valley from the Rimutaka Range read; "a land for the most part covered with fern and grass, easily cleared...while on the banks of the rivers and in different parts of the valley are large groves and belts of trees." (cited from Wassilieff *et al.*, 1986).

Of these early observations it is unclear as to the extent to which the native vegetation of the area had been influenced by Maori occupation. It has been estimated that in 1948 lower Wairarapa Valley supported 32,000 hectares of predominantly "totara, matai, miro, kahikatea, and manuka" and 81,000 hectares of "grass, fern, anice (sic) and toe-toe" (Wassilieff *et al.*, 1986).

Northern Wairarapa was, "thickly wooded with giant trees such as totara, rimu, rata, tawa, white pine, and matai, while the undergrowth was dense with ribbonwood, makomako, konini, poroporo, kowhai, lancewood, tree ferns and myriads of others" (Crewe, 1937).

The vegetative pattern of the valley can be grouped very broadly into geomorphologically controlled zones, where drainage is a dominant factor (Wassilieff *et al.*, 1986):

A. Free draining areas.

The Haukopua Scenic Reserve is the only reserve of well-drained podocarp forest remaining on the alluvial plains. Although this reserve has been logged, a tawa dominated podocarp forest containing kahikatea, totara, matai, and rimu is presently regenerating. The subcanopy and understorey has a predominance of titoki, pukatea, mahoe, tawa, and lacebark, with abundant stinging nettles, (*Urtica incisa*, *U. ferox*) and ferns. Cabbage trees, lacebark, and *Carex* spp., surround many of the clearings.

A large percentage of the better drained areas supported grasslands, tussock and ferns (Hill, 1963). Species such as *Angelica montana*, *A. geniculata* (*Umbelliferae*) and *Aciphylla squarrosa* (porcupine grass) were common. Tussocks such as *Poa anceps* and *Festuca rubra* were co-dominants with *Agrostis* and *Danthonia*. Kanuka and manuka were also prevalent (Hill, 1962; 1963).

B. Semi-swamp plains.

Where poorly drained areas were forested, kahikatea-pukatea / tawa forest prevailed, and on the slightly drier ground titoki and matai dominated the forest with lesser numbers of kahikatea (Wassilieff *et al.*, 1986).

Undrained forest remnants are present in the Tuhitarata and Ohinereiata Scenic Reserves. Ohinereiata Scenic Reserve contains a strong emergent stand of kahikatea and some rimu over a tawa dominated canopy. The broadleaf understorey consists mostly of mahoe, pate, five-finger, horopito, and coprosma with lancewood, lacebark and many divaricating shrubs at the forest margins and in canopy gaps. In Tuhitarata Scenic Reserve there is much less tawa (*Beilschmiedia tawa*). Kahikatea, pukatea, and titoki are the dominant canopy species with scattered emergent kahikatea and pukatea trees. The understorey is thick with karaka (*Corynocarpus laevigatis*), mahoe, *Coprosma* spp., kohuhu, *Fuschia* spp., and a large number of tree ferns and ferns. Dense supplejack and kiekie can be found in places on the reserve.

In the unforested areas, sedges, flax and scrub communities existed. These included toetoe (*Arundo conspicua*), raupo (*Typha angustifolia*), sow-thistle (*Sonchus* spp.), flax, and cabbage trees. Herbs such as *Epilobium* spp., and *Myriophyllum* spp. were also reported, (Hill, 1962; 1963).

C. Swamp communities.

Swamp vegetation comprised mostly of raupo, rushes, sedges and flaxes with scattered kahikatea and cabbage trees depending on the degree of wetness of the area.

"The bush concealed a swamp, a network of deep pools between which 10 or 12 feet high sedges luxuriantly grew" (Colenso, in; Bagnall and Peterson, 1948).

Carter Scenic Reserve contains swamp vegetation that has escaped serious modification. The large range of habitats in this small reserve (31.6 hectares) illustrates the drainage sequence from semi-swamp kahikatea forest to titoki with scattered kahikatea and matai as drainage improves. Totara are found on the well drained sites (Wassilieff *et al.*, 1986).

Part of the Wairarapa Lake Shore Reserve, on the western shore, is low lying and abuts the lakeshore. Pukatea, kanuka, black beech, *Pittosporum*, *Myrsine*, some lemonwood, titoki, nikau (*Rhopalostylis sapida*) and cabbage trees grow above a dense shrub and juvenile undergrowth, with sedges, uncinias and ferns. This reserve is adjacent to the bush clad ranges, and the mixed podocarp-broadleaf forest has extended down to the lake edge (Hill, 1963).

Along the eastern side of the lake, areas of raupo dominated swamp are interspersed with water milfoil (*Myriophyllum propinquum*), sedges (*Carex* and *Scirpus*) and jointed rush (*Leptocarpus*). There are areas of flax, toetoe, manuka, cabbage tree and *Coprosma propinqua* with a few slender kahikatea, ribbonwood (*Plagianthus*), kowhai, lacebark and ngaio (*Myoporum laetum*) further from the lake shore, suggesting that more extensive areas of these once existed, (Moore *et al.*, 1984; Ogle and Moss, 1984).

D. Wetlands and marshlands.

Wetlands and marshlands in the area are now restricted to the eastern edges of Lake Wairarapa where flats are covered by shallow waters. Plants in this area are commonly less than 15 cm tall (Moore *et al.*, 1984) and are characterised by their size and mat-forming ability (Ogle and Moss, 1984). Native plants found on these native tufts include buttercup (*Ranunculus limosella*), small sedges like *Carex cirrhosa*, *C. buchananii* and *Eleocharis pusilla* and *Gratiola sexdentata* a member of the fox glove family, amongst other stunted specimens of characteristically taller plants, (Ogle and Moss, 1984). The deeper waters contain abundant milfoil accompanied by tall sedges and pondweeds (Ogle and Moss, 1984).

E. Coastal vegetation.

The coastal vegetation was dominated by flax, kanuka, karaka, ngaio, with some kowhai, and cabbage trees (Leach, 1981). At Turakirae Head the dominant taxa were matai, totara, rimu, and beech with high amounts of akeake (*Dodonaea viscosa*) and hutu (*Ascarina lucida*). *Cyathea* was the most abundant fern (Mildenhall and Moore, 1983). Bagnall (1975) maintains that coastal forest probably existed everywhere along the coast except on the lowest beach ridges and in waterlogged areas.

Present Vegetation.

Today, scattered throughout a landscape dominated by improved pasture and agricultural activities, are macrocarpa trees (*Cupressus macrocarpa*), *Pinus* spp., and other exotic trees. Willows (*Salix* spp.) are now the dominant wetland tree accompanied by plants such as gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), and tauhinu (*Cassinia* spp.) (Moore *et al.*, 1984). The remaining pockets of native forest are very small.

1.7 PRE-HISTORY OF THE WAIRARAPA VALLEY.

From archaeological evidence, the Maori has been in Wairarapa for at least 800 years (Bagnall, 1976), occupying most of the southern end of the valley east of Lake Wairarapa, from the river valleys to the coast (Hill, 1962). The Maori survived on crops such as kūmara (*Ipomenea batatas*), and berries from tawa, tutu, pura-pura, hinau, matohi, titoki, and fuchsia plants. The fern root *Pteridium esculentum* was commonly exploited in the valley (Leach, 1981). Birds, eels, and fish were hunted from the forest rivers, and sea. Flaxes, sedges, and rushes were plentiful and provided suitable materials for garments and cordage. *Podocarpus totara* was the main source of timber for canoe building (Leach, 1981).

The first Europeans arrived and settled in the valley circa 1841 (Bagnall, 1954; Wassilieff *et al.*, 1986; Leach, 1981; Hill, 1963). By setting fire to the fern and tussock to promote fresh palatable growth, the European settlers were following a long established Maori custom. Forest however, was difficult to burn as it was very wet and healthy. There already existed plentiful scrub and tussock areas, so forest fires were not so common in earlier times.

The Europeans were responsible for the introduction of a large number of plants and animals into the valley. Sorrels and docks (*Rumex* spp.), nettles (*Urtica*), thistles and pasture weeds such as cocksfoot (*Dactylis glomerata*) were carried into the area on baggage or in sheep fleeces. Many native shrubs and juvenile broadleaf species such as mahoe (*Melicytus ramiflorus*), karamu (*Coprosma grandifolia* and *C. tenuifolia*), tawa, karaka, hinau, ribbonwood, kamahi (*Weinmannia racemosa*), and *Hebe* spp.. were all favoured by browsing cattle and sheep.

The composition of the forest gradually changed as the podocarps, less affected by the grazers (Beveridge, 1980) increased at the expence of the more palatable broadleaf species. Cattle trampled and opened up the scrub and fern country, eating toe-toe, bracken fern, flax (*Phormium tenax*) and cabbage trees (*Cordyline australis*) (Hill, 1962; 1963). In many areas, the fern completely disappeared, being replaced by introduced and some native grasses.

1.8 STUDY AREA DESCRIBED.

(A brief precise)

Geology.

The Quaternary deposits and cover geology of the area are mostly of Holocene age, and lap onto the Ohakean aged Waiohine Surface (Vella, 1963) in the north-western corner of the mapped area.

Te Maire Ridge (100m.a.s.l.) which borders the eastern side of the area, and two smaller ridges (rising 15 and 5 metres respectively) in the central and southern regions are loess covered. The loess is of Ohakean age (Palmer, 1982; see also section 1.3). The majority of Holocene deposits are greywacke and argillite-derived alluvial sediments from the major rivers in the area. Where the Holocene and Waiohine deposits meet, peat deposits up to 1.5m deep have accumulated.

Topography.

The landscape is mostly flat (fig 1.9) with a gentle overall slope of less than 5^{o}. The northernmost part is 50 m.a.s.l. gently sloping to 20 metres above sea level in the south. The fan surface is described in more detail by the natural drainage pattern. Abandoned stream channels, wet hollows and small gullies run parallel in a south east direction (fig 1.10), and drain into Otukura Stream. The planar, gently sloping landscape is interrupted by Hiwirau Ridge (approximately 15m high) at the southern end, and four smaller anticlinal ridge features which form a linear north-south striking pattern.

Figure 1.9 Landscape of the central valley near the northern end of the study area. In the background are the Tararua Ranges. The flat country in the foreground consists of Holocene gravels, which extend westward to the Waiohine Surface just beyond the sheds in the middle distance. From this photograph it can be seen that the Waiohine Surface and the Holocene Deposits are both only slightly sloping.

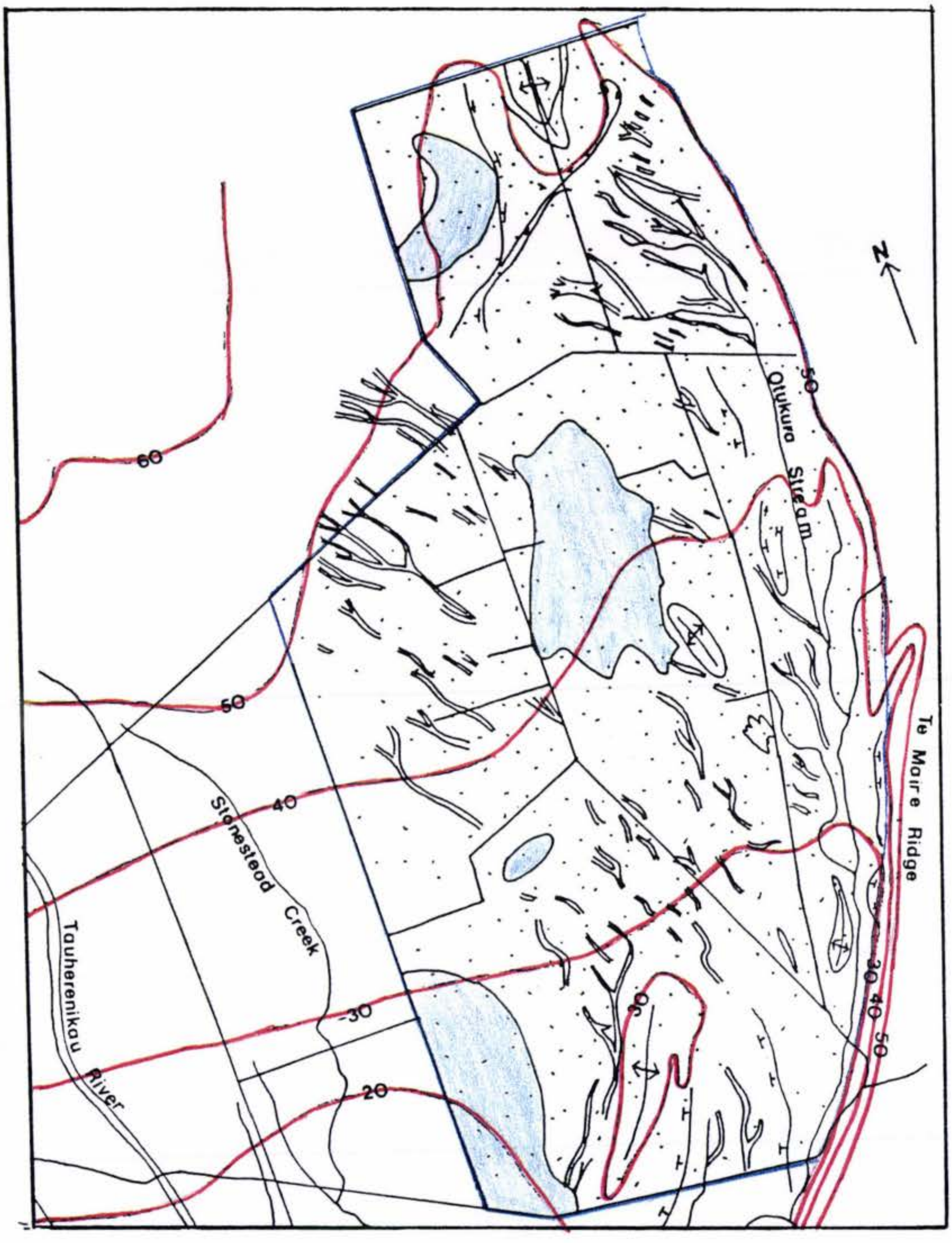
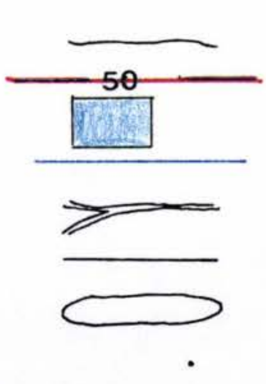


FIGURE 1.10 Contour and feature map of the Study Area, including drainage patterns.

Legend



streams and creeks

contour lines (at 10m intervals, Ref NZMS270 S27B)

areas of peat

study area boundary

abandoned stream channels

anticlinical axis

topographical features

sites of observations

Where drainage is good or has been improved, the microrelief is flat. In areas of poor drainage and peat, hummocky surfaces are common.

Soils.

Described fully in chapter 2, the Holocene soils are gleyed and very stony with predominantly silt loam and fine sandy loam topsoils. These soils are classified as gley soils. Older yellow-brown stony soils occur on the Waiohine Surface. The loess covered ridges have yellow-grey earths, and organic soils have formed in the peat.

Vegetation.

Present vegetation consists of improved pasture with areas of rushes where drainage is poor. There are a few small stands of kahikatea trees. The landscape is dotted with macrocarpa, lawsoniana, and pine trees. Along streams and in wetter areas willows are common.

Utilization.

Most of the area has been extensively drained mostly by the digging of deep straight channels. The only major natural waterway, Otukura Stream has also been straightened and deepened. The improved pasture supports dairy herds and some sheep flocks. Deer and goat farming has become popular in the drier north-west corner of the area.

CHAPTER TWO

SURFACE GEOLOGY AND SOILS.

2.1 SURFACE GEOLOGY.

The majority of the surface deposits in the study area are Holocene in age, with older Ohakean deposits occurring in the northern corner and at higher elevations and on loess covered ridges further south.

2.1.1 OHAKEAN DEPOSITS.

The loess covered Te Maire Ridge along the eastern boundary, and the two smaller loess covered ridges in the central area (Hiwirau Ridge being one) (fig 2.1) are the oldest surfaces in the study area covered by over 120cm+ of Ohakean loess. These surfaces were at an elevation high enough to prevent their being buried by subsequent fluvial cycles, and hence were preserved. The upper loess unit is silty textured whereas older and deeper loesses are weathered to silty clay loams.

The Aokautere Ash (c.20,000 years B.P.) which has been located at Bidwill Hill on Te Maire Ridge (fig 1.0a) at 1.36m depth in the Ohakean loess (Palmer, 1982) was not encountered in the loess on the ridges in the central part of the study area. This time plane however, may exist at depths greater than 120cm.

The Waiohine Surface is mapped in the north-western corner of the field area. This surface was described by Vella (1963) as poorly sorted fluvial aggradational gravels and sands, which form a composite fan built by the Tauherenikau and Waingawa Rivers. In this survey the deposit is characterised by a uniform depth of 0 - 10cm of fine sandy soil over poorly sorted gravels and stones ranging in diameter from <2cm to 30cm. The gravels are subrounded and weakly weathered with mottles and concretions occurring in the matrix. The aggradational surface is now being incised by the Waiohine and Tauherenikau Rivers (fig 2.1).

2.1.2 HOLOCENE DEPOSITS.

Extensive aggradational gravels and alluvium occur in the survey area at the toe of the Waiohine Surface (fig 2.2 in back pocket). These deposits form a typical fluvial depositional pattern of silt filled channels and gravel bars, which have a south-east orientation (fig 2.2) and describe a pattern very similar to that of other river flood plains, such as the Manawatu River flood plain in Kairanga County (Cowie, 1978).

Gley soils with varying depths to weakly weathered greywacke gravels have developed on the Holocene deposits. The soils are weakly to profusely mottled, and post-depositional iron translocation within the profile has resulted in the formation of an iron pan at depths ranging from 40 - 90cm in many soils.

The gravels are subrounded and up to 30cm in diameter, with most being between 2 - 15cm. The gravels are unsorted and occur in a sandy loam matrix. These deposits occur throughout the area, with little variation in profile morphology.

Compared with the Ohakean deposits of the Waiohine Surface, soils on the Holocene alluvial surfaces are poorly developed, having thinner less distinctive B horizons. C horizons occur at shallower depths of about 60cm in the younger gley soils, but 120cm+ in the yellow-brown stony soils of the Waiohine Surface. On the Waiohine Surface, gravels occur within 20cm depth from the surface. In contrast, deep silty channels are interdispersed with shallow silts and gravel bars over the Holocene surfaces, in a clear alluvial pattern.

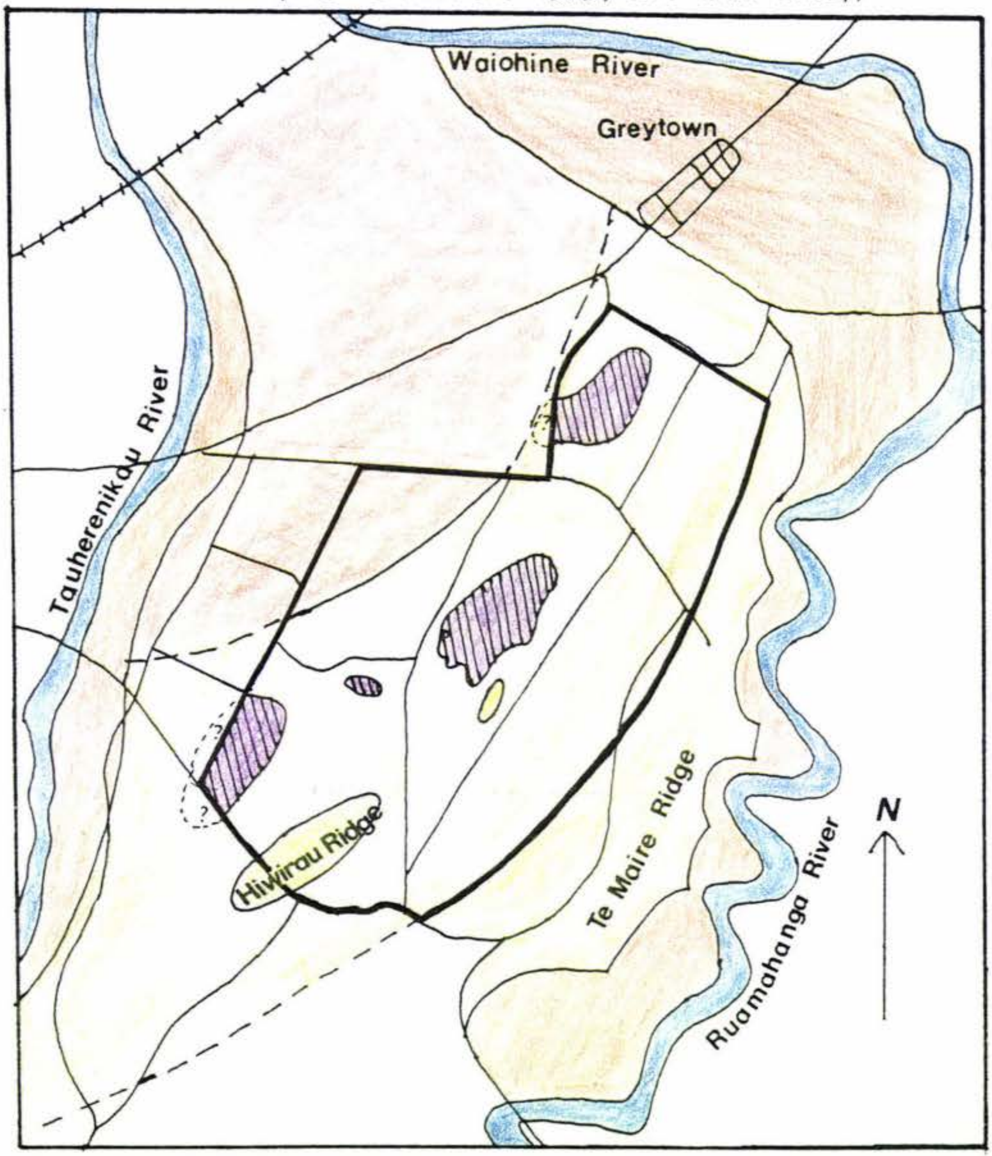
The topography helps to delineate between Ohakean and Holocene deposits in most instances. The higher surfaces are Ohakean deposits whilst the low lying flood plains tend to be Holocene in age. There are however some small ridge features within the valley up to 10 metres high which are similar in appearence to the smallest loess covered ridge. These features are covered by alluvial material of Holocene age, which consists of sandy and silty alluvium with a few stones, overlying abundant gravels which range from 30cm depth to the surface. The pattern of the deposits on these ridges is in keeping with the surrounding Holocene deposits of the former flood plain. These ridges therefore appear to be presently rising anticlines which did not exist when the sediments covering them were deposited.

Holocene peats are found near the contact between the Waiohine surface and Holocene deposits (fig 2.2). The peats overlie poorly sorted subrounded greywacke gravels, or in some cases, a thin (<15cm) layer of very gleyed blue silt over unsorted gravels. The peats and loamy peats are up to 120cm deep, with no interbedded mineral horizons. Logs, woody fragments and plant material occur throughout.

The base of the deepest peat deposit has been dated at 8500 $\pm$ 120 years B.P. (NZ7246A), and 7870 $\pm$ 115 years B.P. (NZ7245A), with an estimated age of c.5,000 years B.P. for the present peat surface. Obvious shrinkage, subsidence and erosion has occured at the surface of these deposits (see section 3.2.2).

In each of the three major peat deposits, the depth of peat describes a smooth basin which gradually shallows to the edges, being the deepest nearer the centre.

FIGURE 2.1 Surface deposits in the Moroa Area. (from Griffiths 1975, and this study)



KEY

Late Quaternary	HOLOCENE EARLY	Recent river alluvium	Road	
		Fluvial deposits	Railway	
	LATE	Peat deposits	Boundary of this survey	
	OHAKEAN	Waiohine aggradational surface		
		Ohakean Loess covered surface		

Scale

0 2 4

kilometers

Figure 2.2: (legend) Late Quaternary Deposits of the Moroa Area south of Greytown.

Holocene Deposits

- from alluvium

< 10cm depth to abundant gravels

10 - 30cm depth to abundant gravels

30 - 100cm depth to abundant gravels

- from peat over alluvium

< 40cm depth of peat over alluvium

> 40cm depth of peat over alluvium

- from reworked loess and alluvium

> 100cm depth of alluviual material

Ohakean Deposits

- from alluvium

< 10cm depth to abundant gravels (Waiohine Surface)

- from Ohakean loess

(see map in back pocket)

Further areas with thin peaty topsoils occur where the Maunui silt loam, peaty topsoil phase, has been delineated. These are not extensive units but are mostly confined to areas of swampy undrained ground adjacent to Te Maire Ridge, where preservation of the thinner peaty surfaces is possible. A small area in the southern part of the survey occurs in a recently drained region.

2.2 SOILS

2.2.1 PREVIOUS WORK IN THE AREA.

Recent, gley recent and gley soils adjacent to the Waiohine and Ruamahanga Rivers near Greytown, have been described and mapped by Cowie and Money (1965). Their physiographical legend of the soils is based on the rate of accumulation of alluvial material from the rivers.

The recent soils have been subject to periodic flooding in recent times. These soils are excessively to moderately well drained with indistinct horizon boundaries and poorly developed structures. The gley recent soils have a high water table, and grey or bluish grey coloured subsoils with reddish brown mottles. The gley soils are poorly drained but are not affected by present flooding. Thus these soils are older and more leached having greyish brown topsoils and grey coloured subsoils.

Of the soils occurring in the Greytown survey, the Otukura series is the only soil which extends southward into the present study area.

Based on information from both Cowie and Money (1965) and Gibbs *et al.* (1975), Griffiths (1975) produced a soils map of the Moroa District as part of an irrigation report. This report included the area mapped in the present study, but here a more detailed soil map using a larger scale has been produced. Very brief descriptions of soils and parent materials are outlined in Griffiths' report.

In this study, soils have been mapped in conjunction with soil parent materials and Quaternary geology at an intensive scale of 1:25,000. No mapping or taxonomic unit sheets from previous surveys are available, but where possible, correlation has been made to soil series already described. Where no recognised correlation exists, a new series has been defined.

Soil mapping unit sheets for all soils in this survey are included in Appendix 1.

2.2.2 SOIL MAPPING AND CLASSIFICATION.

Mapping of soils.

The mapping and classification of soils in this study is based principally on the examination and description of soil profiles, studied down to a depth of about 1.2m, or to impenetrable underlying parent materials or gravels. The soil profiles were examined using auger holes, soil pits, road cuttings, drains and stream banks. Features such as colour, texture, consistence, mottling, structure, content of coarse fragments, and coatings were noted for each horizon. Where pits were dug, or stream or drain banks examined, New Zealand Soil Bureau site/profile SPG1 cards were used to describe the soil (see Appendix 1 for detailed site and soil descriptions).

The environment of each soil profile was also noted. Such features as parent material, drainage, position of the profile in the landscape, vegetation cover, and land use were detailed. 453 profile descriptions and auger holes covered the study area (see fig 1.10)

On the basis of these descriptions and those of previous studies, profiles were grouped into soil series ("A soil series is a grouping of soils which have similar profiles, similar temperature and moisture regimes and are drived from the same or similar parent materials" Palmer *et al.*, (1981)). During mapping these soils were seen to dominate certain areas of the landscape, enabling mapping units to be delineated. Many mapping units have been descibed and classified in earlier studies (Cowie and Money, 1965; Gibbs *et al.*, 1975; Griffiths, 1975). Two further series are proposed in this study, the Watiro series, and the Maunui series, both quite different from existing series, the former being of limited extent.

In the study area, the boundaries between described soil series was well defined. When differentiating at phase level however, the soils tend to merge into one another and mapping unit boundaries are more difficult to delineate.

The mapping units have been grouped according to the New Zealand Genetic Classification System. (see table 2.0, and table 2.1)

Classification of soils.

This study uses previously described soil series renaming them where necessary, as well as creating new series.

The grouping and naming of the yellow-grey earths, organic soils, and yellow-brown stony soils occurring in the study area follows the same classification as that used by Gibbs *et al.* (1975) (table 2.2). However the classification and characteristic features of the gley soils varies slightly from previous interpretations.

The gley soils include three soil series, these being the Otukura, Maunui, and Watiro series. The criteria for division of these soils is found in the variation of the topsoil parent materials, and the depth to abundant weakly weathered gravels.

Table 2.0: Physiographic legend of soils of the Moroa area.

Soils of the flood plains and swamps.

Gley Soils

Otukura series

Otukura stony silt loam

Otukura stony silt loam mottled phase

Otukura stony silt loam strongly mottled phase

Maunui series

Maunui silt loam

Maunui silt loam mottled phase

Maunui silt loam peaty topsoil phase

Watiro series

Watiro silt loam

Organic Soils

Taratahi series

Taratahi peat

Soils of the river terraces and fans.

Yellow - grey earths

Wharekaka series

Wharekaka silt loam

Yellow - brown stony soils associated with intergrade between yellow-brown loams and yellow-brown earths

Tauherenikau series

Tauherenikau very stony silt loam

Table 2.1: Genetic Classification of soils of the Moroa Area.

Gley Soils

- from alluvium
  - Otukura series
    - Otukura stony silt loam
    - Otukura stony silt loam mottled phase
    - Otukura stony silt loam strongly mottled phase
  - Maunui series
    - Maunui silt loam
    - Maunui silt loam mottled phase
    - Maunui silt loam peaty topsoil phase
- from alluvium and reworked loess
  - Watiro series
    - Watiro silt loam

Organic Soils

- from peat over alluvium
  - Taratahi series
    - Taratahi peat

Yellow - grey earths

- from loess
  - Wharekaka series
    - Wharekaka silt loam

Yellow - brown stony soils associated with intergrades between yellow-brown loams and yellow-brown earths

- from alluvium
  - Tauherenikau series
    - Tauherenikau very stony silt loam

(see map in back pocket)

The Watiro series has not been previously recognised. Watiro soils occur in a limited area adjacent to Te Maire Ridge, formed from alluvium and colluvium derived principally from adjacent loess covered hills. Profiles have deep mottled silt loam or silty clay loam topsoils with few stones throughout.

The dominant soil in the area is the Otukura series. Otukura soils have shallow silt to sandy loam topsoils over abundant weakly weathered alluvial greywacke gravels, which occur at depths ranging from the surface to 30cm. The third series the of gley soils is the Maunui Series, a new series. Manui soils have considerably deeper silt to sandy loams overlying gravels which occur at depths greater than 30cm from the surface. Both the Otukura and Maunui series have developed from alluvial parent materials predominantly of greywacke-argillite composition, and are of similar age.

The soils of the Otukura and Maunui series show varying degrees of mottling, from very few mottles in all horizons to profuse mottling and iron accumulation in the subsoils. The series are therefore divided at phase level as follows;

Otukura Series.

Otukura stony silt loam;

Otukura stony silt loam mottled phase;

Otukura stony silt loam strongly mottled phase;

Maunui Series.

Maunui silt loam;

Maunui silt loam mottled phase;

Maunui silt loam peaty topsoil phase.

The Otukura series was described by Cowie and Money (1965), Gibbs *et al.* (1975) and Griffiths (1975) as "shallow to moderately deep" soils "resting on gravels" . Griffths (1975) added that these soils have "formed on alluvium from greywacke which overlies impermeable silty alluvium from reworked loess" (Table 2.3). The impermeable silty layer was not encountered in this survey.

Table 2.2 Correlation of previously named soil types and series with the present proposed nomenclature of soils in the Moroa Area south of Greytown.

Griffiths (1975)	Cowie and Money (1965)	Gibbs *et al* (1975)	Present Study
Otukura soils (gravels at <30cm)	Otukura silt loam (gravels at <30cm)		
	Otukura silt loam (gley recent soil)		Otukura stony silt loam
Moroa soils (gravels at <30cm)		Moroa stony loam (weakly leached gley soil)	Otukura stony silt loam mottled phase
			Otukura stony silt loam, strongly mottled phase
Otukura soils (gravel at >30cm)	Moroa silt loam (gley soil)	Otukura silt loam (moderately leached gley soil)	Maunui silt loam
Moroa soils (gravels at >30cm)	Otukura silt loam (gravels at >30cm)	Moroa loam (moderately leached gley soil)	Maunui silt loam, mottled phase
			Maunui silt loam, peaty topsoil phase
			Watiro series
Taratahi series		Taratahi series	Taratahi series
Martinborough series		Wharekaka soils Martinborough loam	Wharekaka series
Tauherenikau series		Tauherenikau series	Tauherenikau series

Table 2.3 Classification of soils of Moroa area, South Wairarapa. (from Griffiths 1975)

Soils of the flood plains and swamps

Recent soils	
Ruamahanga series	- formed on stony river-bed and flood-channel deposits are shallow stony sands.
Greytown series	- formed on recent greywacke alluvium are deep well drained silt loams and sandy loams.
Papawai series	- formed on recent greywacke alluvium - are moderately well to imperfectly drained sandy loams.
Gley recent soils	
Ahikouka series	- formed on recent greywacke alluvium - are moderately deep silt loams, imperfectly drained with high water table in winter.
Gley soils	
Moroa series	- formed on slightly older greywacke alluvium than the Ahikouka series - are shallow to moderately deep silt loams, imperfectly drained with high water tables in winter.
Otukura series	- formed on alluvium from greywacke which overlies impermeable silty alluvium from reworked loess, which rests on gravels - are shallow to moderately deep, and are poorly drained with the water table at the surface in winter.
Organic soils	
Taratahi series	- formed on varying depths of peat which overlies impermeable silty alluvium.

Soils of the river terraces and fans

Yellow-grey earths	
Martinborough series	- formed on loess - consist of deep silt loams with a hard pan at shallow depth.

Intergrades between yellow-brown loams and yellow-brown earths	
Tauherenikau series	- formed on sandy alluvium derived from a mixture of volcanic ash and greywacke, overlying gravels - vary from excessively drained to droughty, very shallow and stony sandy loams at the head of the fan, to well drained moderately deep sandy loams in the middle of the fan.
Carterton series	- formed at the toe of the fan on alluvium from a mixture of volcanic ash and greywacke - are similar to the Tauherenikau series except for drainage, which varies from moderately good to imperfect because of a high water table in winter.

Cowie and Money (1965) expressed depth to gravels at phase level, using mottling and leaching as their primary criteria for division. They described the "Otukura silt loam" as having "a topsoil 20 - 23cm deep of a very dark greyish silt loam. This overlies a dark grey to bluish grey clay loam or heavy silt loam with few to many distinct reddish brown mottles which grades down to a dark grey sandy loam with few reddish brown mottles." In some profiles, the subsoils are a silty clay loam or heavy sandy loam grading down to sandy loam, while in others, gravels occur at 72 - 91cm from the surface. The Otukura fine sandy loam shallow phase (Cowie and Money, 1965), is mapped where underlying gravels are closer than 46cm from the surface. Table 2.2 shows the correlation of Cowie and Money's (1965) classification and the present proposal. The Otukura fine sandy loam shallow phase is incorporated in the Otukura series of this study, but the Otukura silt loams are divided between the Otukura and Maunui series depending on the depth to gravels in the profiles. These divisions apply also to those soils described by Griffths (1975) and Gibbs *et al.* (1975).

Griffiths mapped a co-dominant gley soil series in the area, the Moroa series (Table 2.3). He described this series as shallow to moderately deep silt loams derived from greywacke alluvium.

In the Interim Report on soils of Wairarapa Valley, Gibbs *et al.* (1975) distinguished between the Otukura silt loam, and Moroa silt loam and loam by describing the Moroa as a weakly leached gley soil, and the Otukura as a moderately leached gley soil. They also stipulated that there was a slow accumulation of sediment on the Moroa soils and negligible accumulation on the Otukura soils. Brief profile descriptions showed the Moroa soils to have 15 - 18cm greyish brown loam over 20 - 30cm greyish brown silt loam with reddish brown mottles. This rested on a silty and stony alluvium. Some profiles were stony to the surface.

In the Interim Report the Otukura silt loam was described as having an 18 - 23cm dark greyish brown silt loam on 25 - 30cm dark greyish to grey silty clay loam with a coarse blocky structure overlying silty alluvium.

In the Greytown Survey (Cowie and Money, 1965), only one small area of Moroa silt loam is mapped. Here the soil is described briefly as being more leached than the Otukura silt loam with gravels between 22 - 33cm below the surface. Profiles show 18cm of a greyish brown silt loam topsoil with faint reddish mottles overlying a grey silt loam with many distinct yellowish brown mottles.

As suggested by Gibbs *et al* (1975), Cowie and Money (1965) also classify the Moroa and Otukura soils as being different ages. Cowie and Money classify the Otukura silt loam as a gley recent soil, whilst the Moroa is said to be a gley soil.

Cowie and Money (1965) and Gibbs *et al.* (1975) briefly describe the Moroa and Otukura soils, but the descriptions are ambiguous. The earlier study classifies the Moroa as a gley soil and the Otukura as a gley recent soil which do not receive deposits of fresh alluvium. Gibbs *et al.* (1975) describes both soils series as gley soils, and also suggests there is a slow accumulation on the Moroa soil, but none on the Otukura soil. Furthermore, Cowie and Money (1965) suggest the Moroa soils are "older and more leached" than the Otukura soils. Gibbs *et al.* (1975) classify the Moroa as weakly leached and the Otukura as moderately leached.

In the present survey, the gley soils all appear to be of equivalent age. As there are no areas where slow accumulation of sediment occurs, no recent, or gley recent soils occur.

The distinction between the previously described Moroa, and the Otukura soils is ambiguous and also very poorly defined in the gley soils of the study area. A new series, the Maunui series, and a re-defining of the Otukura series is proposed. To avoid confusion and ambiguity, the "Moroa series" name has been deleted, and soil taxanomic definitions are provided in the soil mapping unit sheets (Appendix 1).

In summary, the proposed classification for the gley soils (with greywacke-argillite parent materials) in the study area is primarily concerned with the depth to abundant greywacke gravels. The Otukura series includes the gley soils with a thickness of up to 30cm of silt or sandy material over weakly weathered alluvial gravels. The Maunui Series includes the gley soils with a thickness of at least 30cm of silty or sandy material over weakly weathered alluvial gravels.

It was considered that the depth to gravels was the most important limiting variant for the farming or horticultural practises that were observed and should therefore be prominent in any map of soils of the area. Furthermore, in soils with stony subsoils, the thickness of topsoil (or depth to gravels) is a much more lasting feature of the profile than is the degree of mottling or leaching. Hence, the variation of mottling or leaching in the profile separates the soils at phase level, not at type level, as has been the case previously.

2.2.3 SOIL DESCRIPTIONS

Detailed soil descriptions are included in Appendix 1.

GLEY SOILS.

Gley soils occur where accumulation of alluvium has ceased and there is a seasonally or permanently high water table. These soils range in texture from silt loam to coarse sandy loam with varying depths to alluvial gravels. They occur in very poorly to imperfectly drained sites in the central valley. The subsoils are typically grey in colour and are strongly mottled with concretions and iron pans occurring in many profiles.

Gley soils cover the majority of the study area (fig 2.3 in back pocket). Included in this group are three series;

a) Otukura series (alluvium over gravels at <30cm depth);
b) Maunui series (alluvium over gravels at >30cm depth);
c) Watiro series (colluvium and alluvium from loess).

Figure 2.3: (legend) Pedological Legend of soils of the Moroa Area south of Greytown.

Gley Soils

- from alluvium

Otukura Series
Otukura stony silt loam
Otukura stony silt loam mottled phase
Otukura stony silt loam strongly mottled phase

Maunui Series
Maunui silt loam
Maunui silt loam mottled phase
Maunui silt loam peaty topsoil phase

- from alluvium and reworked loess

Watiro Series
Watiro silt loam

Organic Soils

- from peat over alluvium

Taratahi Series
Taratahi peat

Yellow - grey earths

- from loess

Wharekaka Series
Wharekaka silt loam

Yellow - brown stony soils associated with intergrades between yellow-brown loams and yellow-brown earth

- from alluvium

Tauherenikau Series
Tauherenikau very stony silt loam

(see map in back pocket)

Developed primarily from greywacke-argillite derived loamy alluvium and alluvial gravels, the gley soils have stony subsoils and a varying range of depths to unweathered gravels.

The gley soils are often waterlogged in winter with ponding of surface water common. In summer they can become drought-prone because they are able to hold little plant available water in the stony subsoil. In some areas excessive drying can result in surface cracking.

A. Otukura series.

The Otukura soils are the most extensive soils in the survey, occuring on the low lying plains.

Profiles have up to 30cm of silty or silty clay loam over weakly weathered greywacke sandy gravels. Abundant gravels occur at the surface in many profiles (fig 2.3).

The series is divided at phase level according to the degree of mottling and iron cementation in the profiles. In order of increasing mottling and iron accumulation, the phases are;

Otukura stony silt loam; - none to few mottles in surface horizons to many in the subsurface horizons.

Otukura stony silt loam, mottled phase; - mottles throughout the profile, and iron concretions and clay coatings frequent in the subsoil.

Otukura stony silt loam, strongly mottled phase; - Profiles are very, to extremely mottled and often have an iron pan at 40 - 90cm depth. The lower horizons are grey and completely reduced.

Otukura stony silt loam.

The Otukura stony silt loam occurs in the north-west and northern areas of the survey (fig 2.3) where drainage is poor, but ponded surface water is not as common as on the more mottled phases.

A typical profile shows a 10 - 20cm thick brown to dark brown stony silty clay loam A horizon with very few very fine mottles. Structures are moderately developed with varying percentages of coarse fragments (5 - 35%). Underlying this is a 10 - 25cm thick dull yellowish brown silt or fine sandy loam Bg horizon with few dull yellowish brown and bright brown mottles, containing common to abundant stones and gravels (coarse fragments).

This rests on a grey to yellowish grey fine sandy loam Bg or Bgr horizon with common bright brown, and bright yellowish brown mottles or a greyer Bgr horizon. Some profiles show a few discontinuous clay coatings on stones and old root channels. At a depth of 50 - 85+cm is a grey to greyish brown sand with abundant coarse fragments and few fine mottles. The structures of these lower horizons are weakly developed grading downwards to massive or single grain.

Otukura stony silt loam mottled phase.

The Otukura stony silt loam mottled phase is the most extensive soil type in the survey, covering a large area where drainage has been impeded and soils are wet in winter with ponded surface water for long periods. The microrelief tends to be more hummocky than for the Otukura stony silt loam, and abundant rushes in some areas are indicative of the wetter sites (fig 2.4). The Otukura stony silt loam mottled phase represents the transition between the Otukura stony silt loam, and the Otukura stony silt loam strongly mottled phase. Profiles are mottled throughout and iron concretions and clay coatings on ped faces, stones and in cracks are common in the lower horizons.

A typical profile shows 18cm brownish black silt loam Ap horizon with many fine bright brown mottles and few coarse fragments.This overlies a 10 - 30cm thick dull yellowish orange very fine sandy loam or silt loam ABg horizon with many distinct bright yellowish brown and bright brown mottles, and few yellowish brown coatings on peds. Structures in these upper horizons are usually moderately developed fine nuts. Coarse fragments increase with depth.

At a depth of 30 - 70cm is a greyish yellow brown sandy clay loam Bg horizon. There are many to abundant bright brown and bright yellowish brown mottles and common iron coatings on stones. This horizon has abundant coarse fragments and overlies a brownish grey 20 - 30cm thick sand (Cg horizon) which has common bright yellowish brown and brown mottles. There are some iron coatings and concretions and abundant coarse fragments.

Underlying the Cg_1 horizon at 75 - 95cm depth is a grey sand Cg_2 horizon with few to many distinct yellowish brown iron coatings and concretions which can become cemented.

Otukura stony silt loam strongly mottled phase.

Where the water table is very high (often only afew centimeters from the surface in winter), and drainage is very poor, the Otukura stony silt loam mottled phase grades into the Otukura stony silt loam strongly mottled phase. This soil type is commonly restricted to small abandoned or ephemeral channels, which in many cases are too small to delineate separately on the soil map. Areas where the dominant soil type is Otukura stony silt loam mottled phase, simple mapping units are used.

Iron accumulation in the subsoils of profiles in these channels is so profuse that a cemented, impenetrable iron pan has formed at depths of 40 - 80cm. In places, this may be in excess of 60cm thick.

Most profiles show a 10 - 20cm thick brown stony silt loam Ap topsoil with many fine yellowish brown and brown mottles. The topsoil is friable and has a moderate to well developed structure with abundant coarse fragments. Below this is a greyish yellow brown sandy clay loam Bg horizon of variable thickness (10 - 50cm). Many bright brown and orange mottles occur in this horizon with a few iron concretions and coatings on the many stones present.

Figure 2.4a) A view south from the central part of the study area toward the loess covered Te Maire Ridge (trees on top) and Hiwirau Ridge (below). This landscape is typical of gley soils in the region and rushes in the neighbouring field give a hint of the naturally poor drainage

Figure 2.4 b) A typical profile of the otukura stony silt loam, mottled phase (site shown above). Note the 20cm of brownish black silt loam Ap horizon over a very stony ABg horizon. Below this, at 35-50cm depth is a gleyed, mottled stony Bgm horizon. At 50-75cm depth the profile has prominent bright brown mottles in a very gleyed sandy matrix.

Below the Bg horizon, is a dark yellowish grey sandy loam Bgc horizon with many mottles and abundant iron stained gravels and stones. Structures may be very weakly developed, massive or single grain. The iron coatings and concretions become profuse, with depth (40 - 80cm depth) often cementing to form a semi-continuous iron pan (Bm horizon). This overlies a grey sand Cgr horizon with few fine yellowish brown mottles, few fine iron concretions and abundant coarse fragments.

B. Maunui series.

The Maunui series is a new series. Manui soils occur on the low lying floodplains where the depth to gravels is >30cm. In these soils abundant unweathered greywacke gravels underlie 30 - 80cm of silty loam, silty clay loam, or fine sandy loam.

The Maunui series is divided similarily to the Otukura series, using the degree of mottling and iron accumulation as the major determinant. The Maunui silt loams range from having very few mottles but very grey subsoil colours in the profile, to many mottles with some iron concretions and coatings on stones in the lower horizons. The Maunui silt loam mottled phase is mottled throughout the profile, with an iron pan at 40 - 90cm depth in most soils.

Maunui silt loam.

Profiles are similar to the Otukura stony silt loam, but abundant coarse fragments occur at >30cm depth.

A typical profile shows 20cm of brownish black silt loam Ap horizon with few fine reddish brown and greyish brown mottles. This rests on a 20cm thick brown silt loam Bg horizon which has many bright brown and reddish brown mottles. These horizons have moderately developed nut structures and few coarse fragments. At 40cm depth, a dull orange fine sandy loam Bg_2 horizon underlies the Bg_1 horizon. There are common distinct bright yellowish brown and bright brown mottles, and abundant coarse fragments in this horizon. Below a 20 - 30cm thick greyish brown sand (Cgr horizon) with few fine brown and bright brown mottles. This horizon has profuse coarse fragments.

Maunui silt loam mottled phase.

The Maunui silt loam mottled phase occurs in areas where drainage is poor to very poor and there is seasonal surface ponding. Again these soils are similar to the Otukura stony silt loam mottled phase, but with a depth of 30+cm to abundant weakly weathered greywacke gravels. Profiles are strongly mottled and many have a discontinuous iron pan at 40 - 90cm depth.

Profiles show 10 - 25cm of dark brown to brown silty clay loam or silty loam Ap horizon with few brown mottles, over a 10 - 40cm thick yellowish orange silty clay loam Bg horizon which has many distinct yellowish grey and brown mottles. These horizons have weakly to moderately developed nut or crumb structures with few coarse fragments in the topsoil which become more common with depth.

At a depth of 35cm a typical profile has a greyish brown silty clay loam Bg_2 horizon with many medium and coarse greyish yellow and bright brown mottles and common dark reddish brown iron coatings on many of the abundant coarse fragments present. Below is a 20 - 40cm thick greyish yellow brown sandy loam or silty clay loam Bg_3 horizon which has many medium and coarse bright brown mottles occurs. There are many prominent reddish brown iron coatings on the coarse fragments and down cracks.

A bright grey and brown Cgm horizon is underneath the Bg_3 horizon. This is massive and rigid where a discontinuous iron pan has developed.

The Maunui silt loam peaty topsoil phase is of very limited extent, confined to small depressions along the base of Te Maire Ridge, and a small area in the southern part of the survey. Most sites are in, or around the perimeter of swampy areas where the water table is permenantly within 30cm of the surface. The only exception to this, is the area of Maunui silt loam peaty topsoil phase occuring away from Te Maire Ridge. Scattered rushes indicate a variably high water table, but artifical drainage of the area has has lowered the water table by up to 1 metre (fig 3.13).

Profiles show a shallow depth (5 - 20cm) of organic rich silt overlying alluvium and gravels. Mottles occur in all horizons but are more prominent in the alluvial subsurface horizons.

A typical profile has 15cm of brownish black peaty silt loam Ah horizon with a moderately or weakly developed crumb structure and few greyish brown mottles. This rests on a brownish grey silty clay loam Bg horizon with many fine and medium bright brown and reddish brown mottles and a weak structure and many gravels and stones. Below this, is a 20cm thick dull yellowish orange Cg horizon with a coarse sandy loam texture and many distinct yellowish brown mottles and abundant weakly weathered gravels and stones.

C. Watiro series.

The Watiro series, newly recognised in this survey occurs on an abandoned indistinct river terrace or fan and deep channel which has been cut from Te Maire Ridge (fig 2.3). The parent material is predominantly alluvium and colluvium from the surrounding loess ridge. The sites are flat, and imperfectly drained.

The soils characteristically have few stones, with deep silt loam or silty clay loam topsoils and a hard impenetrable horizon at >100cm from the surface.

A typical profile has a 20cm Ap horizon of greyish yellow brown silt loam that has a moderately developed nut structure, with few mottles. This overlies a 30cm thick Bg horizon of dull yellowish orange silt loam with many prominent brown mottles grading into a light yellow silty clay loam (Bg_2 horizon) with prominent mottling. Below 90 - 110cm is a light grey sily clay loam which may have few to abundant gravels and stones. There are many distinct yellowish orange and brown mottles with some dark brown coatings. Textures can vary from silty clay loam to sand, and the horizon is hard, and often impenetrable.

ORGANIC SOILS:

Organic soils are mapped in the central valley in areas with poor to imperfect drainage, where up to 150cm of peat overlies either, silty or sandy textured alluvium and alluvial gravels. Soils included in the Taratahi series are the only organic soils in the area.

Taratahi series.

Taratahi soils include Taratahi peat, loamy peat, and peaty loam, differentiated according to the texture of the topsoil. These soils have developed in peaty swamps where the original vegetation consisted mostly of sedges, flax and kahikatea (*Dacrycarpus dacrydioides*). The present vegetation is modified and has been converted into long term pasture. Since deep drains have been dug, the peat has decomposed and the land surface has lowered. Where drainage has been excessive, surface cracking and wind erosion have occured.

The three major areas where Taratahi series occur (fig 2.3) are well defined, with very sharp boundaries.

Taratahi soils have between 40 - 150cm dark brown to black humic or hemic peaty material overlying gleyed olive grey and grey silt loams or sandy loams to sand with many distinct dark reddish and greyish brown mottles. The peaty material often has plant fragments and logs contained in it. Stones occur throughout most profiles but become profuse below the organic horizons. The peaty material has a weakly developed crumb structure, and becomes massive where the profile is waterlogged (mostly in the lower Oh horizon). The alluvial material below the peaty material is single grain or massive.

YELLOW-GREY EARTHS.

Yellow-grey earths have formed on the raised anticlinal ridges and terraces in the area, and are derived from loess. These soils are imperfectly to poorly drained with silt loam and silty clay textures. Previous studies describe these profiles as having a depth of about 50cm over gravels (Gibbs *et al.*, 1975). In this survey, profiles were described to a depth of 120cm and underlying gravels are not reached. The subsoils are grey with brown mottles throughout. Some profiles have a fragipan at 60 - 80cm below the surface (fig 2.5).

Griffiths (1975) classifies the yellow-grey earths in the study area as Martinborough silt loams following the classification system of the Interim Survey (Gibbs *et al.*, 1975), (Table 2.3). In this survey they are considered to be better classified as Wharekaka soils (Pollock, 1975) as there were no underlying gravels in any of the profiles.

Wharekaka series.

The largest area of Wharekaka soils in this survey borders the eastern side of the study area on Te Maire Ridge. There are two further loess covered ridges, Hiwirau Ridge in the south and another smaller ridge in the central part of the region (fig 2.3).

The Wharekaka series is characterised by yellowish grey silt loam topsoils that have moderately developed structures. Mottles increase with depth from a few in the Ap horizon to up to 50% in the Btg and Bx horizons. The Btg horizons are gleyed, and firm with silty clay loam textures and blocky structures. Subsoil horizons show a varying degree of development of clay coatings on ped faces and in cracks. The lack of sandy textured horizons and stones or gravels in the profile distinguishes these from all others in the area.

In some profiles a compact hard Bxg horizon may occur at 60 - 80cm from the surface. The fragipan is strongly mottled with strong coarse columnar structure and a silt loam texture.

Figure 2.5 The deep yellow-grey earths of Te Maire Ridge on the eastern side of the study area. The fragipan is clearly visible in the middle part of the profile. The sharp break at c.1.5m depth corresponds to the position of the c. 20,000 years B.P. Aokautere Ash.

YELLOW-BROWN STONY SOILS.

These soils form on the well drained river fans of the Waiohine Surface. The topsoils are dark brown very shallow stony silt loams or fine sandy loams over greywacke gravels. Subsoils are brown or yellowish brown rather than the grey colourings of the gley soils in the area. There is a lower silt and clay content in these soils, and the gravels are slightly more weathered than those in the gley soils. Horizons are clearer and horizon boundaries better defined than the Otukura, Maunui, and Watiro soils.

The dominant yellow brown stony soil of the area is the Tauherenikau very stony silt loam.

Tauherenikau soils.

Tauherenikau soils are well drained having dark brown topsoils and brown subsoils with few to common mottles. The profile is extremely stony throughout with a 10 - 20cm thick silt loam Ap horizon and loamy Bw or Bwg horizons overlying a sandy textured stony alluvium. Many of the stones in the subsoil have iron coatings which become more common with depth to the cementation of grains and stones, an iron pan has formed at about 90 - 120cm in most profiles (fig 2.6).

The boundary of these soils forms an arc in the north western part of the survey (fig 2.3) which marks the extent of the older fluvial surfaces.

Figure 2.6 a) The Waiohine Surface is flat and free draining. A man-made pond has provided a bank exposing a Tauherenikau very stony silt loam profile. The Ohakean soils tend to be a much browner colour in comparison to the greyer coloured Holocene soils.

Figure 2.6 b) A typical profile of the Tauherenikau very stony silt loam. Note the brown-red colours throughout the profile which are in part due to the Fe accumulation. At 110cm the profile becomes very hard and cemented where an Fe pan has formed.

2.3 DISCUSSION

The pattern of sedimentation of the Holocene deposits is typical of a fluvial braided flood plain, carrying greywacke gravels from the axial ranges. The orientation of the silty channels and gravel, suggest a south to south-east flowing system which was contained between Te Maire Ridge, and the Waiohine Surface.

Where the Waiohine and Holocene surfaces meet, the contact is not well defined, but rather the deposits merge into one another. Reworking of the gravels at the toe of the Waiohine fan by subsequent fluvial action would have resulted in this indistinct contact.

The peat units are surrounded by Holocene alluvial deposits, but the stratigraphic postion of the peat deposits is not completely proven. Since base of the peat is dated at c.8,000 years B.P. it may rest on Holocene deposits, or alternately the peat may overly reworked Ohakean and Holocene gravels (fig 2.7).

All the peat units are continuous, without interbedded silty or sandy layers within the peaty material. This would suggest that peat accumulation was continuous and uninterrupted by the inundation of flood material or debris. It appears that the peat developed evenly across the sites, as the greatest depth of peat occurs near the centre of each mapped peat unit. If fluvial deposits were accumulating elsewhere in the area at the time of peat development, channels, layers of alluvial material, or abrupt changes in peat thickness might be expected since flood episodes would have engulfed the peat deposits. Furthermore it is likely that the peat deposits in the area were far more extensive than they are presently, as indicated by the existence of shallow peaty topsoils in areas not so severely drained suggests.

Figure 2.7 : Diagrammatic Representation of the Peat Deposits

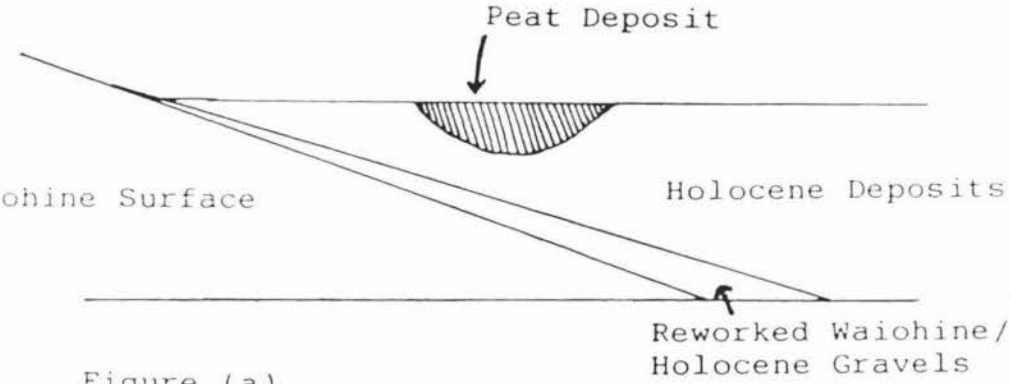


Figure (a)

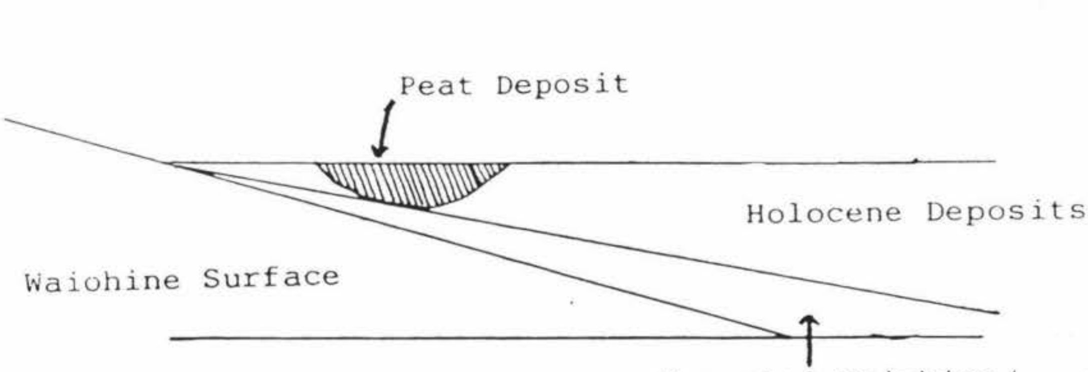


Figure (b)

The peat deposits rest on alluvium which has been deposited durin the Holocene. There are two alternatives, either

(a) the reworked gravels underly Holocene sediments which enclos the peats, or

(b) the peat deposits rest on reworked sediments

CHAPTER THREE.

PALYNOLOGY.

3.1 LITERATURE REVIEW AND BACKGROUND.

3.1.1 USEFULNESS OF POLLEN ANALYSIS.

Many of the interpretations offered in this thesis are based on pollen analysis of peat. For this reason it is important to emphasise some of the limitations of this method.

A significant problem in New Zealand is that many native species may be represented within only one pollen taxon. This is because in general species can only be identified to the generic level. For instance, the *Coprosma* taxon represents 45 species, and the *Metrosideros* taxon represents 11 species. In the case of the grasses, pollen taxa only identify to family level. The reconstruction of past, environments is further complicated by the fact that most of New Zealand's phytosociologically important species have very wide environmental tolerances.

The second important limitation of pollen analysis is that not all pollen types have equal proportional representation in the pollen spectra, (Moar and Myers, 1978; Moar, 1970; 1971; Myers, 1973; Pocknall, 1980; McGlone, 1980a; 1982; MacPhail and McQueen, 1983). The differences in pollen productivity and dispersal power in individual species, the mode of transport and deposition of pollen and spore types, and the likelihood of their preservation are some of the reasons for differences in the amounts of pollen preserved.

Wind pollinated species like conifers, podocarps and beeches tend to be well to over-represented, in contrast to the majority of New Zealand pollen and spore types which are poorly represented in pollen spectra. The latter are mostly insect and bird pollinated species. The few taxa in New Zealand that have inherently high powers of pollen dispersal are; *Cyathea smithii*, *Dacrydium cupressinum*, *Nothofagus fusca* type, *Coprosma*, and Gramineae whilst others like *Dacrycarpus dacrydioides* and Cyperaceae are generally poorly represented in pollen spectra (MacPhail and McQueen, 1983).

It is often difficult to distinguish if the pollen has accumulated in a forested area, an open unforested area, swamp or bog situation because some anemophilous trees have the highest pollen percentages in open tussock and sedgeland samples and not in forest covered peats (eg. McGlone, 1982). Many herbs and shrub species are insect pollinated and hence their presence is shadowed by the wind-pollinated tree pollens from surrounding and distant areas. Where the site is forested, local grass or herb taxa from adjacent areas may be seriously under-represented (Moar, 1970). For these reasons unusual pollen assemblages can be encountered.

There are a small number of important plants in which pollen is very rarely preserved. *Beilschmiedia tawa* (tawa) is not found in pollen assemblages even when modern pollen samples have been taken from within *B. tawa* stands. *B. tawa* dominated forests are, therefore, absent from the pollen record. *Corynocarpus laevigatus* (karaka) is another severely under-respresented pollen taxon, having been postively identified only in modern profiles, (Mildenhall and Moore, 1983).

Long distance transport of some pollen types can be misleading. Moar (1959) found low percentages of both *Podocarpus* spp. and *Nothofagus* in samples from Antipodes Island which suggests these have been carried by the wind from the South Island, New Zealand, some 640 km away.

Finally, it is advantageous to be able to collect modern pollen samples to endeavour to predict the representational proportions of a vegetative community in the area. This also helps in the identification of different plant communities from various pollen assemblages (Moore and Webb, 1978).

Pollen analysis does provide a good indication of the type of vegetation that existed at any one time, and the variations in vegetation over geological time. Detailed analysis of the better represented species, together with clues from more restricted pollen distributions (for example *Ascarina lucida* and *Dacrycarpus*) can provide a satisfactory qualitative description of the history of New Zealand's flora. The consistency of vegetational trends and changes in pollen diagrams from throughout New Zealand (discussed later) has made pollen analysis a valuable tool in increasing our knowledge of past climatic fluctuations.

3.1.2 LATE QUATERNARY VEGETATION CHANGES IN NEW ZEALAND.

(literature review).

Vegetation changes in New Zealand since the last glaciation have been pieced together using pollen analyses from sites throughout New Zealand. The broader trends in vegetation that occur over wide areas may provide climatic inferences although they are often masked by local environmental variations.

All locations and sites mentioned in the text are shown on figures 3.1 and 3.2.

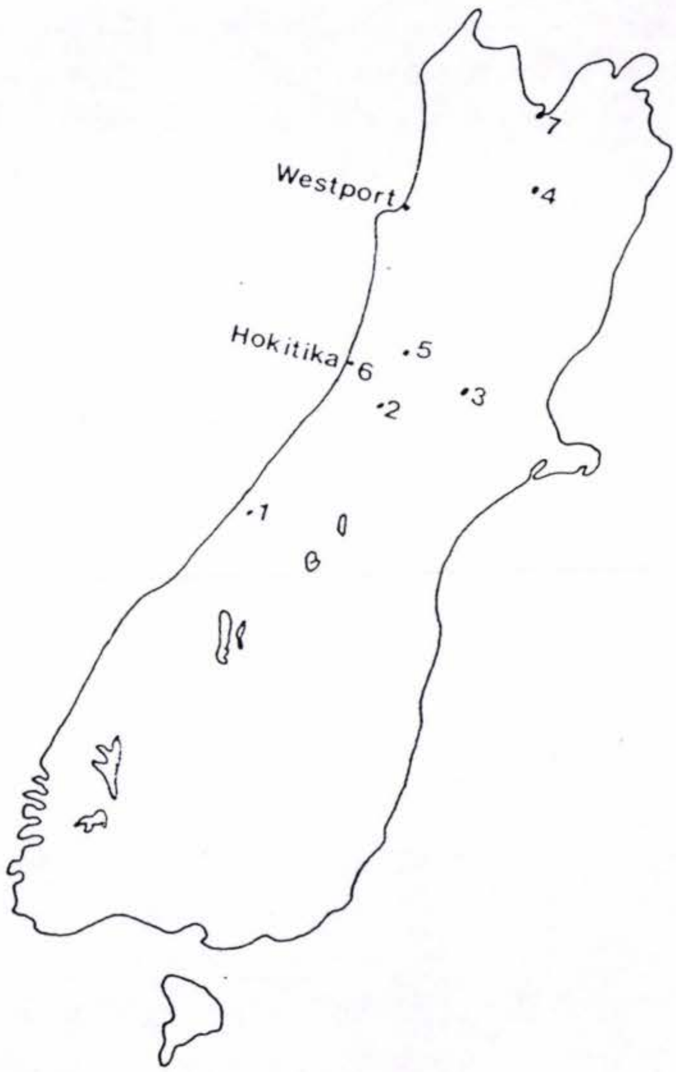
SOUTH ISLAND, NEW ZEALAND.

Studying post-glacial pollens from Southland and Otago, Cranwell and von Post (1936) recognised three pollen zones. These zones of grassland to podocarp forest and then *Nothofagus* forest represented a pattern of warming to a maximum warmth, then a subsequent cooling. No dates for these pollen zones were offered.

After the last glacial maxima, and by 12,000 years B.P. (McGlone, 1980; Moar, 1973), grass and scrubland dominated the South Island vegetation. Forest did not become fully re-established until about 10,000 years B.P. (Moar, 1971). For example in Canterbury when *Podocarpus* forest became dominant about 10,000 years B.P. (Moar, 1973), and in Hokitika (Blue Spur) there post-glacial a *Dacrydium cupressinum* dominated podocarp-hardwood community recorded before 9,000 years B.P. (Moar and Suggate, 1973).

The general pattern of succession from grassland to shrubland and then forest in response to post-glacial climatic changes is seen in most South Island pollen spectra. However, regional differences in plant communities and successions become apparent. Four regions can be broadly differentiated; the west coast, the east coast, southern and northern South Island.

FIGURE 3.1 Approximate location of pollen sites mentioned in the text. (South Island)



1. Gillespies Beach Road Site Moar 1973
2. Lake Henrietta Site; Moar 1973.
3. Cass; Moar 1971.
4. Tophouse; Moar1971.
5. Bell Hill; Moar 1971.
6. Blur Spur Road; Moar and Suggate 1973.
7. Dew Lakes; Dobson 1978.

A. West Coast.

On the western side of the Main Divide, scrubland, predominantly *Coprosma* spp. and *Myrsine* was replaced by *Weinmannia* spp. (mostly kamahi) forest which was succeeded by *Dacrydium cupressinum* dominated forest c.9,000 years B.P., (Bell Hill, Moar, 1971; Gillespies Beach Road site, Moar, 1973) and 11,000 years B.P. in the Fox Glacier region (Moar and Suggate, 1973). At the Gillespies Beach Road site, *Weinmannia* and *D. cupressinum* spread at about the same time, but *Weinmannia* was rapidly overshadowed by *Dacrydium cupressinum*. Important species within the *D. cupressinum* dominated forest were, *Phyllocladus*, *Ascarina*, *Quintinia*, *Podocarpus*, Myrtaceae, and *Weinmannia*. (Moar and Suggate, 1973). In north Westland *D. cupressinum* dominated forest was well established by 5,700 years B.P. (Pocknall, 1980), and has suffered only minor changes since.

B. East Coast.

On the eastern side of the Main Divide a *Dracyophyllum*, *Phyllocladus* shrubland preceded podocarp forest (predominantly *Podocarpus spicatus* at Lake Henrietta, Moar, 1973), which then gave way to *Nothofagus* dominated forests (at Cass; Moar, 1971; Lintott and Burrows, 1973).

Although Harris (1963) thought the spread of *Nothofagus* to be about 2,000 years B.P., Moar (1971) found it to be diachronous. *Nothofagus* had begun spreading by 2,400 years B.P. at Bell Hill (Moar, 1971), and in northern Canterbury by 7,000 years B.P. (Moar, 1973). Further studies show *Nothofagus* forest was well established at Lake Henrietta by 5,000 years B.P. (Moar, 1973), 6,000 years B.P. at Springfield (Moar, 1973), and 8,000 years B.P. at Tophouse (Moar, 1971). This diachronous character is attributed to the poor dispersal power of *Nothofagus* from isolated pockets where forest survived during the Otirian Glaciation (Moar and Suggate, 1973; McGlone, 1980). The majority of dates within the eastern central South Island show the spread of *Nothofagus* occurred between 6,500 and 2,000 years B.P. (Wardle and McKellar, 1978). There are two exceptions, firstly at Tophouse, (8,000 years B.P., Moar, 1971) and secondly at Blue Spur where *Nothofagus* dominance occurred in the late Otiran or early Aranuian (Moar and Suggate, 1973). Both sites occur on the fringes of the Otiran Glacial deposits where *Nothofagus* forest possibly survived, and thus spread much more rapidly, (Wardle and McKellar, 1978). This idea is supported by Suggate (1965) who showed that Nelson-Marlborough, Fiordland-Southland and Banks Penninsula suffered less during Otiran glacial and periglacial activity than did other regions of the South Island.

Lintott and Burrows (1973) related a more detailed sequence of pollen zones from a site near the Cass district to environmental changes. The first two zones (table 3.3) are predominantly i) herbaceous plant groups, and ii) shrub pollens comprising *Coprosma*, then *Halocarpus bidwillii* type (bog pine and pink pine). Zone 2 ended about 10,000 years B.P., and together with zone 1 was interpreted as the terminating cold environment of the Otiran Glacial stage. Zones 1 and 2 are correlated with the grassland stage and initial part of the shrubland stage previously mentioned (Moar, 1971). The dates of these changes are not in dispute, but whether they represent the closing of the Otiran Glacial stage, or simply reflect local changes in vegetation is disputed (Suggate and Moar, 1974) as the changes do not correlate with those found by Moar (1971) from a site only 6km away.

Table 3.3: Summary of the post-glacial vegetation changes in the South Island, New Zealand.

Nelson Area (northern S.I.)	*	West Coast	Moar (1971)	#	East Coast	Southland
Deforestation	B5	Deforestation	C5	Z6	Deforestation	Deforestation
Podocarpus-Nothofagus forest (4,800yrs.B.P.)	B4	*Dacrydium cupressinum* dominance (11,000yrs.B.P.-9,000yrs.B.P.)	C4	Z5	*Nothofagus* dominance (6,500-2,000yrs.B.P.)	*Nothofagus* dominance (>2,000yrs.B.P.
Podocarpus-Dacrydium cupressinum dominance some *Nothofagus* (10,500yrs.B.P.)	B3	*Weinmannia* dominance	C3	Z4	*Podocarpus* dominance (c.8,000yrs.B.P.)	*Dacrydium cupressinum* dominance (5,500yrs.B.P.
?	B2	*Coprosma-Myrsine* (>12,000yrs.B.P.)	C2	Z3	*Phyllocladus-Halocarpus bidwillii, H. biformis* (<10,000yrs.B.P.)	*Dacrycarpus dacrydoides, Podocarpus, Phyllocladus, H. bidwillii, H. biformis* (11,200yrs.B.P.
?	B1	grassland / shrubland	C1	Z2 Z1	grassland / shrubland (>10,000yrs.B.P.)	herbaceous (>11,200yrs.B.P.

* Zones from Moar (1971).

\# Zones from Lintott and Burrows (1973).

In zone 3 (Lintott and Burrows, 1973) *Phyllocladus* peaks soon after 10,000 years B.P., with *Dacrydium cupressinum* and *Coprosma* declining and the podocarps rising slightly. For the dominance of *Phyllocladus*, a moister cooler climate than present is postulated. The expansion of podocarp forest in zone 4 (Lintott and Burrows, 1973) at about 8,000 years B.P., and the persistance of *Phyllocladus*, is thought to correspond to a climate with less extreme, milder temperatures, and moister conditions. This is supported with macrofossils of *Libocedrus*, *Elaeocarpus*, *Pseudowintera*, and *Myrsine*, all requiring mild moist environments (Lintott and Burrows, 1973).

The spread of *Nothofagus* that followed zone 4 and the decline of the podocarps to an unimportant level is interpreted as resulting from a climatic change to greater temperature extremes, lower rainfall, and periodic droughts and storms (Lintott and Burrows, 1973; McGlone, 1980b).

These more specific climatic implications are endorsed by Wardle and Campbell (1976). They suggest that if the succession from grass and *Coprosma* → *Halocarpus bidwilli* type → *Phyllocladus* → *Podocarpus* → *Nothofagus* (Lintott and Burrows 1973, zones 1 - 5) represent solely a climatic warming, then the position of *H. bidwillii* type is anomalous, as it occurs commonly on overmature soils, very seldom reaching altitudes of *Nothofagus* or *Phyllocladus*. Wardle and Campbell (1976) found however, that *H. bidwillii* can withstand temperatures lower than both *Phyllocladus* and *Nothofagus*. The succession therefore, could reflect a decreasing intensity of frosts, as well as increasing mean temperatures. Lintott and Burrows (1973) further suggest that *H. bidwillii* type, and *Phyllocladus* increase rapidly when there is little competition, hence their increase before the forest proper developed.

NORTH ISLAND, NEW ZEALAND.

Before 14,000 years B.P. a cool and possibly dry climate (McGlone *et al.*, 1978) supported grass and shrublands over much of the North Island, with scattered pockets of bush mostly dominated by *Nothofagus*. By 13,000 years B.P. almost all the lowland regions of northern and central North Island had a podocarp - hardwood forest cover (Harris, 1963; McGlone and Topping, 1977). The transition from grass and shrubland to forest seemed to occur quite rapidly (Harris, 1963; McGlone and Topping, 1977; McGlone, 1980a). The relict beech stands did not expand as quickly, the forest becoming dominantly *Libocedrus bidwilli* (mountain cedar), *Phyllocladus aspleniifolius* var. *alpinus* (mountain toatoa), and *Halocarpus bidwilli* (bog pine).

From peats in the Tongariro region, McGlone and Topping (1977) recognised five post-glacial pollen zones (table 3.4) which were dated using tephra layers. With the rapid replacement of the grass and shrubland, which occurred c.14,200 years B.P. (denoting the end of pollen zone A2 of McGlone and Topping, 1977), a podocarp-hardwood forest was established. *Dacrydium cupressinum* was common in this forest, suggesting a milder climate (also supported by McGlone *et al*, 1984).

In zone A3 (14,500 - 10,300 years B.P.) *D. cupressinum* continues to increase as does *Libocedrus*. The forest was dominated by *Prumnopitys taxifolia*, *Halocarpus bidwillii* and *Phyllocladus*, suggesting droughty conditions on occasions. By zone A4, 10,300 - 5,000 years B.P. *D. cupressinum* had become the dominant flora. *Ascarina*, a frost and drought sensitive species (McGlone and Moar, 1977) increased markedly during this period (McGlone and Moar, 1977), together with *Dodonaea viscosa* (akeake) and to a lesser extent *Alectryon excelsus* (titoki). *Leptospermum* spp. increased at the expense of *Halocarpus bidwillii*, and in the wetter sites *Leucopogon colensoi* (silver pine) became dominant. These changes suggest a shift to a moister, warmer, drought-free climate during zone A4 (McGlone and Topping, 1977)

C. Southern South Island.

The pattern of forest change in the southern part of the South Island varies from the more northern regions. By 11,200 years B.P. the herbaceous vegetation of the Otago region was being replaced by a predominantly *Dacrycarpus dacrydiodes*, *Podocarpus spicatus* community, with *Phyllocladus* and *Halocarpus bidwilli / H. biformis* also common (McIntrye and McKellar, 1970).

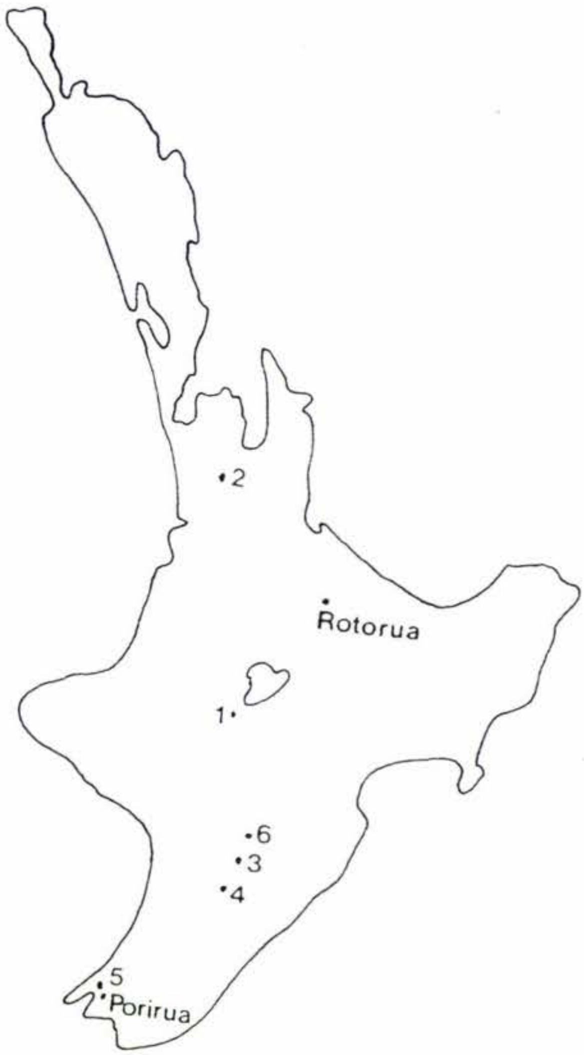
From about 5,500 years B.P. *Dacrydium cupressinum* dominated the Southland landscape, although *H. bidwillii / H. biformis* and *Nothofagus menziesii* also increased (McGlone, 1980a; 1980b). This change in flora is thought to have been induced by a shift to cooler wetter conditions following the post-glacial warming (McGlone, 1980b).

In Fiordland and coastal Southland, *Nothofagus* forest increased to become co-dominant with the *D. cupressinum*-podocarp forest by 2,000 years B.P., (Harris, 1963; McGlone, 1980b; Johnson, 1978). *Nothofagus* has continued to increase to the present day.

D. Northern South Island.

Pollen spectra from the northern South Island show mixed *Nothofagus* - podocarp forest has existed near Dew Lakes since 10,500 years B.P. suffering few minor changes (Dodson, 1978). *Nothofagus* peaked around 4,800 years B.P., accompanied with a decrease in *Podocarpus* spp., but both *Dacrydium cupressinum* and *Podocarpus ferrugineus* remained common in the forest. Dodson (1978) and Burrows (1965) suggest that the reason was probably a refuge area for forest vegetation during the last glaciation, and hence the early occurrence of *Nothofagus*, and the persistence of *Podocarpus* in the region.

FIGURE 3.2 Approximate location of pollen sites mentioned in the text. (North Island)



1. Wairehu and Otamangakau Sites, Tongariro Region; McGlone and Topping 1977.

2. Ohinewai peatlands, Lower Waikato; McGlone et al 1984.

3 & 4. Study sites in southern Ruahine Range; Lees 1981, 1986.

5. Pauatahanui Inlet; Mildenhall 1979

6. Location of northern Ruahine Range sites; Moar 1961, 1967.

7. Wallaceville; Harris 1958. (Hutt Valley)

Table 3.4: Summary of the post-glacial climatic and vegetation changes in the Wellington region, North Island, New Zealand

YEAR	CLIMATE	WALLACEVILLE	PAUATAHANUI	PETONE	TURAKIRAE HEAD
0 -	drier	*'fusca'*	rimu,	rimu	
1800	cooler	beech,	(decreasing	(decreasing	? rimu
		matai,	towards	towards	
		totara,	present)	present)	
		rimu			
....	....	....	matai,	*'fusca'*	....
		'fusca'		beech,	matai,
1800	milder	beech,	totara,		
-	conditions	rimu,		matai,	totara,
3500		matai,	manuka,		
		totara		totara,	rimu,
		Ascarina	rata,		
		(decreasing)		*Ascarina* /	
....	....	....	*'fusca'*	*Dodonaea*	*'fusca'*
		'fusca'	beech,	(increasing	beech,
3500	cooler	beech,		towards	
-	and	matai,	*Ascarina*,	present)	*Ascarina* /
5000	drier	rimu,			*Dodonaea*
	(similar	totara,	*Mrysine*		(increasing
	to present)	*Ascarina*			towards
		(decreasing)			present?)
....	....	....		....	
		rimu,	?	rimu,	
5000	warmer	matai,		*Podocarpus*	
-	and	totara,		spp.,	
10,000	than	manuka,	?	*'fusca'*	
	wetter	*'fusca'*		beech,	
	present	beech		*Ascarina*	
....	....	....		....	....
		matai,		barren	
10,000+	colder	totara,	?	zone	
	and	silver			
	drier	beech,			
	than	kahikatea			
	present				
....	....	....	....	....	....

1) Climate after Topping and McGlone (1977)
2) Wallaceville: Harris (1951,, 1959); Harris and Mildenhall (1980)
3) Pauatahanui: Mildenhall (1980)
4) Turakirae Head: Mildenhall and Moore (1983)

In zone A5 (5,000 years B.P. to present) (McGlone and Topping, 1977), *D. cupressinum* gradually decreases and *Prumnopitys taxifolia* rises to become predominant in the forest. *Halocarpus bidwillii, Nothofagus,* and *Phyllocladus* rise, whilst *Ascarina, Dodonaea viscosa* and *Alectryon excelsus* become scarce. McGlone and Topping (1977) postulate a harsher more frosty and drought prone climate over this time.

These trends in vegetation are supported by many other pollen profiles from the North Island.

Knightsia excelsa (rewarewa), *Libocedrus* and *Phyllocladus* are light demanding plants and prefer open structured or damaged forests. Their increase at about 6,000 years B.P. in the lower Waikato (McGlone *et al.*, 1984) supports the hypothesis that the climate was windier and harsher at this time.

In cores from Pauatahanui Inlet (fig 3.2), Mildenhall (1980) found that before 8,000 years B.P. a *Dacrydium cupressinum* dominated broadleaf - podocarp forest existed. Sub-canopy dominant species included *Leptospermum, Metrosideros, Myrsine, Nothofagus fusca* type, *Ascarina, Dodoneae* and *Pseudowinteria*. At about 5,000 years B.P. *D. cupressinum* and *Ascarina* began to decline and the forest was replaced by a *Nothofagus fusca, Podocarpus* spp., and *Metrosideros* dominated community, conformable with zones A4 and A5 of McGlone and Topping (1977). *Cyathea* spp. also declined steadily up the profile, suggesting a slow deterioration in climatic conditions. At Pauatahanui Inlet about 3,400 years B.P. Mildenhall (1980) found that *K. excelsata* increased, possibly at the expense of less hardy frost sensitive species, but *K. excelsa* is rare or absent from most other sites of similar age in the Wellington area (Mildenhall and Moore, 1983) so this trend seems to be very localised.

At Wallaceville (Hutt Valley, fig 3.2) podocarps were dominant approximately 9,000 years B.P. (Harris, 1958) with significant *Nothofagus menziesii* in the canopy. *D. cupressinum* increased to a maximum at about 4,600 years B.P., then declined along with *Ascarina lucida* as *Nothofagus fusca* type and *Podocarpus* again rose to dominate the rest of the profile. The pattern of vegetation change at this site suggests cool climatic conditions 10,000 years B.P. which gradually warmed till 4,600 years B.P. and subsequently deteriorated to the cooler and slightly drier climate of the present day. These trends also parallel McGlone and Topping's (1977) zone A4 and A5.

In boreholes from Petone (Mildenhall and Moore, 1983; Mildenhall, 1980), the pollen spectra, dated c.9,000 years B.P. at the base (Grant-Taylor and Rafter, 1971) shows *D. cupressinum* to rise to an optimum level by 5,000 years B.P. and steadily decline thereafter. *D. cupressinum* dominates the vegetation as *Nothofagus* increases but does not reach significant levels. *Ascarina* steadily declines up the profile but more rapidly after 5,000 years B.P. to disappear at c.2,000 years B.P. (Mildenhall and Moore, 1983). The profiles from the Wellington area are summarised in table 3.4.

Samples near Hauraki and Hamilton (Harris, 1963) show vegetation changes from grass and shrubland to *Halocarpus bidwillii* type, *Phyllocladus*, *Coprosma*, and *Nothofagus fusca*. This vegetation was then replaced by a podocarp dominated forest. Between c.12,000 years B.P. and 5,500 years B.P. (Grant-Taylor and Rafter, 1963) *D. cupressinum* and *A. lucida* became abundant suggesting a change to lesser extremes of climate. With the recovery of *Podocarpus* that followed in the area (Harris, 1963) the trend to a more droughtier frost-prone climate (McGlone and Topping, 1977 (zone A5)) can be inferred.

Peat bogs in the western Ruahine Ranges have been investigated by Moar (1961;1967). Using the Taupo Pumice and Waimihia Formation to date the deposits, he found a general succession from a podocarp forest (at about 5,000 years B.P.), to a podocarp-*Nothofagus* community to be finally dominated by *Nothofagus*. The rise of *Nothofagus* began before 1,500 years B.P. in the northern Ruahines (Moar, 1967), and between 1,800 and 3,500 years B.P. in the western Ruahines (Moar, 1961).

Lees (1981,, 1986) in the southern Ruahine Ranges found no evidence of a *Nothofagus* dominance during the last 13,000 years B.P.. *Prumnopitys taxifolia* dominated podocarp-broadleaf forest was well established by 12,900 years B.P., indicating that post-glacial amelioration in the area was quite rapid. Some profiles showed a slow rise in *Nothofagus* pollen after 4,000 years B.P.. This trend combined with the decline of *A. lucida*, and the disappearance of *Quintinia acutifolia* from the pollen spectra at 1,800 years B.P. is attributed to increased occurrence of droughts and frosts (Lees, 1986), in keeping with McGlone and Topping's (1977) zone iii.

In the western Ruahine Ranges, Moar (1961) interpreted an increase in *Halocarpus bidwillii*/*H. biformis* to a maximum between 3,000 years B.P. and 2,000 years B.P. accompanied by a return of *Ascarina lucida*, as indicating a slight warming. McGlone and Topping (1977) also suggest a slight recovery to wetter milder conditions between 3,500 - 1,800 years B.P.

In the lower Waikato there was little change in the conifer-hardwood forest between 7,000 and 2,000 years B.P. (McGlone *et al.*, 1984). There was however, a marked increase in *Agathis australis* at about 3,000 years B.P. possibly indicating a drier period (McGlone *et al.*, 1984). This is further supported in Rotorua by McGlone (1978b) where *A. australis*, *Dodonaea*, and *Ascarina lucida*, present in the valley before 1,800 years B.P. are rare or absent subsequently.

To summarize, three major post-glacial pollen zones related to climatic fluctuations have been recognised by McGlone and Topping (1977; 1983) in the central North Island.

(i) 14,000 years B.P. - 10,000 years B.P.; Mainly *Prumnopitys taxifolia* dominated podocarp - hardwood forests. *Libocedrus*, *Phyllocladus*, and *Halocarpus bidwillii* were common. Annual temperatures may have been only 2 - 3^{o}C lower than present but the climate was substantially drier.

(ii) 10,000 years B.P. - 5,000 years B.P.; Almost all lowland and montane areas of New Zealand were forested. A change to *Dacrydium cupressinum* dominated communities with *Ascarina lucida* and tree ferns becoming common throughout western and central North Island. The climate was much wetter and milder than present.

(iii) 5,000 years B.P. - present; Decline of *D. cupressinum* as *Nothofagus* spread and *P. taxifolia* dominated podocarp-hardwood forests return. *A. lucida* declined dramatically. There was a general trend away from the mild climates of (ii) to a more droughtier and frost prone climate. A slight climatic improvement between 3,500 years B.P. and 1,800 years B.P. has also been substantiated.

SUMMARY.

Although the changes in vegetation during the post-glacial period have been very different between the North Island and the South Island, the synchroneity of these changes provide strong reason to believe that they are a direct consequence of climatic fluctuations (McGlone, 1980a). While forest was re-establishing in the South Island and southern North Island (about 10,000 years B.P.), *Ascarina lucida* and *Dacrydium cupressinum* were replacing the podocarp forests in the north. These changes can both be interpreted as being the result of climatic improvement.

Post 5,500 years B.P., cool climate events are not clearly defined in the New Zealand pollen sprectra. However, the decline of *A. lucida*, and the spread of *Nothofagus* and *Prumnopitys taxifolia* at the expense of *D. cupressinum* throughout most of the country at this time does support the onset of harsher climatic conditions. The west coast of the South Island is an exception, where the wetter climate has maintained *D. cupressinum* dominated forests.

3.1.4 DEFORESTATION BY MAN.

Relatively mild climate and uniformly distributed precipitation in New Zealand has favoured forest growth, and prior to the arrival of man, forest covered most of the country (fig 3.3). Central Otago, and adjacent regions may have been the only major exceptions to the forested landscape having the lowest rainfall in New Zealand and the highest occurrence of droughts. It is thought that pre-Polynesian fires reduced forest cover in the area further (Molloy, 1969).

The arrival of the Polynesians to New Zealand occurred between 1,200 and 1,000 years B.P. (McGlone, 1983). Since that time over half of New Zealand's indigenous forests have been destroyed by fire. Evidence for this deforestation is abundant in the form of charcoal and wood in soils, records of soil instability resulting from forest destruction, increased sedimentation rates and evidence from pollen analyses of peats and lake cores.

A sharp decrease of pollen and spores derived from forest vegetation, with a rapid increase in bracken, shrub and grass pollen and spores also denotes a sudden deforestation event. Charcoal fragments are usually very abundant during and subsequent to deforestation (McGlone, 1983).

Most of the Holocene pollen diagrams throughout New Zealand show a sharp and distinctive change in pollen and spore assemblages between about 800 and 600 years B.P. where widespread deforestation has occurred. This "forest clearance horizon" (McGlone, 1983) preceeds the appearence of pollen and spores from the European settlers of the 1800's.

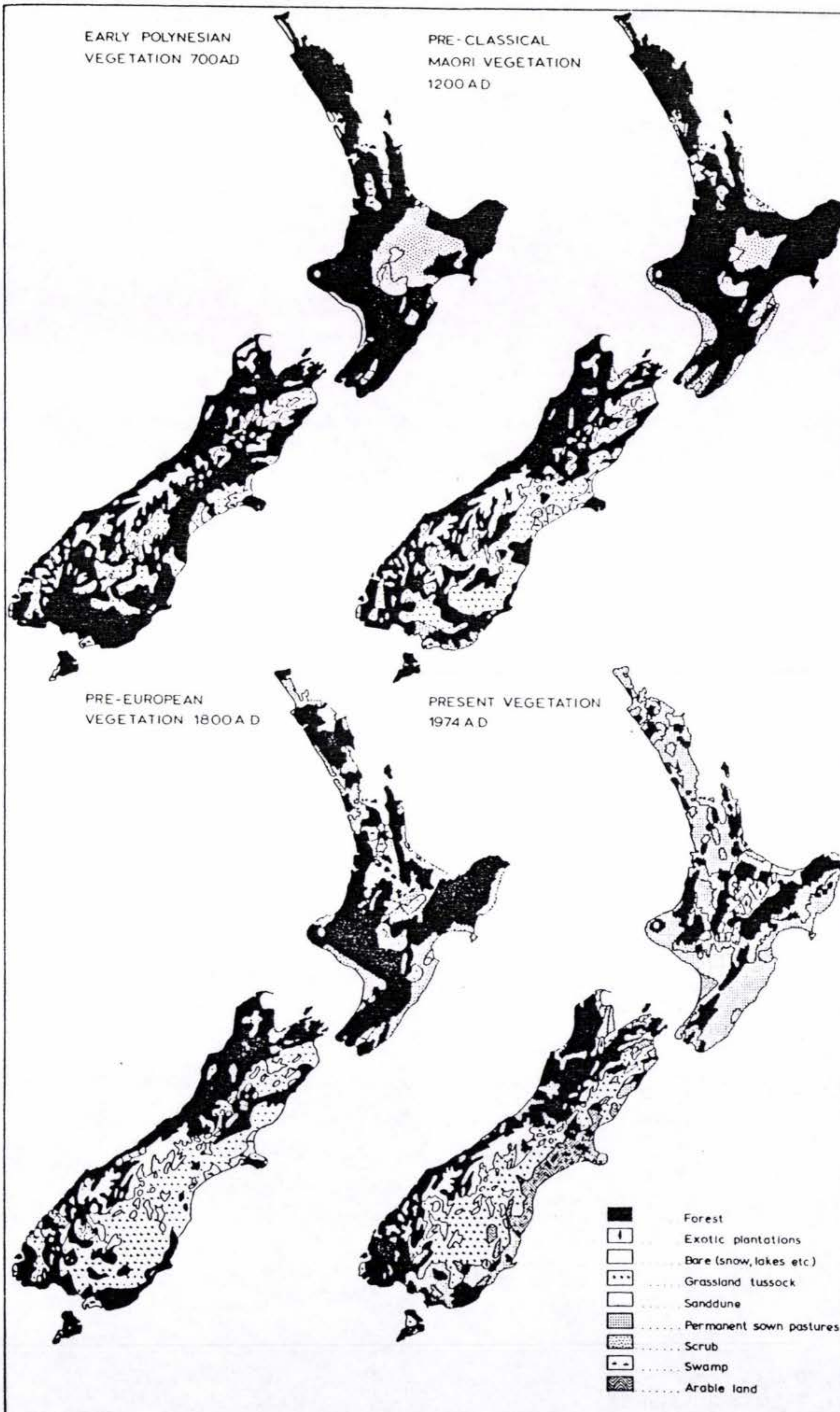


FIGURE 3.3 Deforestation patterns by man. (from Cochrane 1977).

3.2 THIS STUDY.

3.2.1 INTRODUCTION.

Pollen Sampling sites.

Each of the three major peat deposits in the study area were sampled, and the deepest peat was cored (figs 2.2 and 3.4). Four cores were taken from two sites on the peat. Cores A and B were taken at the northern end of the peat at Site 1. Cores C and D from Site 2. Vegetation on the peat consists of improved pasture (mostly ryegrass *Lolium perenne*, brown top *Agrostis tenuis*, and clovers *Trifolium* spp.) with thistles and rushes. The peat has been drained and shrinkage has exposed the roots of the remaining few *Dacrycarpus dacrydioides* trees. The surface of the peat is irregular and hummocky.

At site 1, Core A extended to 1.2m, but a log prevented further sampling. Core B, adjacent, extended to the base of the peat at 1.3m.

Core C was taken from a mound, and may have suffered abnormally high oxidation in the top 30cm, consequently, a second Core D was obtained from an adjacent wetter hollow.

Sampling Methods.

Samples for pollen analysis were collected using a peat borer at a sampling interval of 0.01m. The top 0.015m of each core was not collected as this had been disturbed by ploughing and other farming practices. Drying in the summer months, has led to severe cracking and subsidence of this layer.

Samples of peat were also taken for radiocarbon dating at both sites. At Site 1 peat at depths of 45 - 50cm and 120 - 130cm (the base), were collected. From Site 2, peat was taken at 45 - 50cm and from the base of the peat at 115 - 125cm.

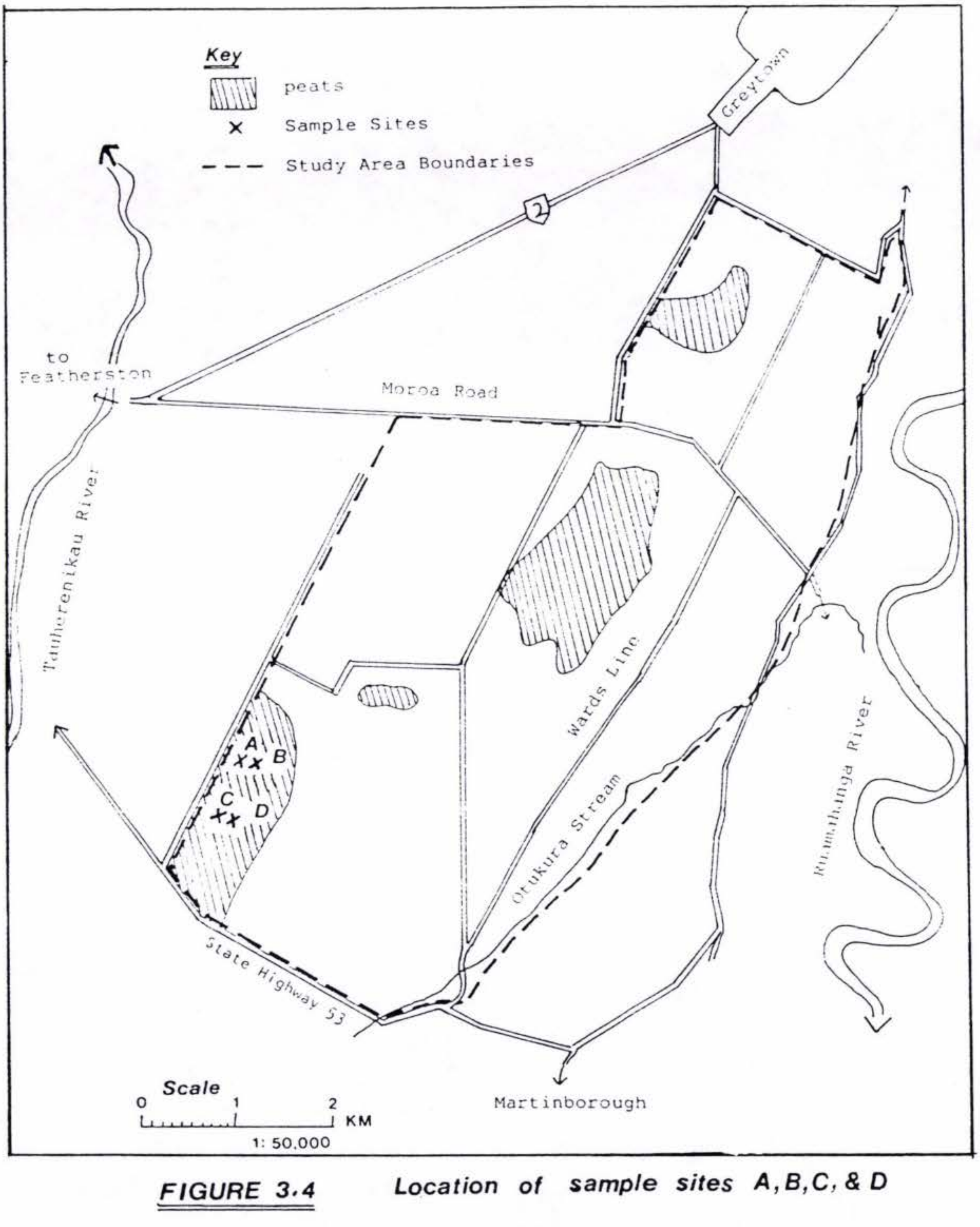


FIGURE 3.4 Location of sample sites A, B, C, & D

Site 1: (A & B)	Grid reference	NZMS 260 106 034
Site 2: (C & D)	———	NZMS 260 107 032

Laboratory Work.

Samples were prepared for pollen analysis by the standard method of Faegri and Inversen (1964). Details of the preparation are outlined in Appendix 2. For each depth, two slides were prepared, the better of the two being used for the pollen count, the other for a scan at a lower magnification to find any pollen taxa not recorded in the initial count. A minimum number of 300 pollen grains were counted on each slide, with most pollen sums being 300 - 400 grains. The presence or absence of charcoal on each slide was also noted.

Further references used in the identification of pollen grains were: McGlone(1978c; 1978d), Pocknall (1981a; 1981b), Moore and Webb (1978).

Presentation of Data.

The pollen taxa recorded are presented as percentages of the total pollen sum on the pollen diagrams. A summary graph of pollen taxa grouped into *Nothofagus*, tree podocarps (including *Dacrycarpus dacrydioides*), woody species, herbaceous, swamp, and, fern and spore components is also presented.

Several pollen taxa are grouped together and described as "type". The "type" name is that of species from the same taxanomic group. The following pollen taxa types are used;

- *Nothofagus fusca* type includes all *Nothofagus* species except *N. menziesii*.
- *Taraxcum* type includes all tribe Cichorieae.
- *Cyathea* type includes *C. smithii*, *C. colensoi*, *C. dealbata*, and *C. medullaris*.
- *Dicksonia* spp. type includes *D. fibrosa*, and *D. squarrosa*.

Where the degradation of pollen grains resulting from excessive battering or corrosion has meant that pollen grains could not be identified to species level, higher taxonomic rankings are used. These occurred mostly in Podocarpaceae and Myrtaceae taxa. If a pollen grain could not be identified due to either severe battering or because reference material was unavalaible the grains were recorded as battered pollen taxa, or unidentified taxa respectively.

Statistical analysis of Data.

The following procedures were adopted to check on consistency of identification and the randomness of pollen counts. Two samples were prepared and analysed in duplicate. In addition, some slides were recounted and compared to the initial information obtained. A total of 300 - 400 grains were counted on each slide, and from these the most common sixteen pollen taxa were compared (table 3.5).

In all samples the variation between each pollen taxon is less than 5%. This variation is acceptable considering the size of the pollen sum (Lees, 1981).

Differences in pollen spectra at various depths were statisically tested to determine if the apparent trends were significant. The statisical equation (Appendix 3) developed by Mosimann (1965) (cited in Moore and Webb, 1978) was used. 95% confidence intervals were used, and any overlap of the intervals calculated indicates that the samples came from the same population (and hence the difference insignificant at that confidence level). Three pollen taxa were selected, *Nothofagus fusca* type, *Dacrydium cupressinum*, and *Podocarpus*.

<u>Table 3.5</u>: <u>Comparison of pollen counts</u>:
(species A - P represent the 16 most common pollen taxa recorded)

A) Same slide counted twice (pollen sum = 380)

species	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	other
1st count	21	78	13	3	19	10	5	76	5	3	13	24	31	16	5	10	48
2nd count	13	80	21	2	16	5	8	80	-	3	18	22	21	20	-	16	45
Difference	8	2	8	1	3	5	3	4	5	0	5	2	10	4	5	6	3

B) duplicate slides (pollen sum = 400)

species	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	other
1st count	33	90	11	13	15	10	5	11	7	44	18	27	16	30	22	8	40
2nd count	27	100	22	10	10	8	5	14	16	48	15	35	18	27	16	5	24
Difference	5	10	11	3	7	2	0	0	9	4	3	8	2	5	5	3	16

C) Duplicate slides (pollen sum = 330)

species	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	other
1st count	27	48	14	18	7	15	10	24	22	8	7	29	11	28	16	14	32
2nd count	21	55	7	14	-	21	14	24	27	7	7	27	19	19	24	18	26
Difference	6	7	7	4	7	6	4	0	5	1	0	2	8	9	8	4	6

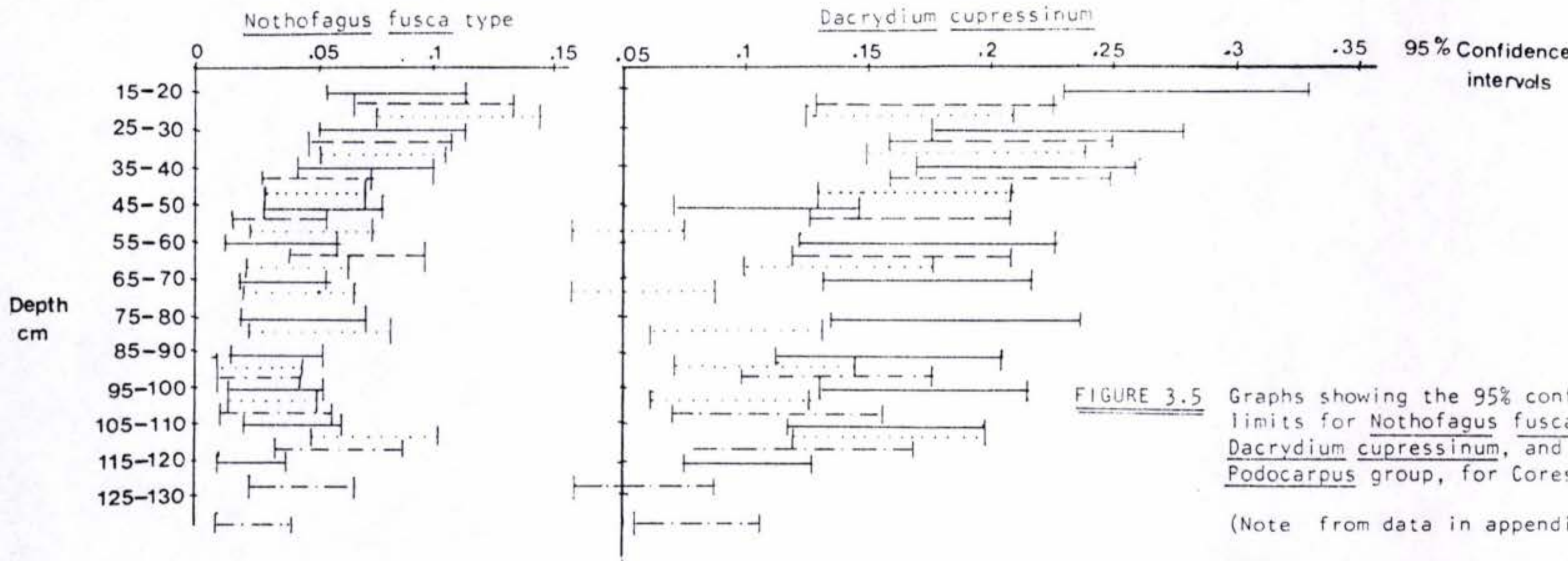
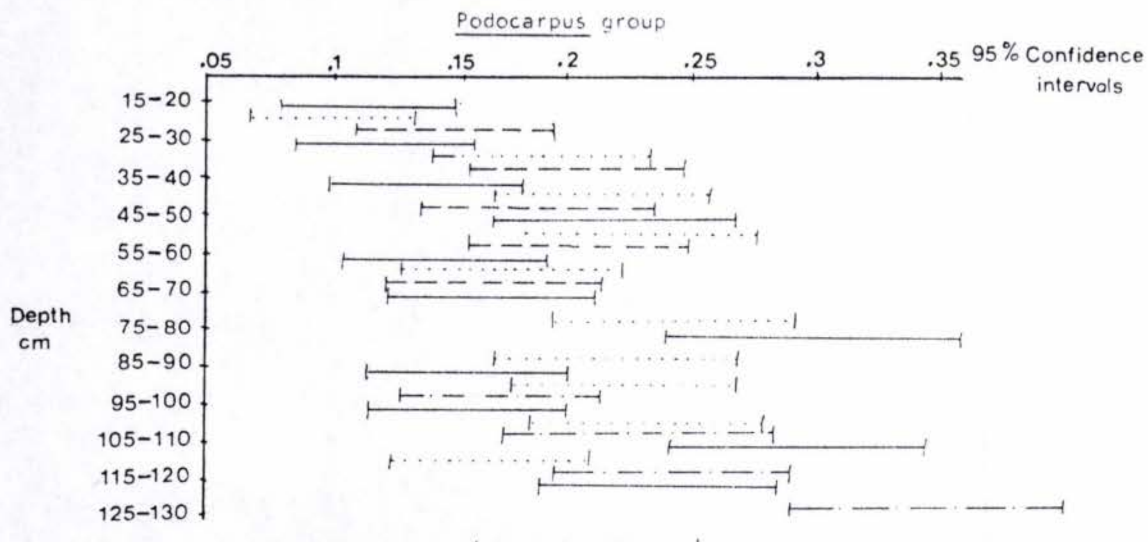
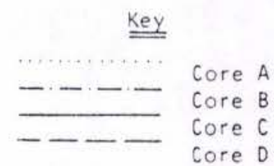


FIGURE 3.5 Graphs showing the 95% confidence limits for Nothofagus fusca type, Dacrydium cupressinum, and Podocarpus group, for Cores A, B, C, D.

(Note from data in appendix 3)





From fig 3.5 it can be seen that the confidence interval for *N. fusca* type from Core A is 0.149 - 0.074 at a 15 - 20cm depth, and is 0.051 - 0.015 at 85 - 90cm. (table 1, Appendix 3). This indicates that there has been a significant increase in pollen of *N. fusca* type at the 95% level over that depth. Unless a very rapid change of vegetation occurs (as might be expected following a heavy ash fall) the 95% confidence limits for consecutive depths could be expected to overlap, as changes to the vegetation are generally gradual, happening over a period of time. The consistency in the conifidence limits between cores also suggests the majority of the samples at corresponding depths originated from similar populations.

3.2.2 ANALYSIS OF DATA.

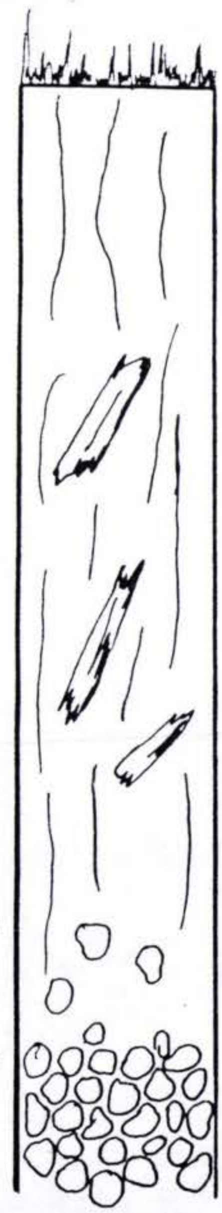
Site One.

The two cores taken at Site 1 consist of Taratahi peat (described in fig 3.6), which overlies gravels. Samples taken for radiocarbon dating at 45 - 50cm were dated at 6350 ± 100 years B.P. (NZ7248A), and at 125 - 130cm, at the base of the peat, 8500 ± 120 years B.P. (NZ7246A).

Core B.

Core B is taken from a depth of 85cm to the base of the peat at 130cm depth. The profile is dominated by the pollen of podocarp (mostly *Dacrydium cupressinum*), *Dacrycarpus dacrydioides*, Myrtaceae and fern spores. *Metrosideros* pollen rises from the base of the profile, to a maximum at 85cm depth. *Nothofagus menziesii* was recorded in all samples.

Figure 3.6: Profile Description of Site One:
(detailed soil description in Appendix 1)
(Grid Reference NZMS260 106 034)



Core A;

Core A shows no great difference in the pollen assemblage of Core B.

The profile (fig 3.7) is dominated by podocarp forest types and associated hardwood taxa. *Dacrycarpus dacrydioides* pollen, with ferns including mostly *Dicksonia*, *Cyathea*, *Phymatodes*, and monolete spores contribute significantly to the sum. Herb and swamp species are consistently low.

Nothofagus fusca type appears throughout the profile, increasing slightly in the top 40cm to 10%. *Nothofagus menziesii* is recorded occasionally nearer the top of the spectrum but not at depth unlike Core B.

Prumnopitys taxifolia and *Podocarpus totara* percentages vary over the profile, but the proportion of podocarp pollen identified to species level is less than 50% of the total podocarp pollen recorded, hence trends at species level are less likely to reflect the population changes. Changes in the *Podocarpus* population are better expressed using the pollen percentages of the Podocarpaceae taxon (podocarp pollen too corroded to be identified to species level) which shows a decline towards the top of the profile.

The most significant changes that occur in the profile are the slow decline of *Dacrycarpus dacrydioides*, and the steady increase of *Dacrydium cupressinum* above 50cm.

There is a great variety of hardwood trees commonly associated with podocarp forest. *Ascarina*, *Syzygium maire*, *Weinmannia*, *Elaeocarpus*, *Pseudopanax*, *Pseudowintera*, and *Nestegis* pollen occur throughout the profile. *Griselinia* and *Freycinetia* pollen are also recorded consistently, although *Freycinetia* percentages decline towards the top of the spectrum. *Astelia* declines very rapidly at 65 - 70cm from being well represented to an occasional occurrence in the top portion of the profile.

Myrtaceae pollen (Note. Mrytaceae "taxon" includes only corroded Myrtaceae pollen not able to be identified to species level) appear to dominate the shrub taxa, (some of this pollen may have come from the lianes, eg. *Metrosideros diffusa*), but decrease nearer the top of the profile. *Myrsine* together with *Leptospermum*, and *Coprosma* decline to low levels above 35 - 40cm. During the same period there is an increase in Gramineae and *Pteridium* as Cyperaceae declines. *Ascarina* percentages increase in the uppermost samples.

Other pollen taxa recorded in the profile include *Muehlenbeckia*, *Compositae*, Malvaceae, *Laurelia*, *Dodonaea*, and *Alectryon*. *Phormium* pollen was noted, and *Typha* appeared occasionally near the top of the profile.

Site Two.

Core C and Core D, sampled from Site two are described in fig 3.8. Both profiles consist of a continuous peat (Taratahi peat) column. Samples taken at 45 - 50cm, and at the base of the peat at 115 - 125cm, were radiocarbon dated at 5700 ± 95 years B.P. (NZ7244A) and 7870 ± 115 years B.P. (NZ7245A) respectively.

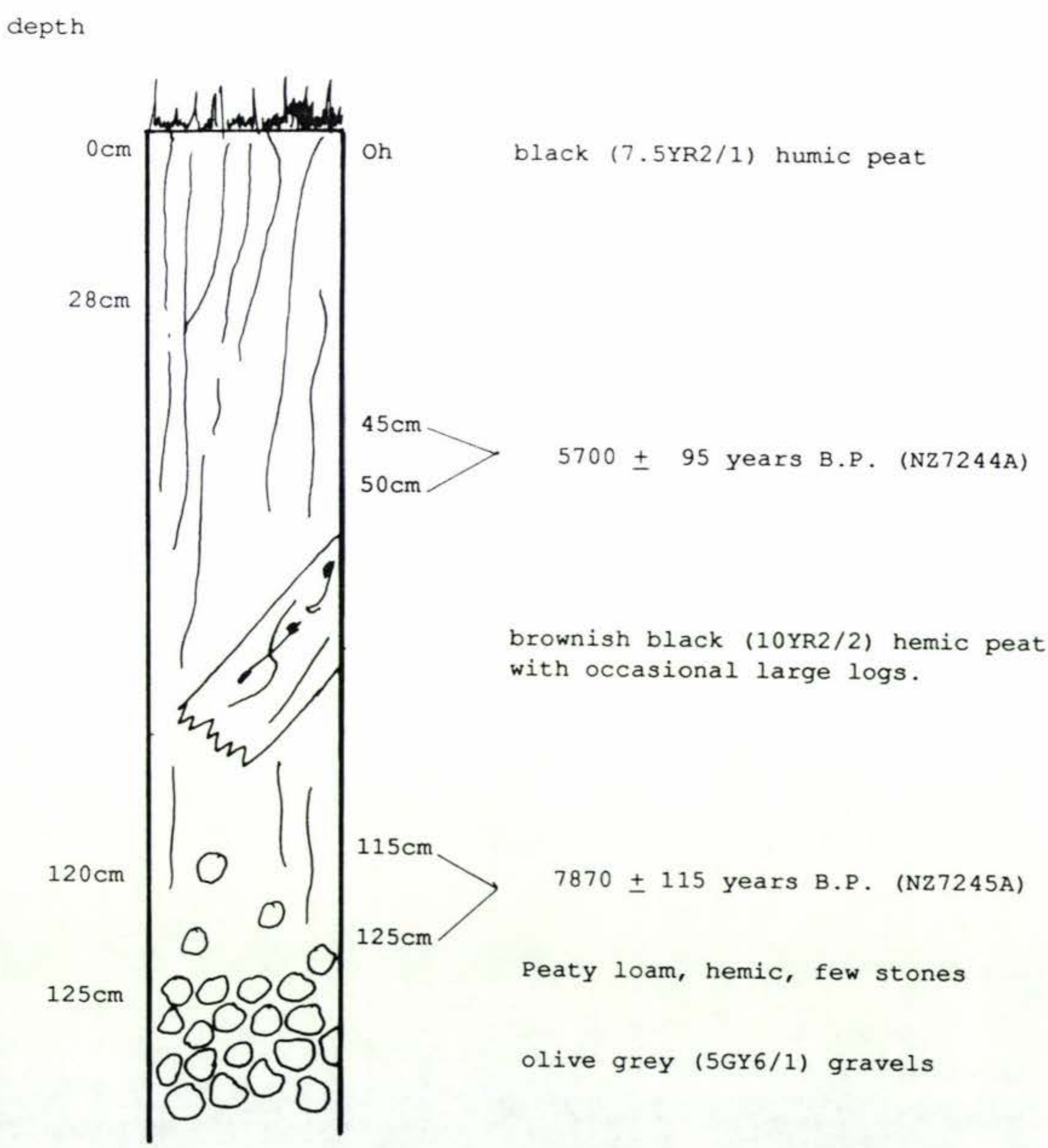
Core C.

Core C (fig 3.9) has a similar pollen spectra to Cores A and B.

The profile is dominated by pollen from podocarp - hardwood taxa, *Dacrycarpus dacrydioides*, and Myrtaceae. *Cyathea*, *Dicksonia*, *Phymatodes*, and monolete fern spores remain relatively high, while herb and swamp pollen have low values throughout the core.

Nothofagus fusca type pollen percentages are low, with a small rise to almost 10% in the top 40cm. *Nothofagus menziesii* pollen is noted throughout the profile in very low frequencies. Podocarpaceae pollen decrease steadily over the spectrum but *Dacrydium cupressinum*

Figure 3.8: Profile Description of Site Two:
(detailed soil description in Appendix 1)
(Grid Reference NZMS260 107 032)



Dacrycarpus dacrydioides pollen fluctuates more in this profile than it does in Core A, but suffers a slight decline in the top 30cm. *Metrosideros* pollen frequences are lower and more consistent in this profile, than in Core A. The Myrtaceae pollen curve is more constant over the spectrum in comparison to Core A, but shows a similar decline in the top sample. These variations are not more than a few percent and could be expected as Cores A and C are about 600 metres apart. The fall of *Leptospermum*, *Coprosma*, and *Myrsine* pollen coincides with a slight rise in Gramineae and *Taraxacum* pollen in the uppermost 20cm. Cyperaceae pollen peaks just below 20cm only to decline again towards the top of the profile.

Sub-canopy species pollen are dominated by *Weinmannia*, *Elaeocarpus*, *Pseudopanax*, *Ascarina*, *Nestegis*, *Syzygium maire*, and *Griselinia*, with *Pseudowintera* and *Quintinia* appearing at a depth of about 70cm. *Freycinetia* and *Astelia* pollen rise to peak at between 100cm and 80cm depth and decline again in the upper samples.

Spores of the tree ferns, *Cyathea*, and *Dicksonia* dominate the fern taxa. High percentages are also recorded for the monolete fern spores and *Phymatodes*. *Pteridium* spores are recorded throughout the profile, but only in very low frequencies. The swamp pollen are dominated by Cyperaceae and possibly *Leptospermum*. *Typha* and *Phormium* pollen occur only in the top samples of the profile.

Pollen degradation and corrosion due to oxidation did not increase to any great extent in the upper part of the core, as was suspected during sampling. It was concluded therefore, that pollen counts from these samples were valid.

Core D.

Core D extends from the surface to a depth of 60cm (fig 3.9), and shows a podocarp hardwood pollen assemblage with high amounts of Myrtaceae and *Dacrycarpus dacrydioides* pollen, much the same as the other three cores. Gramineae, *Taraxacum*, and *Pteridium* pollen values are slightly higher than in the other profiles, but percentages are still low. *Nothofagus fusca* type increases from 5% to over 10% in the top sample. *Dacrydium cupressinum* pollen remains relatively constant, while Podocarpaceae pollen falls to its lowest levels over the same depth. Malvaceae and *Laurelia* pollen are noted throughout the profile.

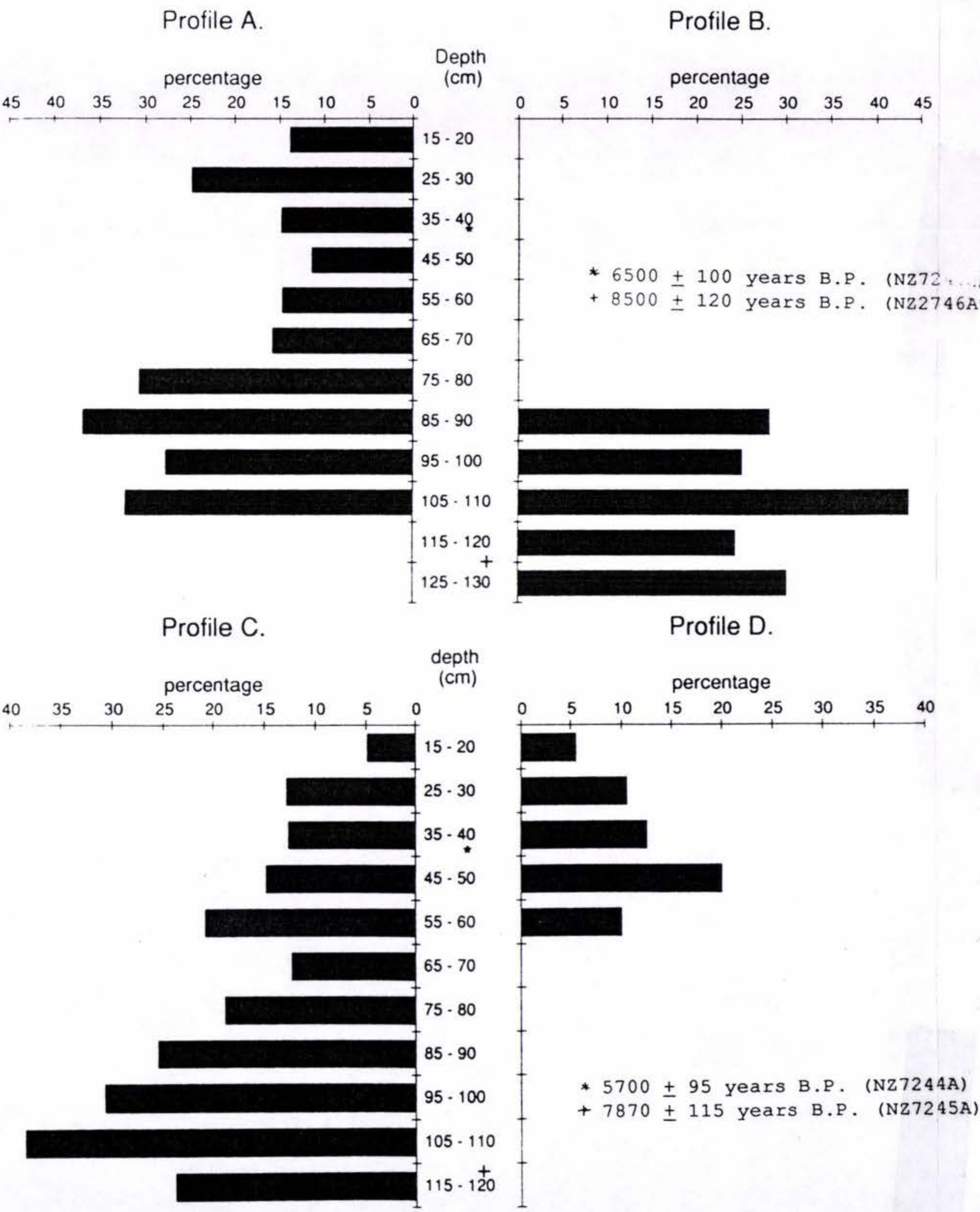
Corrosion of Pollen Grains.

In all cores there were a large number of pollen grains which were too corroded to be confidently identified. The percentage of these pollen was calculated as a percentage of the total pollen sum (fig 3.10). In Cores A and C, the percentages decrease steadily from greater than 30% at the base of the peat to about 15% at 70cm, and then decreases only slowly to approximately 10% near the surface.

The curve in Core D is more variable, averaging about 12%, and the deeper Core B shows a much higher value (25%) of corroded pollen.

The four profiles show a general trend where the occurrence of corroded pollens decreases from a maximum at the base of the profile to about 70cm, where it stabilises at between 5% and 15% in most samples, but again decreases by about 5% in the surface samples. The proportion of corroded Podocarpaceae pollen in the total pollen sum is very high and graphing this taxon shows a curve which declines up the spectrum (figs 3.11 & 3.12). This trend is not expressed in the *Podocarpus* pollen taxa identified to species level (*P. spicatus P. ferrugineus P. totara*). The corroded Podocarpaceae pollen is probably sourced from the ranges. In comparison the *Podocarpus* pollen has probably not been transported far by water, and represents the podocarp population from adjacent forest, not far from the sample sites. Myrtaceae frequencies also decrease in the upper part of figs 3.7 and 3.9, to a lesser extent.

FIGURE 3.10. Graph showing the percentages of total corroded pollen in the pollen samples.



Pocknall (1980) suggested that higher frequencies of corroded *Cyathea smithii* spores from Lady Lake, north Westland, were a result of inwash from exposed stream banks and eroding soils. McGlone (1983) also attributed a high occurrence of corroded pollen to inwash from the catchment around Lake Rotorua. The high percentages of corroded pollen in these profiles does suggest that inwash and water transported pollen have contributed significantly to the pollen spectra.

Subsidence and Accumulation.

The radiocarbon dates from the two sites at each end of the bog show that comparable dates were obtained at similar depths. This would suggest that accumulation was uniform across the bog. Mapping of the peat (fig 2.3) shows that the deposit has accumulated in a smooth depression without any stratigraphic evidence of interruptions in deposition. The profiles show a continuous conformable depth of peaty material, with very little variation in silt or sand components. It appears from these observations, that the bog did not get overwhelmed by flooding or massive erosion during deposition.

Using the radiocarbon dates, peat accumulation rates of 0.28mm/yr for Site 1, and 0.30mm/yr for Site 2 were obtained. These rates were calculated using only the lower part of the profile (ie. the depth of peat between the two known radiocarbon dates) for two reasons; firstly to minimise the effects of shrinkage, more pronounced in the top portion of the profile, and secondly, the upper dates were obtained from a depth of 45 - 50cm, and the age of the surface of the peat is unknown. At both sites the peat has been drained and modified for pastoral development. It was estimated using the exposed root systems

FIGURE 3.11. Graph showing the percentages of *Podocarpus* spp. pollen type (non-corroded pollen grains), and Podocarpaceae pollen (corroded pollen grains), Site One.

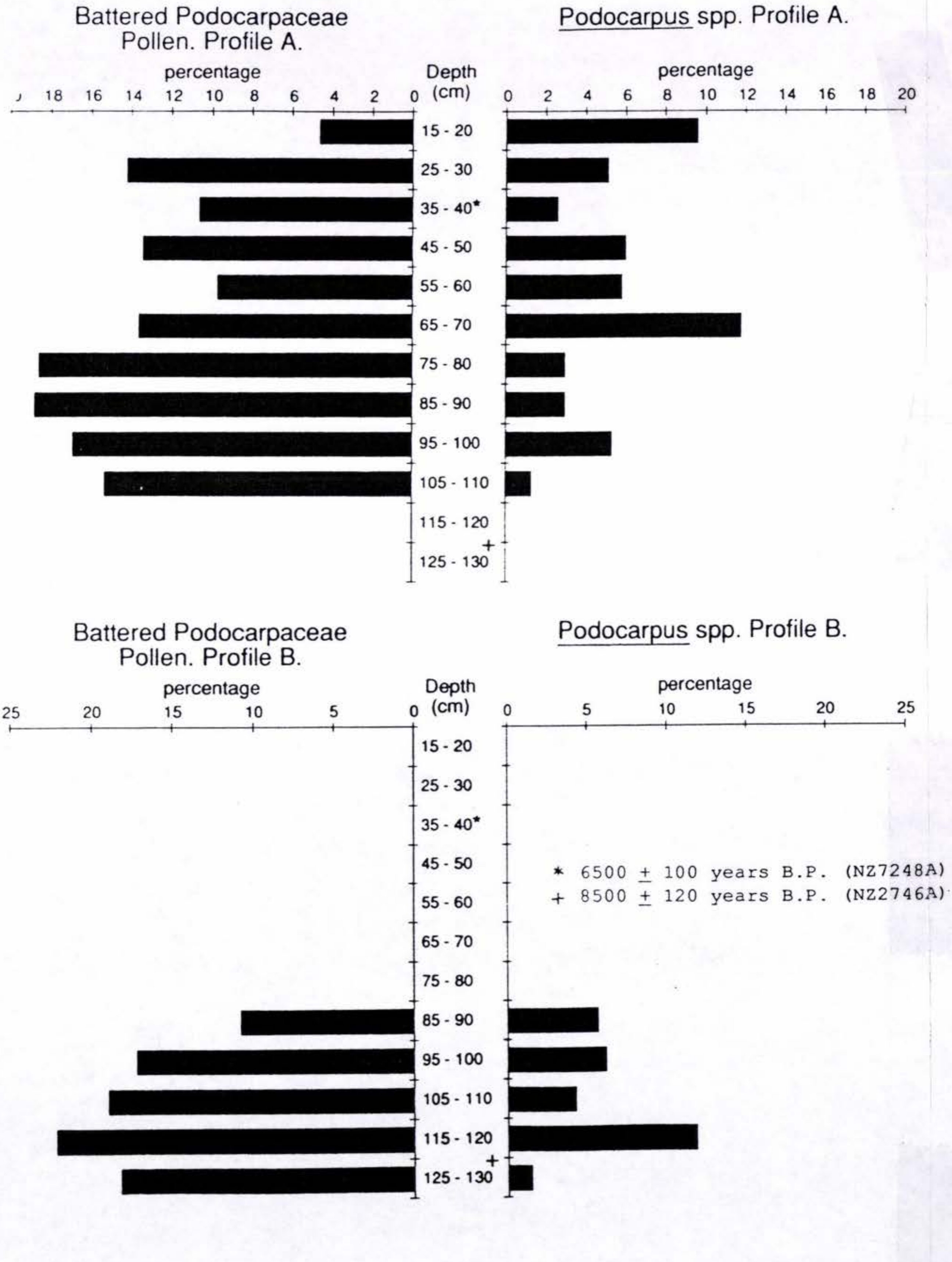
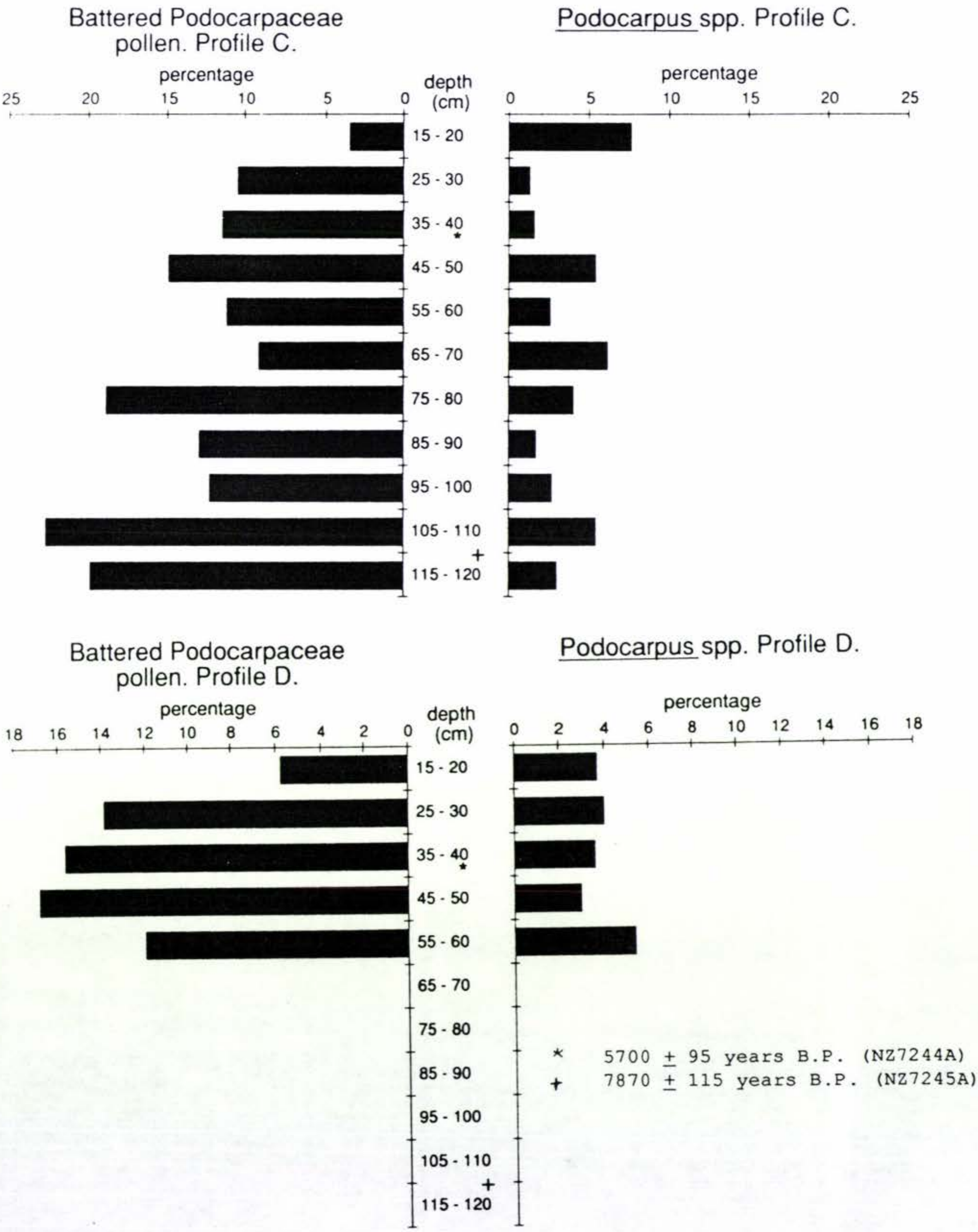


FIGURE 3.12. Graph showing the percentages of *Podocarpus* spp. pollen type (non-corroded pollen grains), and Podocarpaceae pollen (corroded grains), Site Two.



of the remaining *Dacrycarpus dacrydioides* trees, (fig 3.13) that the peat has sunk by up to 1.5m. If a constant rate of accumulation is assumed, then a calculated subsidence of 1.84m has occurred at Site 1, and 1.46m at site 2. It is well known that peaty materials show substantial shrinkage on drying, (Jackson, 1980). Thompson (1980) found peatlands in the Waikato to be sinking an average of 20 mm/yr under grass, and that in the early stages of development subsidence may exceed 200 mm/yr. Bogs in the Whakatane region had sunk 2.5m by 1958 following initial draining 40 years previously (Pullar, 1980).

Wind erosion can result in severe losses when peat is drained and ploughed and allowed to dry out (Hupkens van der Elst, 1980). Ploughing peat surfaces is a common practice in Wairarapa and the loss of peat material may have contributed to the apparent rate of subsidence. Compaction of the surface layers with the use of machinery can also increase surface sinking. A loss caused by subsidence, compaction and erosion of over 1.5m of the pollen record has occured in Cores A, C, and D which emphasises the problems of dealing with peat deposits that have been drained and cultivated.

Using the calculated accumulation rates for the peat, 0.28mm/yr at Site 1, and 0.30mm/yr at Site 2, and the radiocarbon dates, an age of 5500 years B.P. is estimated for the top samples at Site 1, and 4,800 years B.P. for the top samples at Site 2. (Note that the surface of the peat is younger than the ages given above, ie. 5,500 and 4,800 years B.P. as these dates refer to the top samples, taken at 15 - 20cm depth). The surface age is much harder to estimate due to the degree of mixing, cracking and shrinkage that has occurred.

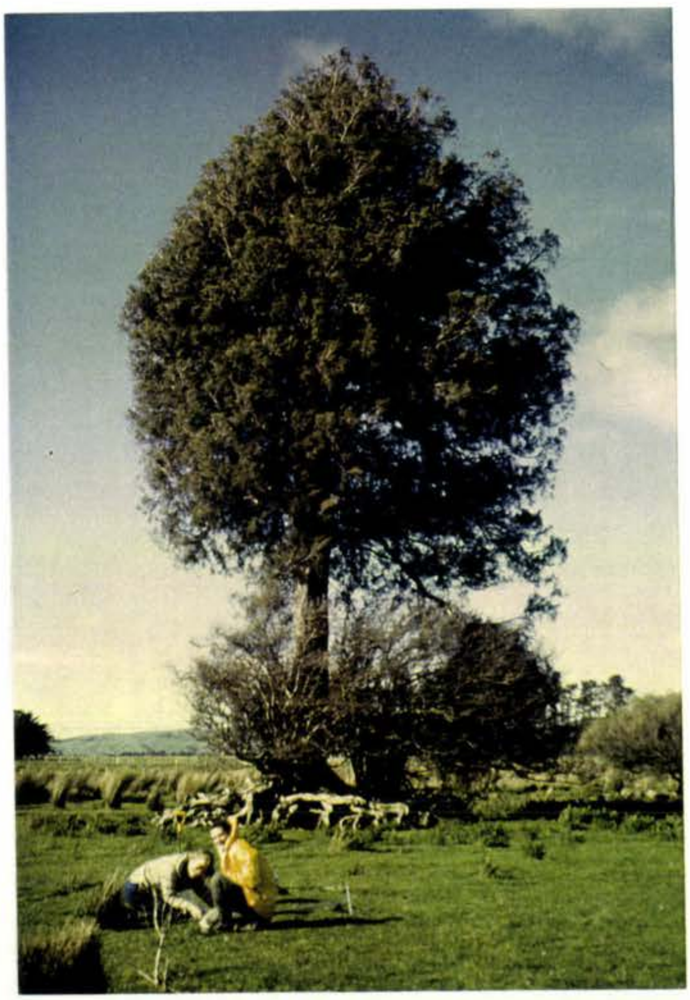


Figure 3.13 Vegetation cover at Site Two. The peat surface has been extensively modified. Improved ryegrass, clover pasture and many rushes cover most of the surface area now. The exposed root systems of the remaining kahikatea trees (*Dacrycarpus dacrydioides*) give an indication of the surface subsidence and erosion that has occurred.

3.2.3 DISCUSSION.

A. Interpretation of Data.

The four profiles analysed provide a continuous record of the vegetation from 8,000 years B.P. to about 5,000 years B.P. The valley was never completely forested during this time, with substantial areas of shrub, herbaceous and swamp vegetation adding to the variation of the local flora. The pollen diagrams analysed did not show a dominance of any one vegetative community over the spectrum but rather a continual representation of herb, swamp, shrub, and forest pollen communities.

The pollen spectrum indicate that a *Dacrydium cupressinum* dominated podocarp-hardwood forest existed over most of the valley between 8,500 years B.P. and 7,500 years B.P. *Dacrycarpus dacrydioides* stands dominated on the wetter sites with small amounts of *Laurelia*.

Mrytaceae, mostly *Metrosideros*, *Syzygium maire*, *Leptospermum*, and *Neomyrtus* were prevalent in the valley. Other prominent subcanopy hardwood species were *Griselinia*, *Eleaocarpus*, *Coprosma*, *Myrsine*, and to a lesser extent *Weinmannia*. *Ascarina*, *Dodonaea*, *Nestegis*, *Pseudopanax*, and *Quintinia* were rarely recorded during this time. Astelia and *Freycinetia* were plentiful. *Cyathea*, *Dicksonia* and monolete fern spore taxa were abundant in the vegetation. *Typha*, *Phormium* and some sedges grew on the bog, but the site was dominated by *D. dacrydioides*. There is no evidence of *Cordyline* in the pollen diagram. This however does not exclude its possible presence, as this pollen taxa is usually under-represented (MacPhail and McQueen, 1983).

Herb taxa appear to have been only a minor constituent of the vegetation around the sites, but may have been more common in drier areas further a field (McGlone, 1982). The spectrum does suggest shrub species dominated the open unforested areas in the valley, but as the bog was surrounded by forest, herb and swamp taxa not around the sample sites may be under-represented in the profile (McGlone, 1982).

The *Nothofagus* curves probably reflect vegetation in the ranges. Myers (1973) and Moar and Myers (1978) showed *Nothofagus* pollen to have travelled 60km from source in the ranges to a pollen trap at Bankside Scientific Reserve (central Canterbury). Similarly, Licitis (1953) found high values of *Nothofagus* pollen in Christchurch which was also sourced from the ranges. Inwashed pollen (ie. more battered pollen; (Pocknall, 1980; McGlone, 1983)) suggest a podocarp-*Dacrydium cupressinum*-*Nothofagus* complex existed on the ranges probably with a large fern, tree-fern and hardwood component. Limited areas of *Nothofagus* were also common in the valley (Leach and Anderson, 1974).

From 7,500 years B.P. to c.5,500 years B.P. there was little change in the composition of the forest, although *Dacrycarpus dacrydioides* frequencies do steadily decline. *Neomyrtus* declined to stay at much lower levels while *Ascarina*, *Weinmannia*, *Dodonaea*, *Nestegis*, *Pseudopanax*, *Pseudowintera*, and *Carpodetus* levels rose. Gramineae *Phymatodes*, and *Pteridium* levels increased indicating perhaps an opening of the forest vegetation.

The most important changes in the pollen spectrum occur after c.5,500 years B.P. (and before c.4,800 years B.P.). An increase in the dominance of *Dacrydium cupressinum* from approximately 15% to 25% occurs while other podocarp pollen frequences decline including *Dacrycarpus dacrydioides* which steadily reduces to less than half the original percentage.

Of the hardwood species, *Ascarina* rises to a peak of 5%, and *Tupeia* and Malvaceae make an appearance in the top samples of cores A, B, and C. *Weinmannia*, *Pseudopanax*, *Pseudowintera*, *Leptospermum*, and *Neomyrtus* drop to their lowest levels, and *Freycinetia*, *Carpodetus*, and *Astelia* disappear altogether.

The steady decline of *D. dacrydioides* with respect to *D. cupressinum* is likely to be a result of local drying around the edges of the bog, allowing *D. cupressinum* to colonise. Drying of the sites could also explain the disappearance of *Astelia* and the decline of Cyperaceae, species both preferring moister conditions. Gramineae and

Pteridium rise considerably but never to substantial percentages. Cyperaceae do peak during this period, but decline again soon afterwards.

Nothofagus pollen rises consistently to peak in the top samples. This steady rise of *Nothofagus fusca* type pollen at the probable expense of the podocarps after about 5,000 years B.P. is likely to reflect an increase in the species over the ranges, substantiated in work by Moar (1956; 1967; 1961) and Lees (1986) in the northern and southern Ruahine Ranges respectively (see section 3.1.2).

The apparent scarcity of herbaceous pollens in all the cores may reflect the high pollen production of the podocarp and *Dacrydium cupressinum* forest adjacent to the sites. (This is the probable reason for the same under-representation at Turakirae Head (Mildenhall and Moore, 1983).

The herb spectra is dominated by Cyperaceae (sedges) and Gramineae. However, the poor representation of these and other herbaceous species like the flaxes (predominantly *Phormium*) is well documented (MacPhail and McQueen, 1983; Pocknall, 1977), and the species were probably common in the wetter areas.

An age of 5,500 - 4,800 years B.P. was obtained for the peat in the top of the sampled profiles using the accumulation rates from both sites. The fact that no *Pinus* type pollen or other exotic tree pollen occur in the upper samples does suggest that the surface of the peat is not modern. Whether the top of the peat has been lost to erosion, or that the peat ceased accumulating before modern times is unknown. A combination of both these explanations, subsidence, and mixing is the most likely reason for the older age of the present surface of the peat deposit. (The present surface of the peat has an estimated age of between 4,200 and 4960 years B.P. because the top samples of the pollen profiles are at a depth of 15 - 20cm)

McGlone and Topping (1977) suggest *Ascarina* was abundant in forests in the west of both the North and South Islands between 10,000 and 5,000 years B.P. but has declined markedly since that time. If it is assumed that the top of the cores are about 5,000 years B.P., then the marked rise of *Ascarina* at a depth of 25 - 30cm indicates an increase in the species between 6,000 and 5,000 years B.P. This trend is then in keeping with McGlone and Topping (1977) and other pollen work in the North Island.

This study provides no record of the vegetation history in Wairarapa Valley after c.5,000 years B.P. Leach and Anderson (1974) suggest that during the last 4,000 years B.P. there was much continuity in the forest type in the valley. They base their assumption on the presence of podocarp floral components in estuarine sediments, and relict podocarp stands in the area today.

Early European records imply a vegetation cover with considerably more open scrub and grassland than the pollen spectrum infers. There are no known accurate descriptions of pre-Polynesian vegetation in the valley (Bagnall, 1974; Hill, 1962; 1963) and hence the effect of the Polynesians on the vegetation may be under emphasised. The pollen spectrum does indicate that the site of the peat samples was surrounded by quite dense forest. This would mean the herb pollen taxa are likely to be very poorly represented in the pollen record (McGlone, 1982), and hence interpretation of the record may under-emphasise the herb and shrub component in the area.

Taraxacum occurs throughtout the profile. All native members of the tribe Cichorieae to which it belongs, are found either in montane-subalpine or coastal areas, and are of very limited distribution. *Taraxacum* spp. is not found in the Ruahine or Tararua Ranges today (pers. com. Cynthia Lees, 1986). The continual appearance of this pollen taxa in the spectra would suggest that it is an exotic species, (thistles are common in the area) indicating a strong possibility of contamination. Farming practices have caused cracking in the top 50cm of the peat and modern pollen may have worked down the profile to quite substantial depths. The absence of other exotic species other than pasture pollens does appear anomolous. Local vegetation consists of pasture and seasonal thistles, with few *Dacrycarpus dacrydioides* trees. Trampling and stock movement may have helped these pollen types to work down the profile.

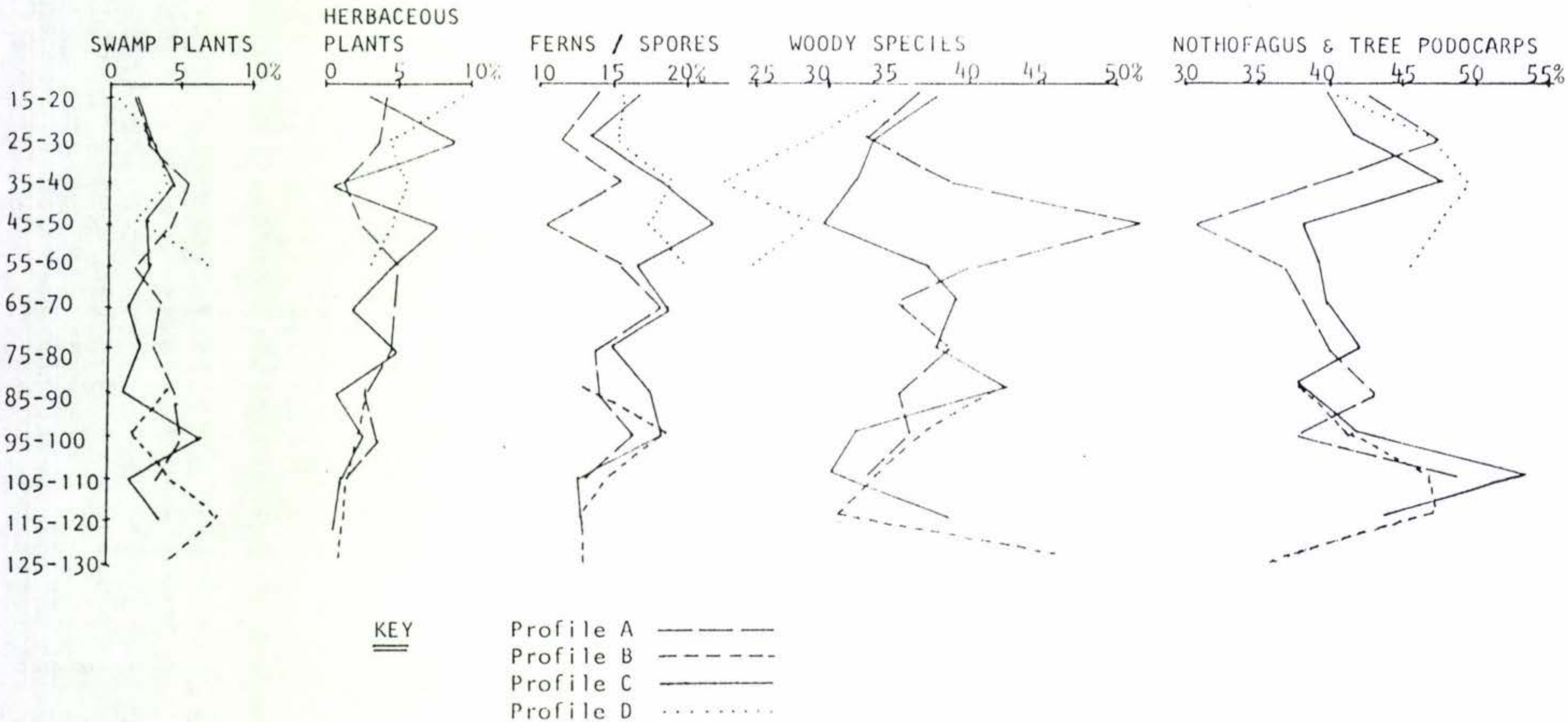
Nevertheless, the trends in the spectra of the four cores sampled, indicate a sequential deposition of pollen taxa showing significant trends (fig 3.5), and without ambiguous pollen trends existing between profiles.

B. Climatic Changes.

At the base of the profile, c.8,500 years B.P. *Dacrydium cupressinum* and the podocarp pollen types were at their lowest levels (fig. 3.14). The woody species (defined in Appendix 4) were more prevalent in the forest at this time. Soon after c.8,500 years B.P. the podocarps became more widespread as the proportion of woody taxa declined (fig 3.15). There was much inwash of pollen to the profile during this time (fig 3.10). These trends probably indicate a wetter climate than present.

By about 6,500 years B.P. *Dacrydium cupressinum* was begining to spread. The appearance of *Nestegis, Alectryon, Knightia* and *Quintinia*, and the rise of *Laurelia, Eleaocarpus, Griselinia, Ascarina, Pseudopanax*, and other species all preferring milder conditions suggests a climatic improvement. *Freycinetia*, and *Astelia* thrived during this time. The continued steady decline of battered pollen frequencies would also suggest the climate was gradually improving.

FIGURE 3.14 Graphs showing trends in vegetation types in the profiles, A, B, C, D.



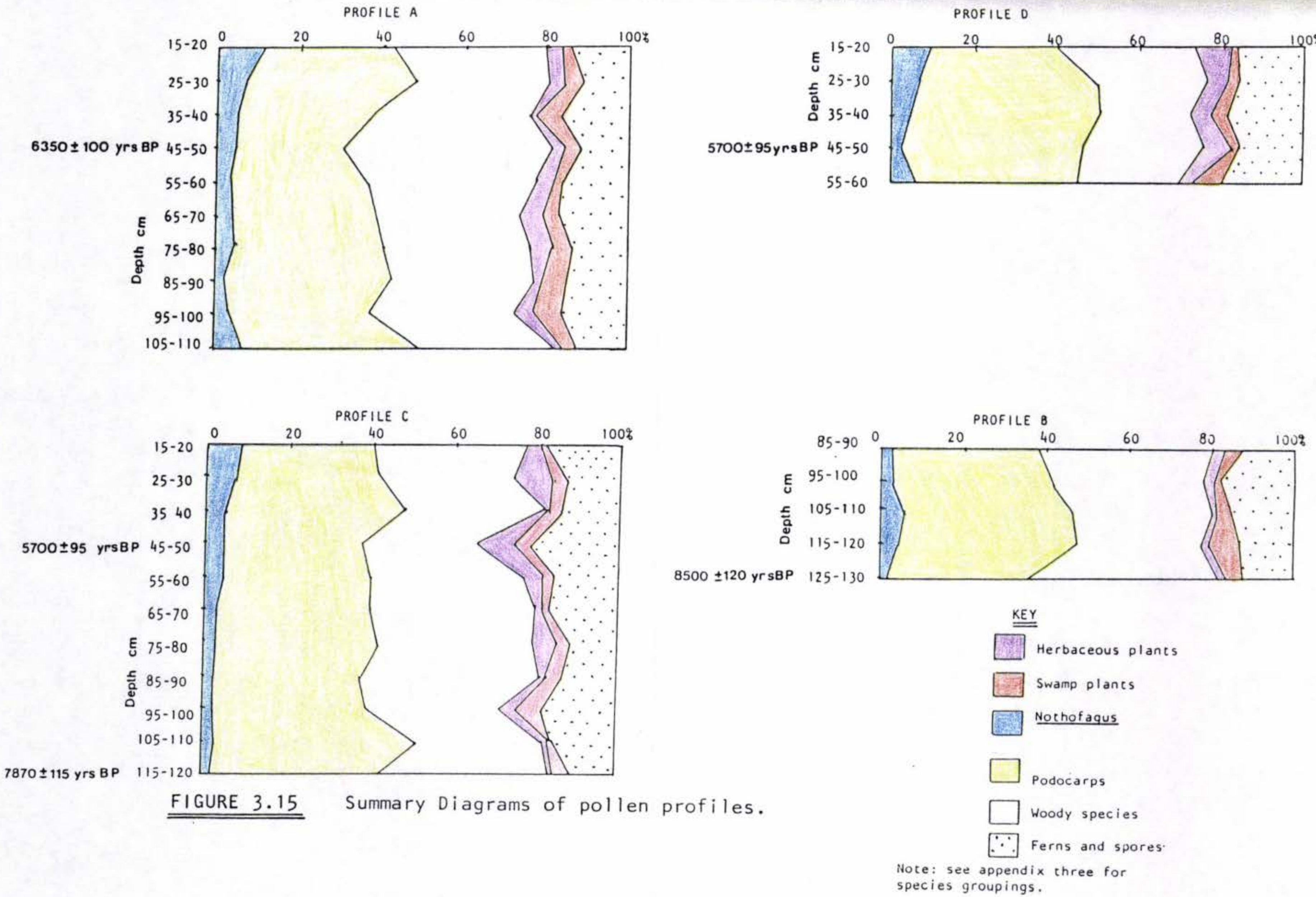


FIGURE 3.15 Summary Diagrams of pollen profiles.

From about 5,500 years B.P. conditions appeared to deteriorate slightly. Moisture loving plants such as *Freycinetia*, and *Astelia* decline markedly. Charcoal fragments are recorded frequently during this period with *Pteridium* and Gramineae reaching more significant levels. The proportion of battered pollens becomes more consistent, but at a much lower level signifying possible stabilisation of climatic conditions. *Ascarina* peaks during this time. Climatic conditions were probably drier and cooler but not necessarily frostier. The decline of *Dacrycarpus dacrydioides* and Cyperaceae supports the suggestion that conditions became drier. This trend may have been in part caused by the retreat of the sea from lower Wairarapa Valley after 6,500 years B.P. and hence the subsequent gradual drying of the bog.

The fact that the bog was begining to dry out by 5,500 years B.P. suggests that the peat accumulation ceased soon afterwards.

fter 5,000 years B.P. a climatic deterioration may have caused the rise in *Nothofagus fusca* type pollen at the expense of the podocarps. Alternatively, this trend may be the effect of a delayed expansion of the beech due to the slow migrating character of the species (Nicholls, 1963; Wardle, 1963; McGlone, 1985; Lees, 1986; Moar, 1961; 1967) rather than an indication of climatic changes. Work by others (ref. North Island section 3.1.2) gives evidence for a climatic deterioration after approx. 5,000 years B.P. If climatic conditions were harsher over this time, then there would have been less competition for the *Nothofagus* forest, and its spread would have been enhanced.

3.2.4 CONCLUSIONS.

It is evident that there has been some contamination involving modern pollen in samples to a depth of approximately 1m in all cores analysed. Significant and comparable trends are however expressed in the pollen spectra of the four cores studied.

The pollen spectrum provides a continuous record of Holocene vegetation history fron 8,500 to c. 5,000 years B.P. Over the period of peat accumulation there were no dramatic changes in the vegetation of the valley. This lack of any major change in vegetation is also illustated in the samples taken from Turakirae Head, where from c.7,000 years B.P., to the top of the profile at c.5,000 years B.P. a podocarp-hardwood forest existed (Mildenhall and Moore, 1983).

There is a rise in *Nothofagus* as the podocarps decline after 5,000 years B.P. *Ascarina lucida*, occuring throughout the profile increases markedly at c.5,500 years B.P. A high frequency of battered pollens at 8,500 years B.P. infers a high proportion of inwashed pollen in the deeper samples, and hence the likelihood of wetter climatic conditions which gradually improve.

These changes in the pollen spectra suggest climatic fluctuations which further support McGlone and Topping's (1977) post-glacial pollen zones.

The steady decline of the *Dacrydium dacrydoides* with respect to *Dacrydium cupressinum* between 5,000 years B.P. and 6,000 years B.P. is likely to be a result of local drying allowing *D. cupressinum* to colonise the edges of the bog. Fluctuations in pollen percentages are not of sufficient magnitude to justify the use of pollen zones in this study.

CHAPTER FOUR

DISCUSSION AND CONCLUDING COMMENTS.

4.1 DISCUSSION

The late Quaternary history of Wairarapa Valley has been reviewed by various authors (see section 1.3.3). It was believed that at the time of the Holocene high sea level (c.6,500 years B.P.) the southern Wairarapa Valley to within 5km of Greytown was an estuary (Palmer, 1982). He further suggested that the gravels of the central valley are less characteristically marine than those on the more exposed coast, and are identified from their form and setting rather than their character.

The pattern of alluvial deposits mapped in this study show that a fluvial flood plain environment existed in the area after the deposition of the Waiohine Surface which ceased accumulating c.10,000 years B.P.. The evidence does not eliminate the possibility of estuarine conditions existing prior to the fluvial activity, although it is unlikely. Estuarine sediments could well have been reworked to form the present pattern of flood plain deposits, but there is no record of estuarine vegetation after 8,500 years B.P..

The Waiohine Surface is believed to be 10,000 years B.P. (Palmer, 1982). If the area was engulfed in an estuary it could only have been for a short period between 10,000 years B.P. and c.8,500 years B.P., the date when peat first started accumulating in the area. The Holocene high sea level is recorded at c.6,500 years B.P. so it is unlikely that estuarine conditions could have prevailed in the area during the Holocene. Furthermore, the Holocene high sea level bench can be traced inland from Pirinoa, around Wairarapa Valley only as far as the northern shore of Lake Wairarapa. It may be that the c.6,500 years B.P. Holocene high sea level did not encroach much further than this.

During the early Holocene, before c.8,500 years B.P. but following the formation of the Waiohine Surface (10,000 years B.P.) the area was being infilled with aggradational gravels and sands as the Waiohine River and probably Ruamahanga River traversed the area. The lateral similarity of the Holocene alluvial deposits and profile features suggests that deposition occured in one episode and hence there is no significant age difference in these deposits. Reworking of the Waoihine Surface gravels, at the contact with the Holocene deposits probably occurred during this time. It is unlikely that the Tauherenikau River encroached into the study area as the alluvial deposits throughout the survey have a northwest - southeast trend (fig 2.2). Nowhere do the Holocene deposits show either a west - southeast, or west - east trend as they would do if deposited by the Tauherenikau River.

Although Ghani (1978) infers that uplift in the central valley could range down to zero (section 1.3.2), he calculated an uplift rate of 1.1m/yr for Bidwill Hill anticline. The topography in the study area does suggest that small rising anticlines do exist in the valley. Along with Te Maire Ridge, Hiwirau Ridge, and the smaller loess covered ridge in the central part of the survey (fig 2.2), there are anticlinal ridges rising from the Holocene alluvial surfaces in the area which are larger than could be expected from an alluvial feature on the former flood plain. These growing structural features may have forced the course of the Waiohine River to the west so it then joined the Ruamahanga River, flowing down the eastern side of Te Maire Ridge. Similarily the Ruamahanga was pushed east of Te Maire Ridge, and alluvial deposition ceased over much of the area. Continued uplift has prevented the river courses reverting back and flowing through the area.

Uplift may not have been the sole cause for the abandonment of the area by the rivers however. Sea level was rising during this time, and saline waters encroached at least as far as the northern end of Lake Wairarapa (Leach and Anderson, 1974). The equilibrium and base levels of the rivers in the valley may have been effected by the rising sea level, and in order to maintain an equilibrium gradient, river courses could have altered. This effect, combined with the tectonic interference are most likely to have been the major factors resulting in the abandonment of the area by the Waiohine, and possibily Ruamahanga Rivers.

The question must then be raised as to why the peat deposits began accumulating in the area? The pollen record, and early settlers accounts of vegetation describe a landscape which was never completely forested. Grasslands, sedge and flax swamps, and forested areas existed in the valley. While sea level was rising the water table in the area would have been higher and without a major drainage outlet, the study area was very wet and swampy. Rising anticlines further hindered drainage in the area. Depressions and hollows in the landscape became swampy and peaty material accumulated.

Since peat deposition, much shrinkage and loss of surface peat layers has occured in the area. The existence of thin peaty surface layers (Maunui silt loam, peaty topsoil phase) found in areas away from the main peat deposits is evidence that peaty materials and deposits were much more extensive than the present occurance would suggest. Drainage and pastoral development has eliminated much of these thinner peaty surface layers.

The fact that there is no indication of peaty material on the small alluvial covered anticlinal ridges in the area may further support the sugestion that tectonic activity hindered drainage in the area, thereby promoting peat deposition. These ridges however are relatively well drained, and the preservation of thin peaty topsoils if they existed would be very unlikely

As suggested in section 2.2.4, the peat deposits are continuous, and have infilled smooth concave depressions. The lack of any apparent succession of colonising flora to stable forest communities in the pollen record, as might be expected if the area was an actively accumulating flood plain at the time of peat accumulation is further evidence that the Waiohine River was no longer depositing sediments in the area when peat accumulation began. The continuous nature of the peat deposits and absence of silty or sandy layers within the peat suggests that the process of peat accumulation was continual and uninterrupted by sudden influxes of sediment or debris from flood episodes. Their also are no apparent discontinuities in the pollen record.

Trends in the corroded pollen percentages (fig 3.10) suggest that at c.8,500 years B.P. the inwash of pollen most likely from the ranges was substantial. Wetter climates could be postulated. By about 5,500 years B.P. with the spread of *Dacrydium cupressinum*, and the decrease of *Dacrydium dacrydioides* and Cyperaceae conditions in the valley appear to be drying slightly.

With the Holocene high sea level shoreline retreating post 6,500 years B.P. drainage may well have improved as the water table dropped in the area.

It is not known when the peat ceased accumulating, but the lack of any quantity of European or introduced pollen taxa to the record is good evidence that peat accumulation had stopped well before the arrival of man in the area.

4.2 CONCLUDING COMMENTS.

This thesis is composed of two parts; the first an interpretation of Late Quaternary events from surface geology and soil patterns; the second an investigation using palynological techniques to understand vegetative changes in the lower Wairarapa Valley in the Late Quaternary and how these changes may reflect changing environmental conditions. By combining disaplines, a more comprehensive account is made possible. From the evidence given in this study, it can be concluded that the c.6,500 years B.P. Holocene high sea level shoreline did not advance inland as far as the present study area.

Following the deposition of the Ohakean Waiohine Surface, the area was being infilled with Holocene alluvial sediments. At c.8,500 years B.P. rising anticlinal features in the area pushed the aggrading Waiohine River and possibly the Ruamahanga River to the east preventing further alluvial deposition in the area. Rising sea level at this time may have contributed to the changing river courses.

Drainage was impeded by tectonic uplift and peats began forming in swampy depressions and hollows. During peat accumulation swampy and wet conditions remained prevalent, in this part of valley.

Pollen evidence indicates that after 6,500 years B.P. a slight improvment in conditions allowed the area to drain slightly and the extensive areas of peat began to decline.

Unfortunately, this study provides no record of vegetation changes after c.5,000 years B.P. Remaining relict stands of native vegetation in the area coupled with early written accounts of vegetation do suggest that gradual drying of the peats and swamplands continued until drainage began in the 18th century.

BIBLIOGRAPHY.

BAGNALL A.G. 1954: Masterton's First Hundred Years. publ. Masterton Centennial Committee.

BAGNALL A.G. 1976: Wairarapa; an Historical Excursion. Hedley's Bookshop, (Masterton).

BAGNALL A.G.; PETERSON G.C. 1948: William Colenso. A.H. and A.W. Reed, Wellington. pp 216-386.

BAGNALL R.G. 1975: Vegetation of the raised beaches at Cape Turakirae, Wellington, New Zealand. *New Zealand Journal of Botany 13*: 367-424.

BEVERIDGE A.E. 1980: Regeneration of Podocarp Forest and Maintanence of Productivity. *In* Lowland forests in New Zealand, Proceedings of a symposium held at the University of Waikato, Hamilton.

BIDWILL W.E.; WOODHOUSE A.E. 1927: Bidwill of Pihautea. Coulls, Somerville and Wilkie Ltd, Christchurch: 1-18

BRADLEY R.S. 1985: Quaternary Paleoclimatology: Methods of Paleoclimatic Reconstruction. publ, George Allen and Unwin London.

BURROWS C.J. 1965: Some Disontinuos Distributions of Plants Within New Zealand and their Ecological Significance. *Tuatara 13*: 9-29.

BURROWS C.J. 1978: The Quaternary Ice Ages in New Zealand: A Framework for Biologists. *Mauri Ora* 6: 69-96.

CLAYTON-GREENE K.A. 1977: Structure and origin of *Libocedrus bidwilli* stands in the Waikato District New Zealand.*New Zealand Journal of Botany 15*: 19-28.

CLAYTON-GREENE K.A. 1978: Aspects of the Distribution of Certain Indigneous Woody Species in the Waikato District, New Zealand. *Journal of the Royal Society of New Zealand 8* (3): 283-291.

COCHRANE R. 1977: The Biological Environment. *In* Anderson A.G. (ed) NEW ZEALAND IN MAPS.

COWIE J.D. 1978: Soils of the Kairanga County. *New Zealand Soil Bureau Bulletin 33*

COWIE J.D.; MONEY S.P. 1965: Soils and Horticulture of Greytown District, Wairarapa, New Zealand. *New Zealand Soil Bureau Report 5.*

CRANWELL L.M.; VON POST L. 1936: Post-Pleistocene pollen diagrams from the Southern Hemisphere. I.N.Z. *Geografiska Annaler 3-4*: 308-347.

CREW J.D. 1937: Pahiatua Herald 21 December 1937.

DODSON J.R. 1978: A vegetation history from north-east Nelson, New Zealand. *New Zealand Journal of Botany 16*: 371-8.

ELDER N.L. 1964: Evidence of Climatic Change from the Vegetation of the North Island, *In* The Ecology of the Hutt Valley. *Proceedings of the New Zealand Ecological Society 10*: 45-48.

FAEGRI K.; INVERSION J. 1964: Textbook of Pollen Analysis. Blackwell Scientific Publications Oxford 237 pp.

FOX Sir W. 1843: *Journal of an Expedition to Wairarapa* (sic) ; Ms. Hocken Collection, University of Otago Library.

FRANKLIN D.A. 1965: The Synecology of the Tararua Indigenous Forests. *New Zealand Forest Service Silviculture report 54.*

GHANI M.A. 1974: Late Cenozoic vertical crustal movements in the central part of New Zealand Unpublished Ph.D. Thesis. Victoria University of Wellington.

GHANI M.A. 1978: Late Cenozoic vertical crustal movements in the southern North Island, New Zealand . *New Zealand Journal of Geology and Geophyscis 21* (1): 117-25.

GIBBS H.S.; COWIE J.D. 1975: Interim report on soils of the Wairarapa Valley, New Zealand. *New Zealand Soil Bureau Report 40.*

GIBBS H.S.; COWIE J.D.; WICKENS A.S. 1974: Interim Soil Map of Wairarapa Valley, New Zealand. *New Zealand Soil Bureau, unpublished map.*

GRANT-TAYLOR T.L.; HORNIBROOK N. de B.; EDWARDS A.R.; VELLA P 1979: xcursion Southern Wairarapa - unpublished field guide. New Zealand Geological Survey Staff Conference, Masterton, December 1979.

GRANT-TAYLOR T.L.; RAFTER T.A. 1963: New Zealand Natural Radiocarbon Measurements I - V. *Radiocarbon 5*: 118-162.

GRANT-TAYLOR T.L; RAFTER T.A. 1971: New Zealand radiocarbon measurements 6. *New Zealand Journal of Geology and Geophysics 14 (2)*: 364-402.

GRIFFITHS E. 1975: Classification of land for Irrigation in New Zealand . *New Zealand Soil Bureau Scientific Report 22.*

HARRIS W.F. 1955: Pollen Characteristics in *Nothofagus. New Zealand Journal of Science and Technology 37*: 731-765.

HARRIS W.F. 1958: Pollen Bearing Deposits and Fossil History, in The Ecology of the Hutt Valley. *Proceedings of the New Zealand Ecological Society 6*: 46-58.

HARRIS W.J. 1963: Paleo-Ecological Evidence from Pollen and Spores. *Proceedings of the New Zealand Ecological Society 10*: 38-44.

HEINE J.C. 1975: Interim report on soils of the Wairarapa Valley, New Zealand. *New Zealand Soil Bureau Report 40.*

HICKS S.R.; WOODWARD D.J. 1978: Gravity models of the Wairarapa region, New Zealand. *New Zealand Journal of Geology and Geophyscis 21* (5): 539-544.

HILL R.D. 1962: The Land and the Squatter, Wairarapa 1843 - 1853. An Essay in Human Ecology: MSc Thesis at Victoria University of Wellington.

HILL R.D. 1963: The Vegetation of the Wairarapa in mid-nineteenth century. *Tuatara 11* (2): 83-89.

HUPKENS VAN DER ELST F.C.C. 1980: Development of Peat Soils for Agriculture. *In* Soil Groups of New Zealand Part 4: Organic Soils : 51-71.

JACKSON R.J. 1980: Physical properties of Organic Soils. *In* Soil Groups of New Zealand Part 4: Organic Soils: 46-50.

JOHNSON P.N. 1978: Holocene plant remains from the shores of Lake Manapouri, New Zealand. *New Zealand Journal of Botany 16*: 141-5.

KAMP P.J.; VUCETICH C.G. 1982: Landforms of Wairarapa in a Geological Context. *In* Soons J.M. and Selby M.J. *(ed)* Landforms of New Zealand.

KING L.C. 1930: Raised beaches and other features of the south-east coast of the North Island of New Zealand. *Transactions of New Zealand Institute 61*: 498-523.

KINGMA J.T. 1967: Sheet 12 Wellington. Geological Map of New Zealand 1:250,000. New Zealand Department of Scientific and Industrial Research, Wellington.

LAMBERT R.A. 1970: Pollen Analysis of a Peat Profile from the Hamilton Basin, N.Z. - Preliminary investigations of the history of forest and bog vegetation. Unpubl. M.Ph. Thesis, Univesity of Auckland, New Zealand.

LEACH B.F. 1981: The Prehistory of the Southern Wairarapa. *Journal of the Royal Society of New Zealand 11* (1): 11-33.

LEACH B.F. 1984: The Terminal age for the Lower Wairarapa environment. *Journal of the Royal Society of New Zealand 14* (2): 207-208.

LEACH B.F.; ANDERSON A.J. 1974: The Transformation from an Estuarine to Lacustrine Environment in the Lower Wairarapa. *Journal of the Royal Society of New Zealand 4* (3): 267-275.

LEAMY M.L.; FIELDS M. 1976: Soils and Land Classification and use. *In* Wards I. *(ed)* New Zealand Atlas.

LEES C.M. 1981: Some Aranuian (post-glacial) Organic Deposits in the South Eastern Ruahine Range, North Island, New Zealand , Investigated by Palynological Methods. Unpubl. M.Ph. Massey University, Palmerston North, New Zealand .

LEES C.M. 1986: Late Quaternary palynology of the southern Ruahine Range North Island, New Zealand. *New Zealand Journal of Botany 24*: 315-329.

LICITIS R. 1953: Air-borne Pollen and Spores sampled at five New Zealand stations, 1951-52. *New Zealand Journal of Science and Technology 34B*: 289-316.

LINTOTT W.H.; BURROWS C.J. 1973: A Pollen Diagram and Macrofossils from Kettlehole Bog Cass, South Island, New Zealand. *New Zealand Journal of Botany 11*: 269-82.

MILDENHALL D.C. 1980: Holocene pollen diagrams from Pauatahanui Inlet, Porirua, New Zealand . *New Zealand Journal of Geology and Geophyscis 22* (5): 585-91.

MILDENHALL D.C.; MOORE P.R. 1983: A Late Holocene pollen sequence at Turakirae Head, and climatic and vegetational changes in the Wellington area in the last 10,000 years. *New Zealand Journal of Science 26*: 447-459.

MILNE J.D.G.; SMALLEY I.J. 1979: Loess deposits in the southern part of the North Island of New Zealand: an outline stratigraphy. *Acta Geological Academiae Scientiarum Hungaricae* 22: 197-204.

MOAR N.T. 1954: Peat Profiles Whareroa Block, Paekakariki, New Zealand. *New Zealand Journal of Science and Technology 36A*: 221-231.

MOAR N.T. 1956: Peat on Mokai Patea, Ruahine Range, North Island, New Zealand. *New Zealand Journal of Science and Technology 37A*: 419-426.

MOAR N.T. 1959: Contributions to the Quaternary History of the New Zealand Flora 3. Pollen Analysis of a Peat Profile from Antipodes Island. *New Zealand Journal of Science 2*: 35-40.

MOAR N.T. 1961: Contributions to the Quaternary History of the New Zealand Flora 4. Pollen Diagrams from the Western Ruahine Ranges.*New Zealand Journal of Science 4*: 350-9.

MOAR N.T. 1967: Contributions to the Quaternary History of the Flora of New Zealand 5. Pollen Diagrams from No Man's Land Bog, Northern Ruahine Range. *New Zealand Journal of Botany 5* (3): 394-9.

MOAR N.T. 1970: Recent Pollen Spectra from Three Localities in the South Island, New Zealand. *New Zealand Journal of Botany 8*: 210-21.

MOAR N.T. 1970b: A New Pollen Diagram from Pyramid Valley Swamp. Rec. Canterbury Museum VIII (5)NM»: 455-461.

MOAR N.T. 1971: Contributions to the Quaternary History of the New Zealand Flora 6. Aranuian Pollen Diagrams from Canterbury, Nelson, and North Westland, South Island. *New Zealand Journal of Botany 9*: 80-145.

MOAR N.T. 1973: Contributions to the Quaternary History of the New Zealand Flora 7. Two Aranuian Pollen Diagrams from Central South Island. *New Zealand Journal of Botany 11*: 291-304.

MOAR N.T. ; SUGGATE R.P. 1973: Pollen Analysis of Late Otiran and Aranuian sediments at Blue Spur Road (S51), North Westland. *New Zealand Journal of Geology and Geophyscis 16*(3): 333-344.

sp

MOAR N.T.; MYERS J.V. 1978: A Note on pollen dispersal in Canterbury, New Zealand. *New Zealand Journal of Botany 16*: 413-415.

MOLLOY B.P.J. 1969: Evidence for post-glacial climatic changes in New Zealand. *Journal of Hydrology 8*: 56-67.

MOORE P.D.; WEBB J.A. 1978: An illustrated guide to Pollen Analysis. Hodder and Stoughton, London.

MOORE P.J.; OGLE C.C.; MOYNIHAN K.T. 1984: Habitat Requirements of Wetland Birds in the Lake Wairarapa Wetlands. *New Zealand Wildlife Service 1984*.

MOSIMANN J.E. 1965: Statistical methods for the Pollen Analyst: Multinomial and negative multinomial techniques. *In* Handbook of Paleotological techniques. Kummel B., Raup D. *(eds)* W. H. Freeman and Company.

MYERS J.V. 1973: A Note on the Dispersal of *Nothofagus* Pollen in Canterbury, New Zealand . *New Zealand Journal of Botany 11*: 311-6.

MacPHAIL .K. 1980: Fossil and modern *Beilschmiedia* (Lauraceae) pollen in New Zealand. *New Zealand Journal of Botany 18*: 453-457.

MacPHAIL M. K.; McQUEEN D.R. 1983: The value of New Zealand pollen and spores as indicators of Cenozoic vegetation and climates. *Tuatara 26 (2)*: 37-59.

McGLONE M.S. 1978a: Forest Destruction by Early Polynesians, Lake Poukawa, Hawkes Bay, New Zealand. *Journal of Royal Society of New Zealand 8* (3): 275-281.

McGLONE M.S. 1978b: Pollen analysis, Waingaehe Stream overflow channel, Holden's Bay, Rotorua. *In* Appendix 1 of Kennedy N.M., Pullar W.A., Pain C.F. Late Quaternary land surfaces and geomorphic changes in the Rotorua Basin, North Island, New Zealand. *New Zealand Journal of Science 21*: 249-64.

McGLONE M.S. 1978c: Pollen structure of the New Zealand members of the Styphelieae (Epacridaceae). *New Zealand Journal of Botany 16*: 91-101.

McGLONE M.S. 1978d: Pollen wall structure of the New Zealand species of *Epacris* (Eparcridaceae). *New Zealand Journal of Botany 16:* 83-89.

McGLONE M.S. 1980a: The History of New Zealand lowland forest since the last glaciation. *In* Lowland forests in New Zealand, Proceedings of a symposium held at the University or Waikato, Hamilton, 27-28 May 1980. Edited by Thompson K., Hodder A.P.H., Edmonds A.S.

McGLONE M.S. 1980b: Post-Glacial Vegetation Change in Coastal Southland. *New Zealand Journal of Ecology* 3: 153-54.

McGLONE M.S. 1982: Modern pollen rain, Egmont National Park, New Zealand .*New Zealand Journal of Botany 20*: 253-262.

McGLONE M.S. 1983: Holocene pollen diagrams, Lake Rotorua, North Island, New Zealand . *Joural of the Royal Society of New Zealand* 13 (1/2): 53-65.

McGLONE M.S. 1985: Plant Biogeography and the late Cenozoic history of New Zealand. *New Zealand Journal of Botany 23*: 723-749

McGLONE M.S.; MOAR N.T. 1977: The Ascarina decline and post-glacial climatic change in New Zealand. *New Zealand Journal of Botany 15*: 485-9.

McGLONE M.S.; NELSON C.S.; HUME T.M. 1978: Palynology, Age and Environmental Signifcance of some beds in the Upper Pleistocene Hinuera Formation South Auckland, New Zealand. *New Zealand Journal of Botany 15*: 749-760.

McGLONE M.S.; NELSON S.C.; TODD A.J. 1984: Vegetation history and environmental significance of pre-peat and surficial peat deposits at Ohinewai, Lower Waikato lowland. *Journal of the Royal Society of New Zealand 14* (3): 233-244.

McGLONE M.S.; TOPPING W.W. 1977: Aranuian (post-glacial) pollen diagrams from the Tongariro region, North Island, New Zealand. *New Zealand Journal of Botany 15:* 749-60.

McGLONE M.S.; TOPPING W.W. 1983: Late Quaternary vegetation, Tongariro region, central North Island, New Zealand . *New Zealand Journal of Botany 21*: 53-76.

McINTYRE D.J. 1970: Pollen Analysis from the Lindale Section Paraparaumu. *In* Appendix 1: Radiocarbon Dating and Pollen Analysis from Otiran Periglacial Fans in Western Wellington, Fleming C.A. *Transactions of the Royal Society of New Zealand: Earth Sciences* 7 (11): 197-208.

McINTYRE D.J.; McKELLAR I.C. 1970: A Radiocarbon dated Post-Glacial Pollen Profile from Swampy Hill, Dunedin, New Zealand . *New Zealand Journal of Geology and Geophyscis 13*: 346-9.

NICHOLLS J.L. 1963: Vulcanicity and indigenuous vegetation in the Rotorua District. *Proceedings of the New Zealand Ecological Society 10*: 58-65

New Zealand Forest Service 1977: Tararua State Forest Park Draft Management Plan 1977 - 1987.

New Zealand Meteorological Service 1973: Rainfall Normals for New Zealand 1941 to 1970. *New Zealand Meteorological Service Misc. Publication 145.*

New Zealand Meteorological Service 1983: Part 1: Climatological Stations Climatic Map Series 1:2,000,000. *New Zealand Meteorological Service Misc. Publication 175.*

New Zealand Meteorological Service 1983: Temperature Normals 1951 to 1980. *New Zealand Meteological Service Misc Publication 183.*

OGLE C.C.; MOSS T.C. 1984: Lake Wairarapa- it's natural values include plants. *Forest and Bird February 1984.*

PALMER A.S. 1982: The Stratigraphy and Selected Properties of Loess in Wairarapa, New Zealand. unpubl. PhD Thesis at Victoria University of Wellington.

PALMER R.W.P.; NEALL V.E.; POLLOCK J.A. 1981: Soils of Egmont and part Taranaki Counties North Island, New Zealand. *New Zealand Soil Survey Report 64.*

POCKNALL D.T. 1978: Relative pollen representation in relation to vegetation composition, Westland, New Zealand . *New Zealand Journal of Botany 16*: 379-386.

POCKNALL D.T. 1980: Modern pollen rain and Aranuian vegetation from Lady Lake, north Westland, New Zealand . *New Zealand Journal of Botany 18*: 275-283.

POCKNALL D.T. 1981a: Pollen morphology of the New Zealand species of *Dacrydium* Solander, *Podocarpus* L'Heritier, and *Dacrycarpus* Endlicher (Podocarpaceae). *New Zealand Journal of Botany 19*: 67-95.

POCKNALL D.T. 1981b: Pollen morphology of the New Zealand species of *Libocedrus* Endlicher (Cupressaceae) and *Agathis* Salisbury (Araucariaceae). *New Zealand Journal of Botany 19*: 267-272.

POLLOCK J.A. 1975: A Comparative Study of certain New Zealand and German Soils formed from loess. Rheinischen Friedrich-Wilhelms-Universitat, Bonn.

POWELL A.W.B. 1961: SHELLS OF NEW ZEALAND. Whitcombe and Tombs, Dunedin.

PULLAR W.A. 1980: Distribution and Pedology; Coastal Bay of Plenty. *In* Soil Groups of New Zealand Part 4: Organic Soils: 26-29.

ROBBINS R.G. 1962: The Podocarp-Broadleaf Forests of New Zealand. *Transactions of the Royal Society of New Zealand 1* (5): 65-74.

SINGH L.J. 1971: Uplift and tilting of the Oterei Coast, Wairarapa, New Zealand, during the last ten thousand years. *In* Collins B.W., Fraser R. *(eds)*. Recent Crustal Movements.*The Royal Society of New Zealand Bulletin 9: 25-30.*

SOONS J.M.; SELBY M.J. 1982: LANDFORMS OF NEW ZEALAND. publ. Longman Paul Ltd.

STEVENS G.R. 1956: Earth Movements in the Wellington Area. *New Zealand Geographer* 12: 189-199.

STEVENS G.R. 1969: Raised beaches at Turakirae Head, Wellington. *New Zealand Science Review* 27: 65-68.

SUGGATE R.P. 1965: Late Pleistocene geology of the northern part of the South Island, New Zealand. *Bulletin of the New Zealand Geological Survey* 77.

SUGGATE R.P.; MOAR N.T. 1970: Revision of the Chronology of the Late Otira Glacial. *New Zealand Journal of Geology and Geophyscis 13* (3): 742-746.

TAYLOR N.H.; POHLEN I.J. 1968: Classification of New Zealand Soils. *In* Soils of New Zealand Part 1. *New Zealand Soil Bureau Bulletin 26 (1)*: 15-45.

THOMPSON K. 1980: Peat and Peatlands; Structure, functioning and classification. *In* Soil Groups of New Zealand Part 4: Organic Soils: 7-17.

TOMLINSON A.I. 1976: Climate. *In* Wards I. *(ed)* New Zealand Atlas.

VELLA P. 1963: Upper Pleistocene succession in the inland part of Wairarapa Valley, New Zealand. *Transactions of the Royal Society of New Zealand: Geology 2* (4): 63-78.

VINCENT K.W. 1984: Distribution and description of yellow-grey earths in the Wairarapa. *In* Soil Groups of New Zealand Part 4: Yellow-Grey Earths. New Zealand Society of Soil Science.

WARDLE P. 1962: Subalpine Forest and Scrub in the Tararua Range. *Transactions of the Royal Society: Botany 1* (6): 84-89.

WARDLE P. 1963: Evolution and Distribution of the New Zealand Flora, as affected by Quaternary Climates. *New Zealand Journal of Botany 1* (1): 3-17.

WARDLE P. 1967: Vegetation of the Aorangi Range, Southern Wairarapa. *New Zealand Journal of Botany* 5: 22-48.

WARDLE P.; CAMPBELL A.D. 1976: Seasonal cycle of tolerance to low temperatures in three native woody plants, in relation to their ecology and post-glacial history. *Proceedings of the New Zealand Ecological Society 23*: 85-89.

WARDLE P.; McKELLAR M.H. 1978: *Nothofagus menziesii* leaves dated at 7,490 yr B.P. in till-like sediments at Milford Sound, New Zealand . *New Zealand Journal of Botany 16*: 153-7.

WASSILIEFF M.C.; CLARK D.J.; GABITES I. 1986: Scenic Reserves of the Lower North Island. Biological Survey of Reserves Series No 14, Department of Lands and Survey.

WELLMAN H.W. 1969: Tilted Marine Beach Ridges at Cape Turakirae, New Zealand . *Tuatara 17*: 82-93.

WELLMAN H.W. 1972: Rate of Horizontal Fault Displacement in New Zealand . *Nature* 237: 275-277.

APPENDIX 1.

Abbreviations used in Tables of "Range of profile features".

MOTTLES

none	0
few	0 - 2%
many	2 - 20%
abundant	20 - 50%
profuse	> 50%
fine	< 5mm
med	medium (5-15mm)
coarse	> 15mm
faint	
dist	distinct
prom	prominent

TEXTURE

co s	coarse sand
l co s	loamy coarse sand
co s l	coarse sandy loam
s l	sandy loam
f s l	fine sandy loam
v f s l	very fine sandy loam
si l	silt loam
s cl l	sandy clay loam
si cl l	silty clay loam
sand	sand
l s	loamy sand

STRUCTURE

wkly dev	weakly developed
mod dev	moderately developed
dev	developed
med	medium
bking	breaking

CONSISTENCE

l	loose
fr	friable
extr	extremely firm

Abbreviations and terms used in "Typifying Profile Descriptions":

MOTTLES

none	0%
few	0 - 2%
many	2 - 20%
abundant	20 - 50%
profuse	> 50%

fine	< 5mm
medium	5 - 15mm
coarse	> 15mm

COATINGS: (clay, Fe and organic)

none	0%
few	0 - 10%
common	10 - 50%
many	> 50%

COARSE FRAGMENTS:

none	0%
few	< 5%
common	5 - 15%
many	15 - 35%
abundant	35 - 70%
profuse	> 70%

SOIL SERIES: Otukura series

NEW ZEALAND GENETIC CLASSIFICATION: gley soil

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY:

Otukura series is the most extensive soil type in the survey, occuring on the Holocene flood plain and alluvial covered anticlinal ridges.

Otukura stony silt loam;

There are two large areas of Otukura stony silt loam in the survey. The first is in the northern part of the area, on sloping terrain adjacent to a peat deposit. The second occurs next to the Waiohine Surface, and extends into the central area.

Otukura stony silt loam, mottled phase:

Predominantly located down the center of the study area, near Te Maire Ridge and in the south, The Otukura stony silt loam, mottled phase is the most commonly occuring soil in the survey.

Otukura stony silt loam, strongly mottled phase:

Occurs mostly in old stream channels and meanders where drainage is very poor. This soil phase occurs as inclusions in all Otukura and Maunui soil units excluding the Maunui silt loam, peaty topsoil phase. The most extensive area is in the central part of the survey, against Te Maire Ridge, where accumulation of iron has developed an iron pan and a mapping unit can be delineated.

PARENT MATERIAL: Quartzo - feldspatic greywacke gravels and alluvium

PHYSIOGRAPHIC POSTION IN THIS SURVEY: Flood plains and alluvial deposits of the valley (with negligible accumulation)

MICRORELIEF: hummocky - flat - rolling country

LANDFORM GENESIS: fluvial

VEGETATION AND LANDUSE: ryegrass / clover pasture, some rushes
Long term pasture

RANGE OF ELEVATION: 20 - 55 m.a.s.l.

DRAINAGE CLASS: imperfect to poorly drained

RAINFALL RANGE: 750 - 1320mm

FLOODING: nil

EROSION: nil

SURFACE STONES: nil - 2% (most have probably been picked up from the surface)

CHARACTERISTIC PROFILE FEATURES:

Profuse - abundant gravels at < 15cm depth in all profiles.

Otukura stony silt loam: Mottling and few Fe concretions occur in the lower horizons, and very little mottling in the topsoil.

Otukura stony silt loam, mottled phase: Mottled throughout the proflie. Fe concretions and clay coatings are frequent in the lower B or upper C horizons. The C horizons are more gleyed than in the Otukura silt loam and subsoil textures vary from coarse loamy sand to sand.

Otukura stony silt loam, strongly mottled phase: Profiles are very mottled and have formed often formed an Fe pan at 40 - 90cm depth. Horizons below the pan, or at depths of >70cm are reduced and grey, being much less mottled than horizons above. Textures vary throughout the profile but tend to be more sandy than other soils in the series. Structures in the subsoil are mostly massive or single grained. Profuse stones are often found to the surface.

<u>MAPPING UNITS AND AREAS IN THE PRESENT SURVEY</u>:

Otukura series is separated into three units;

Otukura stony silt loam - moderate extent

Otukura stony silt loam, mottled phase - extensive

Otukura stony silt loam, strongly mottled phase - limited extent (often found in Otukura stony silt loam mottled phase unit, and Maunui silt loam mottled phase unit occuring in most abandoned stream channels and cut off meanders)

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Otukura stony silt loam)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-20	10YR4/3- 3/2, 5/3	may have very few faint 7.5YR6/8[1]	si l, si cl l	few-many stones	fr to very fr	coarse block bking to nut; mod dev med and coarse nut
Bg or Bg$_1$ or Bgm	10-25	10YR5/3, 5/4, 6/3 6/4, or 50% 10YR6/3 and 50% 7.5YR5/6, 10YR5/6	few - common med dist, faint to prominent 10YR4/1,5/6,6/6, 2.5Y6/6, 5/3, many fine faint 7.5YR5/6,6/6,5/8	si l, si cl l, v f s l	many - abundant stones	fr, firm	mod-wkly dev fine- coarse block bking to nut
Bg$_2$ or Bgr or Br	20-40	10YR6/2- 6/4, 2.5Y6/2, 6/1, 7/2 [2]	few - common med dist 10YR6/8, 4/8 7.5YR6/8, 5/8, 2.5Y6/6	si l, v f s l, co s l	abundant- profuse stones	firm	massive; wkly dev coarse block, med nut, crumb
Cgr or Cg	20-40+	2.5Y6/1, 6/2, 7/2-7/3, 10YR6/1, 5/1	few fine faint 10YR6/8,7.5YR4/6, very few - few fine and coarse dist 7.5YR5/8	l co s, sand	abundant- profuse stones	l	massive; single grain

(Range of features based on 14 profiles and auger descriptions)

Notes for Table:

1) may have 5YR4/8 down root channels
2) soft black concretions in root channels, few discontinuous 7.5YR4/6, 5/8 coatings.

<u>TYPIFYING PROFILE</u>: Otukura stony silt loam

LOCATION: In paddock on north west side of Phillips Line and Battersea Road intersection

GRID REFERENCE: NZMS260 S27 128 043

TOPOGRAPHY: flat

SLOPE: nil

DRAINAGE: imperfectly drained

PARENT MATERIAL: Quartzo - feldspatic greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 15cm	brownish black (10YR3/2) silt loam; slightly sticky; slightly plastic; friable; moderately strong soil strength; moderately firm ped strength; moderately developed coarse blocky structure breaking to moderately developed medium and fine nut structure; common weakly weathered subrounded gravels; many fine and very fine roots; very few very fine faint reddish brown (5YR4/8) mottles down old root channels; distinct wavy boundary,
Bg	15 - 35cm	dull yellowish brown (10YR5/3) silt loam with 15% fine sand; slightly sticky; non plastic; friable; moderately weak soil strength; moderately weak ped strength; moderately developed fine nut plus moderately developed fine blocky structures; few medium distinct yellowish brown (10YR5/6) and faint yellowish brown (2.5Y5/3) mottles, and common fine distinct bright brown (7.5YR5/8) mottles; abundant weakly weathered subrounded stones and gravels; many very fine roots; distinct wavy boundary,
Bgr	35 - 50cm	yellowish grey (2.5Y6/1) fine sandy loam; non sticky; non plastic; friable; moderately weak soil strength; moderately weak ped strength; weakly developed medium nut plus moderately developed medium crumb structures; common medium distinct bright yellowish brown (10YR6/8), and bright brown (7.5YR5/8) mottles, and few fine and medium distinct bright yellowish brown (2.5Y6/6) mottles; abundant weakly weathered subrounded stones

		and gravels; few very fine roots; few distinct brown (7.5YR4/6) clay coatings on ped faces; distinct wavy boundary,
Cgr	50 - 85+cm	greyish brown (2.5Y7/2) sand; non sticky; non plastic; loose; single grain; few fine faint and distinct brown (7.5YR4/6) and bright brown (7.5YR5/8) mottles; abundant weakly weathered gravels and stones.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Otukura stony silt loam, mottled phase)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-30	10YR3/2, 4/2,4/3, 2.5Y3/2	many very fine dist 7.5YR5/8, or none	si l, si cl l	few to many stones	fr to very fr	weak,mod strongly dev med crumb,med -fine nut
Bgm or Bgm$_1$ or ABg	10-30	10YR7/2, 7/1, 6/1-6/3, 2.5Y4/2, 8/1, 7/2	many med dist 7.5YR6/8, 5/8, 10YR6/8 - 7/8, 6/6, 6/4[1]	si l, si cl l, v f s l	common - abundant stones	fr, firm	wkly-mod- strongly dev nut, crumb
Bgm$_2$ or Cgr or Cgr$_1$ or Cgm$_1$	10-40	10YR7/1, 6/1,6/2, 2.5Y7/1, 7/2,7/4, 4/2	many - abundant med and fine dist 7.5YR6/8, 5/8, 10YR6/8 - 7/8, 6/6, 6/4[2]	sand, cl l, s cl l, co s l	abundant stones	l, very firm	mod-wkly dev med and fine nut and crumb; single grain; massive
Cgm or Cgm$_2$ or Cgr or Cgr$_1$ or Cgr$_2$	20-30+	5Y7/1, 5/1, 2.5Y7/1, 7/2,7/4,	many med and fine dist 10YR6/8, 5/8, 7/3, 7.5YR6/8, 5/8, 4/6,[3] or none	l s, co l s, sand	abundant stones	l	single grain; massive[4]
Cgr or Cgr$_1$ or Cgr$_2$	20-30+	5Y7/1, 5/1, 10G5/1	none	sand, l c, co s l	abundant stones	l	single grain; massive

(Range of features based on 30 profile and auger descriptions)

Notes for Table:

1) may have soft black concretions, clay and Fe coatings
2) may have few Fe concretions, and clay coatings
3) Fe concretions and clay coatings
4) maybe semi-cemented

TYPIFYING PROFILE: Otukura stony silt loam, mottled phase

LOCATION: 20m south of Phillips Line

GRID REFERENCE: NZMS260 S27 113 039

TOPOGRAPHY: flat

SLOPE: 2^{o}S

DRAINAGE: naturally poorly drained (has been artifically drained)

PARENT MATERIAL:greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 18cm	brownish black (10YR3/2) silt loam; non sticky; non plastic; friable; moderately strong soil srength; moderately firm ped strength; moderately developed medium and fine nut structure; many fine faint bright brown (7.5YR5/8) mottles; few weakly weathered subrounded gravels; many fine and very fine roots; distinct irregular boundary,
ABg	18 - 30cm	dull yellowish orange (10YR6/3) very fine sandy loam; non sticky; non plastic; friable; moderately strong soil strength; moderately firm ped strength; moderately developed fine nut structure; many fine distinct bright yellowish brown (10YR7/6) mottles and many medium distinct bright brown (7.5YR5/8) mottles down old root channels and cracks, few faint greyish yellow brown (10YR6/2) clay

		coatings on peds; common weakly weathered subrounded gravels; common very fine roots; indistinct boundary,
Bgm	30 - 50cm	greyish yellow brown (10YR6/2) sandy clay loam; non sticky; slightly plastic; friable; moderately strong soil strength; moderately weak ped strength; weakly developed fine nut structure; common fine distinct bright yellowish brown (10YR6/6) and many fine distinct bright brown (7.5YR5/8) mottles mainly in old root channels and cracks, few distinct yellowish brown (10YR5/6) Fe coatings; abundant weakly weathered subrounded gravels and stones; common very fine roots; indistinct boundary,
Cgr_1	50 - 75cm	brownish grey (10YR6/1) sand; non sticky; non plastic; loose; moderately strong soil strength; massive; common fine and medium prominent brown (7.5YR4/6) mottles and common fine prominent bright yellowish brown (10YR6/8) mottles; few distinct yellowish brown (10YR5/6) Fe coatings; abundant weakly weathered subrounded gravels and stones; sharp wavy boundary,
Cgr_2	75 - 95+cm	grey (5Y5/1) sand; non sticky; non plastic; loose; single grain; few distinct yellowish brown (10YR5/6) Fe coatings becoming cemented with depth; abundant weakly weathered subrounded gravels and stones.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Otukura stony silt loam, strongly mottled phase)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-20	10YR4/3, 4/2, 5/3	many fine faint 7.5YR5/8, 5/6, 10YR4/6,5/6,5/8, few fine faint 10YR3/3 [1]	si l, v f s l	many to profuse stones	fr to very fr	mod-well dev med coarse, nut, crumb, block
Bg or Bgm	10-50	10YR6/3, 6/2, 5/3	many med dist 7.5YR5/8, 6/8, few - many fine dist 10YR5/2, 5YR4/8	si l, co s l, v f s l	many - profuse stones	fr, firm	mod-wkly dev crumb, block, nut
Bgc_1[2]	10-20	2.5Y5/2, 4/2,6/3, 8/2	many to abundant med, coarse dist 7.5YR5/8-5/6, 6/8, 8/8, many fine and med dist 5YR4/4, 4/8	s l, v f s l, co s l, s cl l, si cl l	abundant- profuse stones (mostly Fe coated)	firm to very firm	massive; wkly dev med-fine block
Bgc_2[3] or Bgc	10-30	2.5Y6/1, 7/3, 10YR7/2, 6/2	up to 50% med dist 7.5YR5/6, 6/8, 7/8, common med dist 5YR5/3	co s l, sand, si cl l	abundant- profuse stones (mostly Fe coated)	firm to very firm	massive; wkly dev med-fine blocky
Cgr[4] or Cgr_1	20-40+ or 20-40	2.5Y6/1, 5Y6/1, 10YR6/2, 7/1, 10G5/1	many fine dist 10YR5/6, 7.5YR5/6, 5/8, 7/8, few fine dist 5Y4/3, 3/2, may have none	sand, l co s, s cl l	abundant- profuse stones	l- fr	massive; single grain
Cgr_2[5]	20-30+	5Y7/1,5/1, 10G5/1	none	sand, l s	abundant- profuse stones	l	single grain

(Range of features based on 46 profile and auger descriptions)

Notes for Table:

1) this horizon may have Fe concretions
2) this horizon may be absent. Fe concretions may have cemented
3) profuse Fe concretions in most profiles, many semi-cemented
4) may have hard black concretions.
5) this horizon is often absent

TYPIFYING PROFILE: Otukura stony silt loam, strongly mottled phase

LOCATION: west of Wards Line approximately 2 km from S.H. 53

GRID REFERENCE: NZMS260 S27 135 027

TOPOGRAPHY: in old stream channel

SLOPE: nil

DRAINAGE: poorly to very poorly drained

PARENT MATERIAL: Quartzo - feldspatic greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 12cm	dull yellowish brown (10YR4/3) silt loam; non sticky; non plastic; friable; moderately strong soil strenght; moderately firm ped strenght; moderately developed medium nut plus moderately developed fine block structures; many fine distinct brown (10YR4/6), yellowish brown (10YR5/8) and indistinct dark brown (10YR3/3) mottles; many weakly weathered subrounded gravels; many fine and very fine roots; distinct wavy boundary,
Bg	12 - 40cm	dull yellowish orange (10YR6/3) sandy clay loam; slightly sticky; slightly plastic; friable; moderately strong soil strength; moderately strong ped strength; weakly developed medium nut structure; many medium distinct bright brown and orange (7.5YR5/8 + 6/8) mottles, and few medium distinct reddish brown (5YR4/8) mottles; abundant weakly

		weathered subrounded stones and gravels; light grey and reddish brown 7.5YR8/8 + 5YR4/8) stainings on some stones; few fine distinct bright brown (7.5YR5/8) Fe coatings and concretions; many very fine roots; distinct wavy boundary,
Bgc	40 - 50cm	dark greyish yellow (2.5Y5/2) coarse sandy loam; non sticky; non plastic; rigid soil strength; massive; many coarse and medium distinct bright brown, orange and reddish brown (7.5YR5/8 +6/8 + 5YR4/8); common medium distinct reddish brown (5YR5/8) Fe concretions; abundant to profuse weakly weathered subrounded stones and gravels; reddish brown (5YR4/8) stains on most stones; common bright brown (7.5YR5/8) Fe coatings on peds and stones; discontinuous Fe pan; distinct wavy boundary,
Cgr	70 - 100+cm	grey (5Y6/1) sand; non sticky; non plastic; loose; single grain; few fine distinct yellowish brown (10YR5/6) and bright brown (7.5YR5/6) mottles; abundant weakly weathered gravels and stones; few fine Fe concretions.

SOIL SERIES: Maunui Series

NEW ZEALAND GENETIC CLASSIFICATION: Gley soil

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY:

Maunui series occurs in limited strips throughout the flood plains, and is divided into three main mapping units
Maunui silt loam:
Located in pockets mostly in the central floodplain area.
Maunui silt loam, mottled phase:
Occurs in the west, and south west predominantly in areas of surface ponding and very poor drainage.
Maunui silt loam, peaty topsoil phase:
Occurs in very small areas adjacent or near to Te Maire Ridge

PARENT MATERIAL: Quartzo-feldspatic greywacke gravels and alluvium

PHYSIOGRAPHIC POSTION IN THIS SURVEY: Lowlying alluvial fans and deposits, and on slowly rising anticlinal ridges Maunui silt loam, peaty topsoil phase occurs in depressions and swampy hollows

MICRORELIEF: hummocky to flat to rolling country, 0 - 7^{o} slope.

LANDFORM GENESIS: fluvial

VEGETATION AND LANDUSE: rye grass / clover pasture often with rushes, long term grazing

RANGE OF ELEVATION: 20 - 55 m.a.s.l.

DRAINAGE CLASS: imperfectly to poorly drained, (Maunui silt loam peaty topsoil phase is very poorly to porrly drained)

RAINFALL RANGE: 750 - 1320 mm

FLOODING: nil, surfaca ponding in some places. (Maunui silt loam, peaty topsoil phase usually has long term surface water)

EROSION: nil

SURFACE STONES: nil - 2% surface stones (some stones have probably been picked up from the surface)

CHARACTERISTIC PROFILE FEATURES:

Profiles have a minimum of 30cm of silt loam to fine sandy loam with some stones over more sandy textured subsoils with abundant to profuse stones, gravels and boulders.

Maunui silt loam: Profiles range from having very few mottles in the profile to many mottles in the lower horizons. Fe accumulation is not substantial in these soils.

Maunui silt loam, mottled phase: Mottles throughout the profile. Many profiles have an iron pan at 40 - 90cm depth. Profiles resemble Otukura series soils (mottled phase), but abundant stones occur at a depth of >30cm.

Maunui silt loam, peaty topsoil phase: Profiles have 5 - 20cm of brownish black or dark brownish black peaty material over alluvium. There are few stones in the peaty surface horizon, but below this there are few to many stones in a silty loam or silty clay loam matrix. Mottles are prominent in the subsurface horizons. Depth to abundant stones and gravels varies from 40 - 90cm below the surface. Fe concretions are uncommon.

MAPPING UNITS AND AREAS IN THE PRESENT SURVEY:

The Maunui Series is separated into three units:

Maunui silt loam - limited extent
Maunui silt loam, mottled phase - limited extent
Maunui silt loam, peaty topsoil phase - very limited extent

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Maunui silt loam)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-25	10YR4/3- 2/2, 5/3, 7.5YR4/2	may have very few faint 7.5YR6/8, 5YR4/2, 4/8	si l, si cl l	none to few stones	fr	wkly to mod dev med - coarse crumb, fine-med nut
Bg or Bgm or Bgm_1	10-45	10YR5/2, 5/3, 6/3, 7.5YR5/6, 10YR5/6	many fine dist 10YR5/6, 6/6, 2.5Y6/6, many fine and med faint to dist 7.5YR5/6, 5/8, 5YR4/8	si l, si cl l, v f s l	few - common stones	fr, firm	mod-wkly dev med- coarse block, med to coarse nut
Cgm[1] or Bgm or Bgm_2	20-35	10YR6/2- 6/4, 2.5Y6/2, 6/1, 7/2	few fine - common med dist 10YR5/8, 4/6, 7.5YR6/8, 5/8, 2.5Y6/6	v f s l, co s l	abundant- profuse stones	firm	massive; wkly dev med nut, med crumb
Cgr or Cg	20-40+	2.5Y6/1, 6/2, 7/2-7/3, 10YR6/1, 5/1	few fine faint 10YR5/8, 4/6, few fine dist 7.5YR5/8[2]	l co s, sand, f s l	profuse stones	l	massive; single grain

(Range of features based on 9 profile and auger descriptions)

Notes for Table:

1) this horizon is often absent where the water table is high. (above 20cm)
2) some Fe concretions and clay coatings may be present in this horizon.

TYPIFYING PROFILE: Maunui silt loam

LOCATION: In a flat paddock directly east of Phillips Line and Battersea Road intersection

GRID REFERENCE: NZMS260 S27 138 042

TOPOGRAPHY: flat

SLOPE: nil

DRAINAGE: imperfectly drained

PARENT MATERIAL: Quartzo - feldspatic greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 20cm	brownish black (10YR3/2) silt loam; slightly sticky; slightly plastic; friable; moderately strong soil strength; moderately firm ped strength; moderately developed medium and fine nut structure; very few very fine faint reddish brown (5YR4/8) and greyish brown (5YR4/2) mottles; few weakly weathered subrounded gravels; many fine and very fine roots; distinct wavy boundary,
Bg	20 - 40cm	dull brown (10YR6/3) silt loam; slightly sticky; non plastic; friable; moderately weak soil strength; moderately weak ped strength; moderately developed fine and medium structure; many fine distinct bright reddish brown (10YR5/6 + 7.5YR5/8) mottles, and many fine distinct brown (5YR4/8) mottles; few weakly weathered subrounded stones and gravels; many very fine roots; distinct wavy boundary,
Bgm	40 - 60cm	dull orange (10YR6/4) fine sandy loam; non sticky; non plastic; friable; moderately weak soil strength; moderately weak ped strength; weakly developed medium nut structure; common medium distinct bright yellowish brown (10YR6/8), and bright brown (7.5YR5/8) mottles; abundant weakly weathered subrounded stones and gravels; few very fine roots; few distinct brown (7.5YR4/6) clay coatings; distinct wavy boundary,
Cgr	40 - 95+cm	greyish brown (2.5Y7/2) sand; non sticky; non plastic; loose; single grain; few fine faint brown (10YR4/6) and distinct bright brown (7.5YR5/8) mottles; profuse weakly weathered gravels and stones.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Maunui silt loam, mottled phase)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-25	10YR3/3, 4/2-4/4, 10YR5/3, 7.5YR3/3	may have few fine faint 10YR5/8 mottles	si l, si cl l 5-10% s	none to few stones 1 - 5cm	fr	wkly-mod dev, fine -med, nut, crumb
Bg1	10-40	10YR5/3- 6/3, 6/4	many, common med and fine dist 10YR5/6, 6/8, 7.5YR5/6, 4/6, 5YR4/8; few fine dist 10YR6/2, 7/2 2.5YR6/1	si cl l 5-10% s, s l	few to common stones < 5cm, many 5 - 10cm	fr l	mod dev, med nut; fine bl; massive
Bg2 or Bgfe1	15-25	10YR5/3, 6/8, 7.5YR6/2	many med dist 5YR8/2, 3/6, 7.5YR8/2; many med- fine dist 10YR4/6, 5/6, 7/2, 5/2, 2.5Y6/2 - 6/1, 7.5YR5/8 - 6/8	s l, si cl l 5-10% s	many - abundant stones [1]	fr- firm	mod dev fine-med nut; fine blocky; single grained
Bg3 or Bgfe2 or	20-40	10YR5/6, 6/2, 2.5Y6/2- 7/2	many fine faint 10YR5/6 - 5/8, 4/6, 6/3; many fine dist 5YR4/8, 7.5YR5/8	si cl l 20% s, s l, sand, co s l	abundant -profuse stones [2] < 10cm	l	single grain; mod dev fine block
Cgs or Cg1	10-30+	10YR4/3- 4/6, 5/1- 5/3, 7.5YR4/6	many fine and med dist 5YR3/6, 10YR5/6, 7.5YR5/8	sand, co s l	abundant -profuse stones [3] mostly < 10cm	very firm	massive
Cg2 or Cgs	20-60+	10YR5/2- 6/3, 2.5Y6/2, 7/2	many fine and med 10YR5/8, 4/6, 7.5YR5/8, 4/6	sand, co s l, co s	profuse stones [3] < 10cm	very firm to firm	massive

(Range of features based on 26 profile and auger descriptions)

Notes for table:

1. Some stones may be cemented, Fe concretions in Bgfe horizons.
   Fe staining along root channels.
2. Fe coatings on most stones, many cemented in Bgfe horizons.
3. Fe pan continuous or discontinuous.

TYPIFYING PROFILE: Maunui silt loam, mottled phase.

LOCATION: approximately 1 km west of Hiwirau in a flat paddock (south of Greytown)

GRID REFERENCE: NZMS260 S27 114 024

TOPOGRAPHY: flat

SLOPE: approximately 1°SW

DRAINAGE: imperfectly to poorly drained (frequent ponding of surface water)

PARENT MATERIAL: greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 15cm	dark brown (7.5YR3/3) silty clay loam, 3% sand; slightly sticky; slightly plastic; friable; moderately weak soil strength; moderately weak ped strength; moderately developed fine crumb structure; few weakly weathered subrounded stones and gravels; abundant fine roots; distinct wavy boundary,
Bg_1	15 - 35cm	dull yellow orange (10YR6/4) silty clay loam with 5% sand; slightly sticky; slightly plastic; friable; moderately weak soil strength; moderately developed ped strength; weakly developed medium nut structure; many medium distinct yellowish grey (2.5Y6/1) and many medium distinct brown (7.5YR5/8) mottles; common weakly weathered subrounded gravels and stones; many fine roots; distinct wavy boundary,

Bg_2	35 - 50cm	greyish brown (7.5YR6/2) silty clay loam with 20% sand; slightly sticky; slightly plastic; firm; moderately firm soil strength; moderately weak ped strength; moderate to weakly developed medium nut structure; many medium and coarse distinct greyish yellow (2.5Y5/8) and many coarse distinct bright brown (7.5YR5/8) mottles; abundant weakly weathered subrounded gravels and stones; common distinct dark reddish brown (5YR3/6) Fe coatings down old root channels and on many stones; few very fine roots; distinct wavy boundary,
Bgfe	50 - 75cm	greyish yellow brown (10YR6/2) silty clay loam with 20% sand; non sticky; non plastic; firm; moderately firm soil strength; moderately weak ped strength; weakly developed medium nut structure; many medium and coarse distinct bright brown (7.5YR5/8) mottles; abundant weakly weathered subrounded gravels and stones; many distinct and prominent reddish brown (5YR4/6) Fe coatings on stones and down cracks; very few very fine roots; distinct wavy boundary,
Cgs	75 - 120+cm	50% bright grey (10YR5/1) and 50% brown (7.5YR4/6) coarse sandy loam; non sticky; non plastic; rigid soil strength; massive; many fine distinct bright brown (7.5YR5/8), dark reddish brown (5YR3/6) and yellowish brown (10YR5/6) mottles; profuse weakly weathered subrounded gravels and stones; many prominent reddish brown (5YR4/6) Fe coatings on stones and gravels; discontinuous Fe pan.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:
(Maunui silt loam, peaty topsoil phase)

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ah or Oh	5-20	10YR2/2, 4/3, 7.5YR4/2	many med dist 5YR4/2	slightly p si l, p si l, p l, l p, peat	may have few stones	fr to very fr	wkly-med dev fine crumb
Bg or Bgr	25-35	10YR6/2, 6/3, 5/2	many fine and med dist 7.5YR5/8, 5YR4/8, many fine dist 10YR4/6 near base	cl l, si cl l	none to many stones	firm	wkly-med dev med block, coarse- med nut
Cg or Cgr	10-35+	10YR7/2, 7/3	few fine to many med dist 10YR5/8, 4/6	cl l, f s l, f s cl l	abundant stones unsorted	firm to very firm to l	massive; single grain

(based on 4 profile descriptions)

<u>TYPIFYING PROFILE</u>: Maunui silt loam, peaty topsoil phase

LOCATION: Approximately 2 km south along Greytown Bidwlls Cutting Road from Glenmorven Road, in a depression on the western side of the road.

GRID REFERENCE: NZMS260 S27 163 046

TOPOGRAPHY: on edge of depression (soil type occurs in the depressions also)

SLOPE: $3^{O}E$

DRAINAGE: poorly - very poorly drained, often swampy at surface (frequent ponding of surface water)

PARENT MATERIAL: Thin organic silt or peat over alluvium and gravels

VEGETATION: Mostly ryegrass and some clover, abundant rushes.

HORIZON	DEPTH	DESCRIPTION
Ah	0 - 15cm	brownish black (10YR2/2) peaty silt loam; non sticky; non plastic; friable; weakly to moderately developed fine crumb structure; few fine distinct greyish brown (5YR4/2) mottles; many fine roots; distinct wavy boundary,
Bg	15 - 45cm	brownish grey (10YR6/2) silty clay loam with 2% sand; slightly stiicky; slightly plastic; firm; weakly developed medium nut structure; many fine distinct bright brown (7.5YR5/8) and many medium distinct reddish brown (5YR4/8) mottles; many weakly weathered subrounded stones and gravels in lower parts of horizon; few fine roots; indistinct wavy boundary,
Cg	45 - 60+cm	dull yellowish orange (10YR7/2) gravelly sandy loam; non sticky; non plastic; loose; single grain; many medium distinct yellowish brown (10YR5/8) and brown (10YR4/6) mottles; abundant weakly weathered subrounded gravels and stones; very few very fine roots.

SOIL SERIES: Watiro Series

NEW ZEALAND GENETIC CLASSIFICATION: Gley soil

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY: Adjacent to Te Maire Ridge on eastern side of study area, very limited extent

PARENT MATERIAL: reworked loess and alluvium

PHYSIOGRAPHIC POSTION IN THIS SURVEY: In old stream channel and adjacent small fan

MICRORELIEF: flat

LANDFORM GENESIS: fluvial

VEGETATION AND LANDUSE: ryegrass / clover pasture with rushes; long - term pasture

RANGE OF ELEVATION: 30 - 32 m.a.s.l.

DRAINAGE CLASS: imperfectly drained

RAINFALL RANGE: 750 - 1320mm

FLOODING: nil

EROSION: nil

SURFACE STONES: nil to 1%

CHARACTERISTIC PROFILE FEATURES:

Very few, if any stones or gravels in the profile. Deep silt loams and silty clay loams generally mottled throughout often having a hard or impenetrable horizon at 100cm or deeper.

MAPPING UNITS AND AREAS IN THE PRESENT SURVEY:

The Watiro Series has one mapping unit;
Watiro silt loam - very limited extent (there are inclusions of Otukura series soils in the mapping unit).

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	10-25	10YR4/2-4/4,5/3	few fine faint 10YR6/4, many fine dist 7.5YR4/4,5/8	si l, si cl l	none	very fr	mod dev med nut or crumb
Bgm_1	10-30	10YR7/2, 7/3, 6/2-6/3, 2.5Y7/3	many med prominent 10YR5/2, 7.5YR5/8, 7/8, many med and fine 10YR6/6, 5/6, 6/4	si l, si cl l	may have few stones[1]	fr	mod dev med nut and crumb
Bgm_2	20-40	2.5Y7/1-7/3, 6/6, 6/2, 10YR7/3, 7/2	many med dist 10YR6/6,5/6,4/6, many fine dist 2.5YR2/3, may have 7.5YR5/8 at base	si cl l	may have few stones	firm	mod-wkly dev nut and crumb
Cgm[3]	20-30+	5Y8/2, 10YR6/2, 6/3	many med dist 7.5YR5/8, 10YR5/6, 5/8, few med dist 7.5YR7/8	si cl l, s l	may have few stones < 1cm[2]	firm	mod-wkly med and fine nut and crumb
or Cgs[3]	20-30+	2.5Y7/2, 10YR5/2, 5/3, 7.5YR5/8	many med dist 7.5YR5/6, 10YR5/6	si cl l, cl l, sand	some profiles have profuse stones	firm	massive; single grain

(Based on 6 profile descriptions)

Notes for the table:

1) some coatings on stones
2) some 7.5YR3/3 crustings
3) often inpenetrable, 7.5YR5/8 colouring if a pan.

TYPIFYING PROFILE: Watiro silt loam

LOCATION: On terrace adjacent to old river channel 0.5 km west of Maunui on the Greytown Bidwills Cutting Road

GRID REFERENCE: NZMS260 S27 150 028

TOPOGRAPHY: flat

SLOPE: 0^{o}

DRAINAGE: imperfectly drained

PARENT MATERIAL: reworked loess and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 20cm	greyish yellow brown (10YR4/2) silt loam; non sticky; non plastic; very friable; moderately developed medium nut structure; few fine distinct dull yellowish orange (10YR6/2) mottles; many fine roots; distinct wavy boundary,
Bgm_1	20 - 50cm	dull yellowish orange (10YR7/3) silt loam; non sticky; non plastic; friable; moderately developed medium and fine nut structure; many medium distinct greyish yellow brown (10YR5/2) and many medium prominent bright brown (7.5YR5/8), and many fine prominent yellowish orange (7.5YR7/8) mottles; few fine roots; very few stones; indistinct wavy boundary,
Bgm_2	50 - 90cm	light yellow (2.5Y7/3) silty clay loam; slightly sticky; slightly plastic; firm; weakly developed nut structure; many dull yellowish orange (10YR7/3) patches; many medium distinct bright yellowish brown (10YR6/6) mottles; few stones; very few very fine roots; distinct wavy boundary,
Cgm	90 - 120+cm	light grey (5Y8/2) silty clay loam; slightly sticky; slightly plastic; very firm; massive; many medium distinct bright brown (7.5YR5/8) and common yellowish orange (7.5YR7/8) mottles; few fine and medium dark brown (7.5YR3/3) crustings; few < 1cm stones.

SOIL SERIES: Taratahi Series

NEW ZEALAND GENETIC CLASSIFICATION: organic soil

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY: Three seperated areas of moderate extent occur in a linear pattern down the centre of the survey area.

PARENT MATERIAL: peat overlying alluvium

PHYSIOGRAPHIC POSTION IN THIS SURVEY: surface organic deposits in slight depressions or low lying areas

MICRORELIEF: hummocky

LANDFORM GENESIS: lacustrine

VEGETATION AND LANDUSE: ryegrass clover pastures often with many rushes and scattered kahikatea (*Dacrycarpus dacrydioides*) trees; Long term pasture, sheep and dairy farming

RANGE OF ELEVATION: 20 - 50 m.a.s.l.

DRAINAGE CLASS: very poorly drained - poorly drained

RAINFALL RANGE: 750 - 1320 mm

FLOODING: nil

EROSION: nil

SURFACE STONES: nil

CHARACTERISTIC PROFILE FEATURES:

Peat ranging in depth from 30 - 100+cm on very gleyed silty or sandy alluvium with stones and gravels. Buried tree stumps and large plant remains are common in the peat. Stones are often found throughout the profile. Water

MAPPING UNITS AND AREAS IN THE PRESENT SURVEY:

Taratahi Series is dominated by Taratahi peat, with Taratahi peaty loam, and Taratahi loamy peat.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Oh_1	3-20	10YR2/1-2/2, 7.5YR2/1, 2/2, 3/2, 5YR2/2	none	l peat, humic peat, peat	may have few small stones	very fr	massive; wkly dev crumb
Oh_2[1]	10-110	10YR2/2, 7.5YR2/2, 3/2, 5YR2/2-2/1	may have few faint 5YR2/4, 7.5YR3/4	l peat, hemic peat, peat	may have few <10cm	very fr	massive; wkly dev crumb
Cr_1[1]	10-30	5GY5/1-6/1, 10BG6/1 or 2.5Y5/2, 6/2, 10YR6/2-5/2, 6/1-7/1, 7.5YR5/2	few dist 2.5YR5/6 and 7.5YR6/2 many med dist 2.5Y6/8, 10YR5/8-5/6, 7/3	cl l, si cl l, s l	10% stones < 10cm	very firm to fr	single grain
$2Cr_1$ or Cr1	10-30	7.5YR5/1, 5GY5/1-6/1, 10BG6/1, 10YR5/1	many med dist 7.5YR6/2, 2.5YR3/3, 10YR5/6-5/8	s cl l, co s l, l co s	< 20% stones < 10cm	firm	single grain
$2Cr_2$ or Cr_2	20+	10BG6/1, 5GY5/1-6/1	few faint 10YR5/6 - 5/8	co s	profuse stones and gravels	firm	single grain

(Based on 4 profile and 33 auger descriptions)

Notes for table:

1) in some profiles this horizon may be absent.

TYPIFYING PROFILE: Taratahi peat

LOCATION: south of Greytown and east of Featherston, about 10m east of Phillips Line

GRID REFERENCE: NZMS260 S27 107 028

TOPOGRAPHY: flat

SLOPE: flat

DRAINAGE: very poorly drained

PARENT MATERIAL: peat over greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Oh_1	0 - 20cm	black (7.5YR2/1) humic peat; slightly sticky; slightly plastic; weakly developed fine and medium crumb structure; few plant remains; abundant fine roots; indistinct boundary.
Oh_2	20 - 90cm	brownish black (10YR2/2 - 7.5YR3/2) loamy peat; non sticky; slightly plastic; firable; massive; few very fine faint very dark reddish brown (5YR2/3 - 2/4) mottles; few weakly weathered subrounded stones; many plant fragments partially decayed; many fine roots; sharp smooth boundary.
Cr_1	90 - 100cm	olive grey (5GY5/1) sandy loam; firm; non sticky; non plastic; massive breaking to single grain; few fine distinct greyish brown (7.5YR6/2) mottles; common weakly weathered subrounded gravels and stones; many woody plant fragments; distinct wavy boundary.
$2Cr_1$	100 - 115cm	olive grey (5GY6/1) loamy coarse sand; loose; non sticky; non plastic; single grain; few fine distinct greyish brown (7.5YR6/2) mottles; abundant weakly weathered and unweathered subrounded stones and gravels and some boulders; occasional woody plant fragments; distinct wavy boundary.
$2r_2$	115 - 120+cm	olive grey (5GY5/1) coarse sand; loose; non sticky; non plastic; single grain; profuse weakly weathered subrounded gravels, stones and boulders.

SOIL SERIES: <u>Wharekaka series</u>

NEW ZEALAND GENETIC CLASSIFICATION: Moderately gleyed central yellow-grey earth

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY: Borders on the west side of the survey with two small areas mapped at the southern end on anticlinal ridges

PARENT MATERIAL: loess of mainly greywacke origin, Ohakean in age

PHYSIOGRAPHIC POSTION IN THIS SURVEY: On loess covered terraces and anticlinal ridges

MICRORELIEF: flat - rolling

LANDFORM GENESIS: fluvio - eolian

VEGETATION AND LANDUSE: ryegrass / clover pasture, some browntop (*Agrostis tenuis*). Long term pasture

RANGE OF ELEVATION: 30 - 80 m.a.s.l.

DRAINAGE CLASS: imperfectly - moderately well drained

RAINFALL RANGE: 750 - 1320mm

FLOODING: nil

EROSION: nil

SURFACE STONES: nil

CHARACTERISTIC PROFILE FEATURES:

Loess ranging in depth between 1 - 2m deep (Vincent 1984)

The soil wets up in winter and dries out in summer.

Profiles have deep yellowish grey silt loam topsoils with moderately developed structures. Subsoils are grey and firm with brown mottles throughout. Some profiles have a fragipan developing at 60 - 80cm below the surface. Textures are silty loam or clay loams, the lack of sandy textures and stones is a characteristic of these soils in the area.

<u>MAPPING UNITS AND AREAS IN THE PRESENT SURVEY</u>:

Wharekaka Series is dominated by Wharekaka silt loam

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap or Ap_1	10-25	10YR4/2, 3/2	none	si l	none	fr	mod dev fine and med nut- crumb
Ap_2 [1]	10-20	10YR4/3, 4/2, 3/2	few to many fine dist 10YR6/6	si l	none	fr	mod dev fine and med nut- crumb
ABg	10-20	10YR5/3, 6/3, 4/3	few-common fine dist 10YR6/8, 6/6, 5/8	si l	none	fr	mod dev fine and med nut
Btg_1	20-35	10YR7/3- 7/2, 6/2-6/4	many med dist 10YR5/6, 6/8, many coarse dist 7.5YR5/6	si l, si cl l, cl l	none	firm	wkly dev med - coarse blocky [2]
Btg_2	15-25	10YR6/3, 7/1-7/2, 2.5Y7/2	<50% med dist 7.5YR5/8, 10% med dist 10YR6/8, 4/6 5/8, 30% med - coarse 7.5YR5/6	cl l, si cl l	none	firm to very firm	wkly-mod dev med- coarse blocky [2]
Cg or	30-50+	5Y7/2, 10YR7/1- 7/2	30% coarse prom 7.5YR5/8, 20% med dist 7.5YR5/6, <50% med dist 10YR6/6, 6/8	si l	none	very firm	mod dev coarse prismatic bking to med - coarse blocky [2]
Cxg [3]	30-50+	5Y7/2, 10YR7/1- 7/2	many coarse prom 7.5YR5/8, many med - coarse 7.5YR5/6, profuse med dist 10YR6/6- 6/8	si l	none	extr firm	massive- coarse prismatic

(Range of profile featurse based on auger descriptions and, 7 profile descriptions and reference to Palmer 1982)

Notes for Table: 1) this horizon is often absent
2) clay coatings on ped faces
3) fragipan occuring mostly at about 65 - 80cm depth

TYPIFYING PROFILE: Wharekaka silt loam

LOCATION: On an anticlinal ridge 50m north of S.H.53 between Phillips Line and Fenwicks Line

GRID REFERENCE: NZMS260 S27 113 017

TOPOGRAPHY: ridge crest

SLOPE: flat - gently rolling

DRAINAGE: imperfectly drained

PARENT MATERIAL: loess

HORIZON	DEPTH	DESCRIPTION
Ap_1	0 - 15cm	greyish yellow brown (10YR4/2) silt loam; friable; non sticky; non plastic; moderately developed medium nut structure; many fine roots; indistinct boundary,
A_{p2}	15 - 30cm	dull yellowish brown (10YR4/3) silt loam; friable; non sticky; non plastic; moderately developed medium and fine nut structure; many fine roots; indistinct boundary,
Btg_1	30 - 50cm	dull yellowish orange (10YR7/2 - 7/3) silty clay loam; slightly sticky; slightly plastic; firm; weakly developed medium block structure; many medium distinct bright yellow brown (10YR6/8) and many coarse distinct bright brown (7.5YR5/6) mottles; few distinct bright brown (7.5YR5/8) clay coatings on peds; few very fine roots; distinct boundary,
Btg_2	50 - 70cm	50% dull yellow orange (10YR7/2) and 50% bright brown (7.5YR5/6) silty clay loam; firm; slightly sticky; slightly plastic; weakly developed medium blocky structure; few medium distinct bright yellowish brown (10YR6/8) mottles; few distinct bright brown (7.5YR5/8) clay coatings; very few very fine roots; distinct wavy boundary,
Cg	70 - 120+cm	light grey (10YR7/1) silt loam; very firm; non sticky; non plastic; moderately developed medium and coarse blocky structure; many medium and coarse distinct bright brown (7.5YR5/6) and few medium distinct yellow brown (10YR6/8) mottles; few distinct bright bright brown (7.5YR5/8) clay coatings in cracks and on ped faces.

SOIL SERIES: Tauherenikau series

NEW ZEALAND GENETIC CLASSIFICATION: yellow-brown stony soil associated with intergrade between yellow-brown loams and yellow-brown earths

GEOGRAPHICAL DISTRIBUTION IN THIS SURVEY: The western side of the survey area toward the Tauherenikau River

PARENT MATERIAL: very stony and sandy greywacke alluvium

PHYSIOGRAPHIC POSTION IN THIS SURVEY: on gently sloping river fans and river terraces of Ohakean age

MICRORELIEF: flat

LANDFORM GENESIS: fluvial

VEGETATION AND LANDUSE: ryegrass / clover pasture
Sheep, deer, and goat grazing, some dairying
Long term grass

RANGE OF ELEVATION: 30 - 50 m.a.s.l.

DRAINAGE CLASS: well drained

RAINFALL RANGE: 750 - 1320mm

FLOODING: nil

EROSION: nil

SURFACE STONES: 1% - 5% (most have probably been picked up from the surface)

CHARACTERISTIC PROFILE FEATURES:

Profiles have typically brown topsoils and brown subsoils with few to common mottles. Profiles are extremely stony throughout with many of the stones in the subsoil iron coated. In most profiles the cementation of Fe coatings with stones and gravels has produced an Fe pan occuring at 90 - 120cm. The stones and gravels in the profiles tend to be more weathered and the profile a much browner colour than the gley soils.

MAPPING UNITS AND AREAS IN THE PRESENT SURVEY:

Tauhereikau series is dominated by Tauherenikau very stony silt loam mapping unit.

RANGE OF PROFILE FEATURES WITHIN THE SURVEY:

HOR	THICKNESS (cm)	COLOUR	MOTTLES	TEXTURE	STONES	CONSISTENCE	STRUCTURE
Ap	18-23	10YR2/1, 2/3, 3/2	none	si l	many - abundant (15-70%) stones	very fr to fr	mod dev fine nut, coarse crumb
AB	7-10	10YR4/2- 4/4,3/2	may have 2 - 20% fine-med, faint-distinct 10YR5/8 or 10YR3/3 [1]	si cl l	abundant (35-70%) stones and few boulders	fr	mod dev fine-med nut, coarse crumb
Bw_1	15-25	10YR5/3, 7.5YR4/3- 5/3	may have 2 - 20% fine - med dist 10YR5/8, 5/6, 7.5YR5/8 - 5/6	si cl l, sandy l	abundant (35-70%) stones [2] and boulders	fr to firm	mod dev med and fine nut, coarse crumb
Bw_2	13-20	10YR5/3- 5/4	may have 2 - 20% 7.5YR4/6, fine faint 10YR5/6	co s l, s l, l s	abundant (35-70%) stones [3] and boulders	fr to firm	mod-wkly dev med- fine crumb
Bms_1 or B_c [4]	25-30	10YR4/3, 7.5YR4/4	may have fine faint 7.5YR5/8, 10YR5/8	l co s, co s l	abundant (35-70%) stones and boulders	firm to very firm	massive, single grain
Bms or Bms_2	10-18	10YR4/3, 7.5YR4/4	none	l co s, co s l	profuse (>70%) stones [5] and boulders	very firm to extr firm	massive
BC [6]	20+	10YR5/3- 5/4	none	l co s, co l s	abundant- profuse	very firm	single grain

(Based on auger descriptions and 7 profile descriptions)

Notes for table:

1) many profiles have no mottles in this horizon
2) some stones may have Fe coatings and concretions
3) may have 0 - 10% distinct 5YR4/6 - 4/8 clay and Fe coatings on stones
4) some horizons have semi or continuous cementation Fe pan. 5YR4/6 - 4/8 clay coatings
5) many (>50%) clay and Fe 5YR5/6 coatings Continuous Fe pan
6) uncemented, many clay 10YR5/6 coatings

TYPIFYING PROFILE: Tauherenikau very stony silt loam

LOCATION: Profile in bank adjacent to large man made pond on the southern side of Moroa Road, approximately 2 km west of Morrisons Bush substation

GRID REFERENCE: NZMS260 S27 130 069

TOPOGRAPHY: gently sloping fan

SLOPE: flat (0^{o})

DRAINAGE: well drained

PARENT MATERIAL: Quartzo - feldspatic greywacke gravels and alluvium

HORIZON	DEPTH	DESCRIPTION
Ap	0 - 21cm	brownish black (10YR3/2) silt loam (rubbed; brownish black 7.5YR3/2); friable; non sticky; non plastic; moderately developed fine nut structure plus strongly developed coarse crumb structure; abundant weakly weathered subrounded gravels and stones; abundant very fine roots; distinct wavy boundary.
AB	21 - 30cm	brown (10YR4/4) rubbing to 7.5YR4/4 silty clay loam; friable; slightly sticky; slightly plastic; moderately developed medium nut structure plus moderately developed coarse crumb structure; abundant weakly weathered subrounded gravels and stones; abundant very fine roots; indistinct boundary,

Bw_1	30 - 46cm	brown (7.5YR4/4) silty clay loam; friable; slightly sticky; non plastic; moderately developed fine nut structure plus moderately developed coarse crumb structure; abundant weakly weathered subrounded gravels, stones and boulders; few distinct dull reddish brown to reddish brown (5YR4/4 - 4/8) clay, organic and Fe coatings on stones; many very fine roots; indistinct boundary,
Bw_2	46 - 65cm	dull yellowish brown (10YR4/3) coarse sandy loam; rigid; non sticky; non plastic; weakly cemented moderately developed medium crumb structure plus weakly developed fine nut structure; abundant weakly weathered subrounded stones, gravels and boulders; few distinct reddish brown (5YR4/6) clay, organic and Fe coatings on stones; abundant very fine roots; indistinct wavy boundary,
Bms_1	65 - 90cm	dull yellowish brown to brown (10YR4/3 - 7.5YR4/4) loamy coarse sand; extremely firm; non sticky; non plastic; continuous Fe pan; massive; profuse weakly weathered subrounded gravels stones and boulders; many prominent bright reddish brown (5YR4/6) clay, organic and Fe coatings on stones; distinct wavy boundary,
Bms_2	90 - 106cm	brown (7.5YR4/4) loamy coarse sand; extremely firm; non sticky; non plastic; continuous Fe pan; massive; profuse weakly weathered subrounded gravels, stones and boulders; many prominent bright reddish brown (5YR4/6) clay, organic and Fe coatings on stones; distinct wavy boundary,
BC	106 - 140+cm	dull yellowish brown (10YR5/3) loamy coarse sand; firm; non sticky; non plastic; single grain; abundant weakly weathered subrounded gravels stones and boulders; many distinct yellowish brown (10YR5/6) clay coatings on stones.

APPENDIX 2.

METHOD FOR THE PREPARATION OF POLLEN FROM FIELD SAMPLES FOR POLLEN ANALYSIS.

1. Treatment with Potassium Hydroxide (KOH);

(KOH removes the humic acids from the peat and unclumps the peat).

Place about 1 - 5 grams of peat in centrifuge tubes. Add 5 mls of 10% KOH (or to 3/4 fill the tube). Disperse the sediment in the solution with a glass rod. Warm in waterbath for at least 10 minutes, keep just below boiling point, stirring occasionally with glass rods. (8 samples are proceeded at one time).

2. Sieving to Remove Plant Fragments;

Pour the contents of the tube through a 100 mesh sieve to remove most of the sediment and plant fragments. Retain contents of sieve for examination. Rinse tube and sieve several times with distilled water collecting sample into numbered beakers. Between sieving each sample;

1) Rinse sieve twice in tap water and once in distilled water.

2) Heat sieve to red hot over flame. Allow to cool.

All the filtrate must be centrifuged and decanted from the beakers so that only the pollen remains in the tube. Centrifuge at 2000 $^{rev}/_{min}$ for 4 minutes.

3. Treatment with Hydrofluoric acid (HF);

N.B. If the sample contains $CaCO_3$ (shell material etc.) add 10% HCl and continue to till the production of CO_2 ceases. (it is dangerous if HF is added to a sample that contains $CaCO_3$).

Add enough 70 - 95% alcohol to the sample to flush it from the tube into a nickel crucible. (Nickel crucibles are used because of the corrosive effects of HF). The remainder of this procedure must be carried out in a fume cupboard. PROTECTIVE CLOTHING MUST BE WORN.

Add a small quantity of 40% HF to each sample. Crucibles are then placed on a pre-heated sand bath till sediment has gone and fluid has evaporated. (Tripor beakers and a water bath may be used here) (The amount of HF used depends on the quantity of sand and inorganic matter that has to be removed). When samples are nearly dry remove from heat and add enough 10% HCl to 3/4 fill clean centrifuge tubes. Clean crucibles in plenty of water. (it is now no longer nessesary to use the fume cupboard,

4. Flocculation;

The tubes are now placed in 250 ml beaker of warm water and gently heated wihout boiling. The silicates will pass into solution and the supernatant fluid will turn green (until then the sediment will remain at the bottom of the tube) A reliable guide to the complete removal of the silicates is the supernatant becoming completely clear. (This may need to be repeated if there is a large amount of inorganic material in the original sample, if not removed the silicates make the slides cloudy and hard to examine.)
Centrifuge and decant, add distilled water, centrifuge and decant.

5. Bleaching;

Add bleach (recipe supplied) up to 3 cm below top of tube CAREFULLY. Leave the tubes of up to one hour stirring occasionally. Centrifuge and decant into sink of running water. Rinse in distilled water, centrifuge and decant, twice.

6. Acetolysis;

(for the removal of cellulose)

1) Add 3 mls of Glacial acetic acid to each tube. Stir, centrifuge and decant.
2) Make up the acetolysis mixture as follows; Using extreme care pour 1.5 mls of conc. Sulphuric acid gently into 13 mls of Acetic Anhydride, mix gently.
3) Add a few mls into each tube, and transfer tubes into boiling waterbath in the fume cupboard, and heat for exactly 4 minutes. Remove from heat.
4) Centrifuge and decant into running water in sink.
5) Add 5 mls Glacial acetic acid, stir centrifuge and decant.
6) Add 10 mls distilled water, stir, centrifuge and decant.

7. Staining;

1) Add 10 mls of distilled water and 3 drops of 10% KOH, stir centrifuge and decant.
2) Adddiluted Basic Fuchsin stain to each tube. Stir and leave ten minutes, stir centrifuge and decant. (more or less staining may be needed)
3) Add 10 mls distilled water, stir, centrifuge and decant

8. Mounting;

Use rectangular cover slips size 40 by 22 mm.

1) Stir pollen gently. Use a new disposable pipette each time, and place two drops on warm slide. Add two drops of Gycerine Jelly and stir gently with sterile toothpick.
2) Lower cover slip onto slide, remove slide from warm plate to cool and set.

Preparation of Bleach for treating fossil pollen;

To make 500 ml.

Add 280 ml of Glacial acetic acid to 157 ml distilled water.

Add 75.5 grams of Sodium Chlorate.

To this add very slowly and carefully (5 ml at a time) 35 ml conc. Sulphuric acid.

Stir until dissolved.

Preparation of Glycerine jelly;

Dissolve 42 grams of gelatine in 114 mls of warm distilled water, add 6 grams of phenol crystals and 157 ml Glycerine (AR). Complete dissolving by gentle warming. When dissolved centrifuge in large tubes to remove insoluble residue. Bottle the jelly. If correctly made it should set to a firm consistency. After the jelly has been heated a number of times it will become darker and stickier and should be discared.

Source:

Dr M.S. McGlone, Botany Division, D.S.I.R., Lincoln.

APPENDIX 3.

ESTIMATION OF THE TRUE PROPORTION AND THE CONFIDENCE INTERVAL FOR A POLLEN TYPE WITHIN THE SUM.

(after Mosimann 1965)

At each depth in the pollen spectra the proportion p of a pollen taxa within the pollen sum is estimated by the ratio $^{x}/_{n}$ where x = number of grains of the pollen type, and n = pollen sum.

If n > 200 then the confidence interval of the esimated proportion of the grain (p), at the 95% confidence level is calculated accordingly;

$$95\%\ c.l. = \frac{p + \left[\frac{(1.96)^2}{(2n)}\right] \pm (1.96)\ \frac{[\,p\,(1-p)\,]}{n} + \left[\frac{(1.96)^2}{(4n^2)}\right]}{1 + \left[\frac{(1.96)^2}{n}\right]}$$

For an example pollen from *Nothofagus fusca* type in Core A, at 15 - 20 cm is tested, where p = 0.127 and n = 300.

$$95\%\ c.l. = \frac{0.127 + \left[\frac{(1.96)^2}{(600)}\right] \pm (1.96)\ \frac{[\,0.127\ (1-0.127)\,]}{300} + \left[\frac{(1.96)^2}{(1200^2)}\right]}{1 + \left[\frac{(1.96)^2}{300}\right]}$$

95% c.l. = 0.149 - 0.074

For the sample at 85 - 90 cm, the 95% confidence interval is 0.051 - 0.015. These intervals do not overlap so each sample can be said to have come from a different population. There is therefore, a significant difference in the pollen grain counts of *Nothofagus fusca* type at these depths. Table 1 gives the figures calculated for figure 3.5.

TABLE ONE: Tables of figures of 95% confidence limits for;
(where n = 300)

A: *Nothofagus fusca* type;

Depth	Core A	Core B	Core C	Core D
15 - 20cm	0.149-0.074		0.113-0.053	0.131-0.066
25 - 30cm	0.104-0.047		0.106-0.048	0.109-0.050
35 - 40cm	0.075-0.028		0.097-0.042	0.072-0.026
45 - 50cm	0.072-0.023		0.076-0.027	0.053-0.015
55 - 60cm	0.063-0.021		0.058-0.015	0.095-0.038
65 - 70cm	0.066-0.020		0.055-0.017	
75 - 80cm	0.070-0.022		0.069-0.018	
85 - 90cm	0.043-0.008	0.043-0.010	0.051-0.015	
95 - 100cm	0.051-0.015	0.056-0.012	0.053-0.015	
105- 110cm	0.106-0.048	0.085-0.032	0.060-0.019	
115- 120cm		0.067-0.023	0.036-0.008	
125- 130cm		0.039-0.009		

B: *Dacrydrium cupressinum*:

(where n = 300)

Depth	Core A	Core B	Core C	Core D
15 - 20cm	0.209-0.126		0.333-0.232	0.226-0.127
25 - 30cm	0.239-0.150		0.270-0.177	0.251-0.160
35 - 40cm	0.213-0.129		0.261-0.170	0.249-0.159
45 - 50cm	0.076-0.027		0.146-0.073	0.210-0.127
55 - 60cm	0.177-0.101		0.228-0.124	0.208-0.121
65 - 70cm	0.087-0.029		0.216-0.132	
75 - 80cm	0.133-0.063		0.238-0.132	
85 - 90cm	0.146-0.073	0.177-0.101	0.206-0.124	
95 - 100cm	0.128-0.063	0.158-0.071	0.216-0.132	
105- 110cm	0.202-0.121	0.161-0.088	0.216-0.132	
115- 120cm		0.088-0.033	0.136-0.070	
125- 130cm		0.177-0.056		

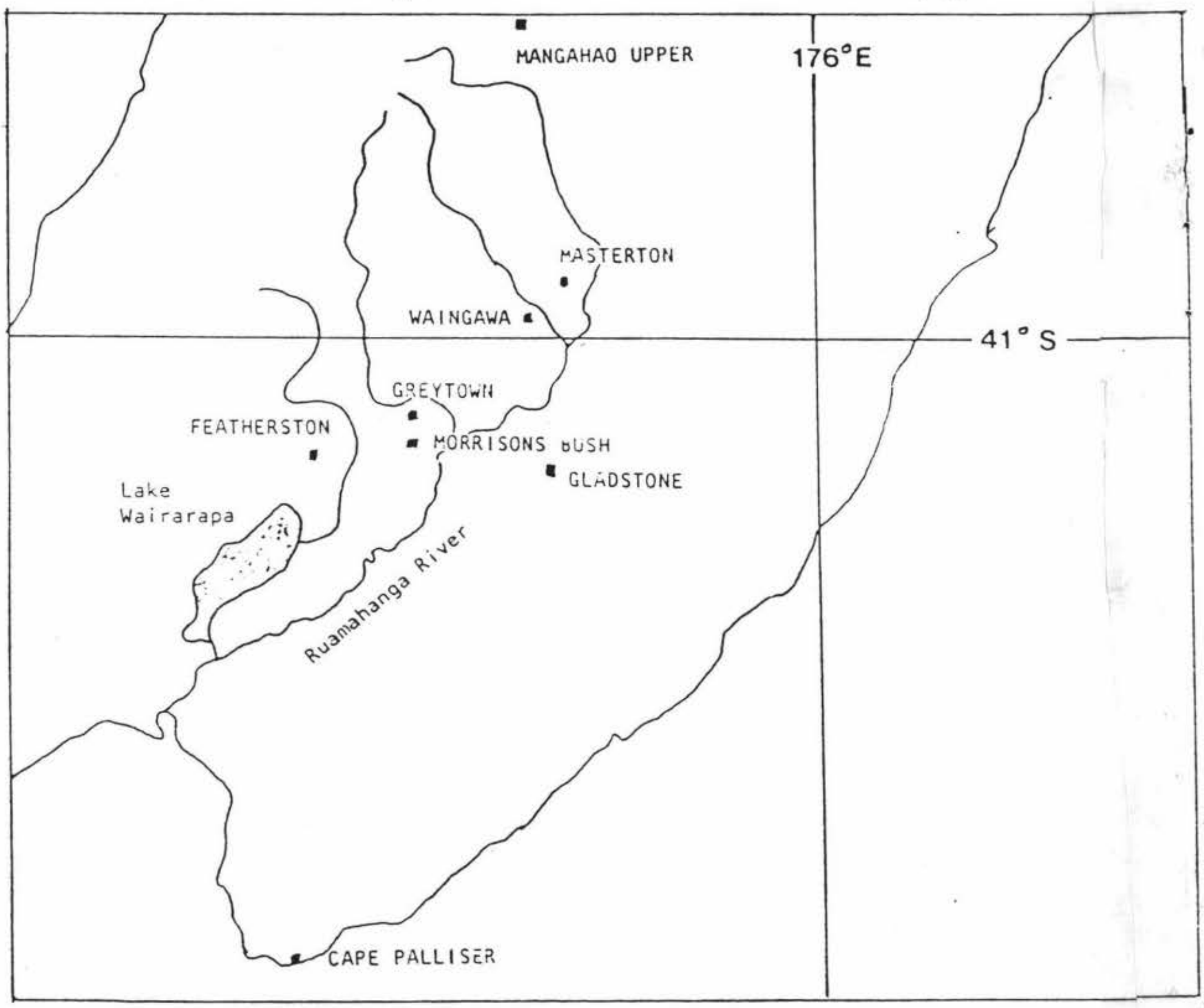
C: Podocarp group

(where n = 300)

Depth	Core A	Core B	Core C	Core D
15 - 20cm	0.191-0.110		0.150-0.080	0.133-0.068
25 - 30cm	0.243-0.155		0.155-0.084	0.227-0.141
35 - 40cm	0.227-0.134		0.177-0.101	0.254-0.164
45 - 50cm	0.243-0.155		0.262-0.166	0.270-0.177
55 - 60cm	0.212-0.124		0.186-0.104	0.218-0.129
65 - 70cm	0.288-0.189		0.206-0.124	
75 - 80cm	0.262-0.166		0.353-0.234	
85 - 90cm	0.265-0.173	0.210-0.127	0.195-0.114	
95 - 100cm	0.275-0.182	0.279-0.170	0.195-0.114	
105- 110cm	0.206-0.124	0.286-0.191	0.339-0.236	
115- 120cm		0.395-0.289	0.281-0.186	
125- 130cm		0.249-0.159		

APPENDIX FOUR a)

Locations of climatical stations mentioned in text and tables (from N.Z. Met. Ser. Misc. Pub. 175)



APPENDIX 4b).

Definition of Environmental Groups used in Figure 3.14 and 3.15.

Nothofagus.
- *Nothofagus fusca* type
- *Nothofagus menziesii*

Tree Podocarps.
- *Podocarpus* total (corroded)
- *Prumnopitys taxifolia*
- *Prumnopitys ferruginea*
- *Podocarpus totara*
- *Dacrydium cupressinum*
- *Dacrycarpus dacriodes*

Woody species.
- *Metrosideros*
- Mrytaceae (corroded)
- *Syzygium maire*
- *Laurelia*
- *Alectryon*
- *Weinmannia*
- *Carpodetus*
- *Knightia*
- *Quintinia*
- *Elaeocarpus*
- Malvaceae
- *Nestegis*
- *Paratrophis*
- *Griselinia*
- *Pseudopanax*
- *Dodonaea*
- *Ascarina*
- *Muehleneckia*
- *Rubus*
- *Freycinetia*
- *Tupeia*
- *Leptospermum*
- *Coriaria*
- *Coprosma*
- *Myrsine*
- *Compositae*
- *Dracophyllum*
- *Paratrophis*
- *Neomyrtus*

Herbs.
- Gramineae
- *Taraxacum* type
- *Collospermum*
- *Astelia*

Swamp Plants.
- Cyperaceae
- *Typha*
- *Phormium*

Ferns and spores.
- *Cyathea*
- *Dicksonia*
- Monolete fern spores
- *Phymatodes*
- *Hymenophylum*
- *Histiopteris*
- *Lycopodium*
- *Pteridium*

FIGURE 2.2 MAP OF THE LATE QUATERNARY DEPOSITS OF THE MOROA AREA.

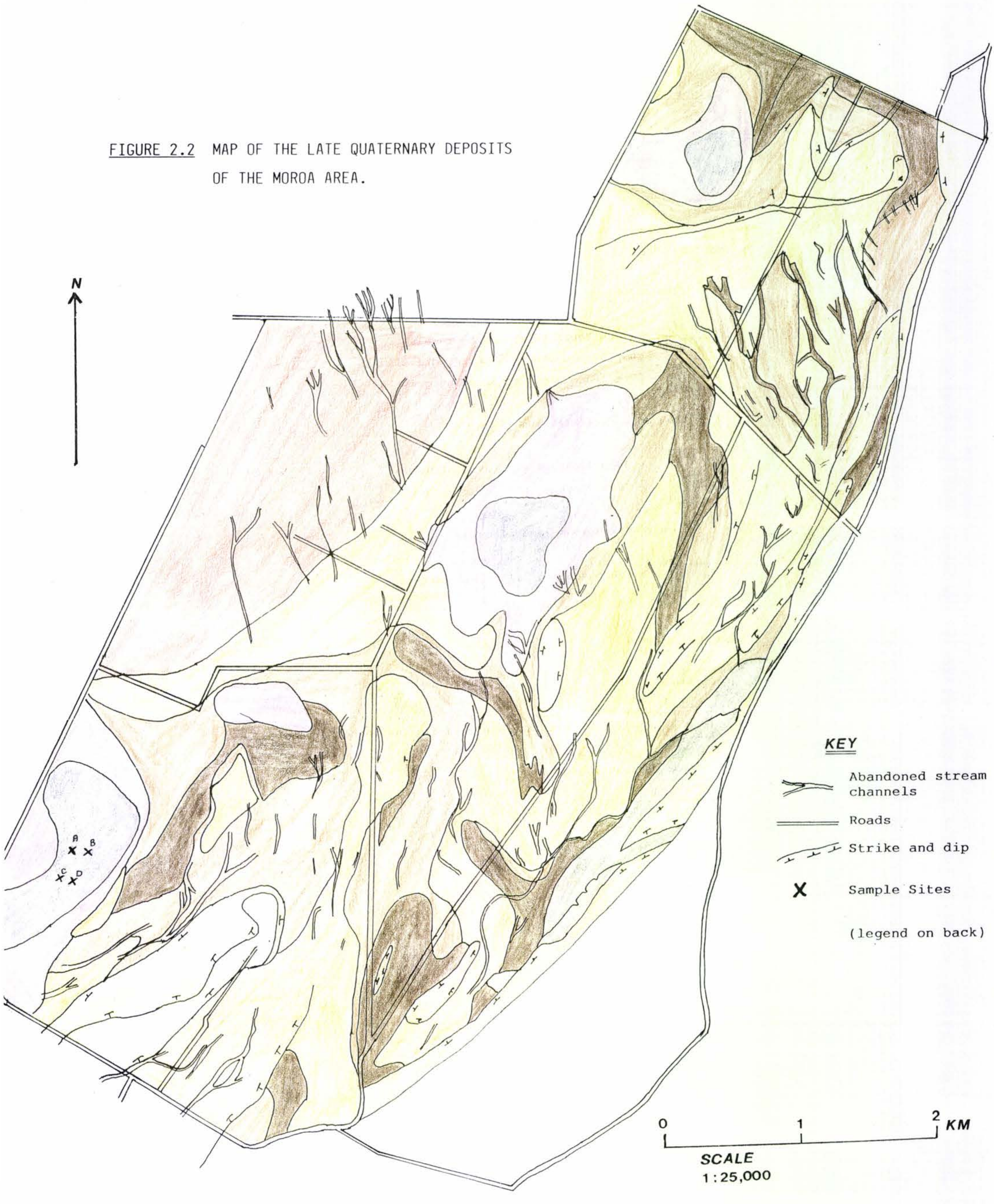


Figure 2.2: (legend) Late Quaternary Deposits of the Moroa Area south of Greytown.

Holocene Deposits

- from alluvium

< 10cm depth to abundant gravels

10 - 30cm depth to abundant gravels

30 - 100cm depth to abundant gravels

- from peat over alluvium

< 40cm depth of peat over alluvium

> 40cm depth of peat over alluvium

- from reworked loess and alluvium

> 100cm depth of alluvial material

Ohakean Deposits

- from alluvium

< 10cm depth to abundant gravels (Waiohine Surface)

- from Ohakean loess

FIGURE 2.3 MAP OF THE SOILS OF THE MOROA AREA

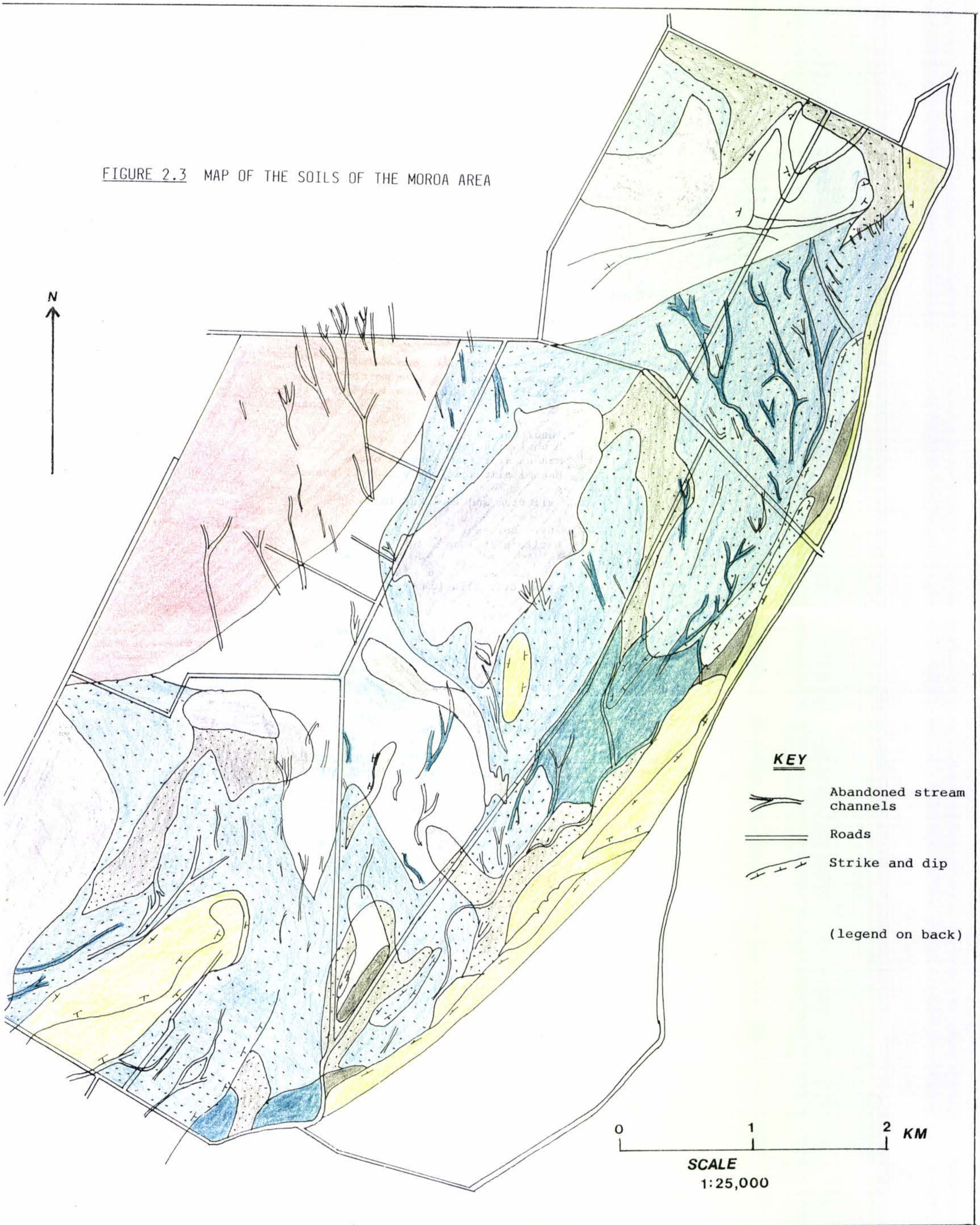


Figure 2.3: (legend) Pedological Legend of soils of the Moroa Area south of Greytown.

Gley Soils

- from alluvium

Otukura Series
Otukura stony silt loam
Otukura stony silt loam mottled phase
Otukura stony silt loam strongly mottled phase

Maunui Series
Maunui silt loam
Maunui silt loam mottled phase
Maunui silt loam peaty topsoil phase

- from alluvium and reworked loess

Watiro Series
Watiro silt loam

Organic Soils

- from peat over alluvium

Taratahi Series
Taratahi peat

Yellow - grey earths

- from loess

Wharekaka Series
Wharekaka silt loam

Yellow - brown stony soils associated with intergrades between yellow-brown loams and yellow-brown earth

- from alluvium

Tauherenikau Series
Tauherenikau very stony silt loam


SUMMARY DIAGRAM
Nothofagus
Tree Podocarps
Woody species
Herbs
Swamp plants
Ferns & Spores
0
20
40
60
80
100%
NOTHOFAGUS AND TREE PODOCARPS
WOODY SPECIES
HERBS
SWAMP PLANTS
FERNS AND SPORES
Nothofagus fusca type
Nothofagus menziesii
Podocarpus total
Prumnopitys taxifolia
P. ferrugineus
Podocarpus totara
Dacrydium cupressinum
Dacrycarpus dacrydiodes
Metrosideros
Myrtaceae
Syzygium maire
Laurelia
Alectryon
Weinmannia
Carpodetus
Knightia
Quintinia
Elaeocarpus
Malvaceae
Nestegis
Parsonsia
Griselinia
Pseudopanax
Pseudowintera
Dodonaea
Ascarina
Muehlenbeckia
Rubus
Freycinetia
Tupeia
Leptospermum
Coriaria
Coprosma
Myrsine
Compositae
Dracophyllum
Pittosporum
Neomyrtus
Gramineae
Taraxacum type
Collospermum
Astelia
Cyperaceae
Typha
Phormium
Cyathea
Dicksonia
Monolete fern spores
Phymatodes
Hymenophyllum
Pteridium
PROFILE C
metres
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
1·2
1·25
5700 ± 95 yrs B.P. (NZ7244)
7870 ± 115 yrs B.P. (NZ7245)
Scale
0
5
10
15%
Key
+ = < 1%
peat
peat & charcoal
PROFILE D
metres
0·1
0·2
0·3
0·4
0·5
0·6
5700 ± 95 yrs B.P. (NZ7244)
Scale
0
5
10
15 %

FIGURE 3.9


SUMMARY DIAGRAM
Nothofagus
Tree Podocarps
Woody species
Herbs
Swamp plants
Ferns & Spores
0
20
40
60
80
100%
NOTHOFAGUS AND TREE PODOCARPS
WOODY SPECIES
HERBS
SWAMP PLANTS
FERNS AND SPORES
Nothofagus fusca type
Nothofagus menziesii
Podocarpus total
Prumnopitys taxifolia
P. ferrugineo
Podocarpus totara
Dacrydium cupressinum
Dacrycarpus dacrydiodes
Metrosideros
Myrtaceae
Syzygium maire
Laurelia
Alectryon
Weinmannia
Carpodetus
Knightia
Quintinia
Elaeocarpus
Malvaceae
Nestegis
Parsonsia
Griselinia
Pseudopanax
Pseudowintera
Dodonaea
Ascarina
Muehlenbeckia
Rubus
Freycinetia
Tupeia
Leptospermum
Coriaria
Coprosma
Myrsine
Compositae
Neomyrtus
Gramineae
Plantago
Taraxacum type
Astelia
Cyperaceae
Typha
Phormium
Cyathea
Dicksonia
Monolete fern spores
Phymatodes
Histiopteris
Pteridium
Lycopodium
PROFILE A
metres
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
6350 ± 110 yrs B.P.
(NZ7248)
Scale
0 5 10 15 %
Key
+ < 1 %
peat
peat & charcoal
Scale 0 5 10 15 %
PROFILE B
metres
0
20
40
60
80
100 %
0·8
0·9
1·0
1·1
1·2
1·3
8500 ± 120 yrs B.P.
(NZ7246)
25

FIGURE 3.7