THE LATE HOLOCENE VEGETATIONAL AND CLIMATE HISTORY OF WESTERN HAWKES BAY, NEW ZEALAND

A thesis submitted in partial
fulfilment of the requirements for the degree of

Master of Science
in Quaternary Science

at
Massey University, New Zealand

by
Colleen Thérèse Hannan
1998

Frontispiece: Balls Clearing Scenic Reserve, Puketitiri

ABSTRACT

Sediments from (a) a flush, two peat mires and two ponds from a 94 km transect along the Mohaka Fault trace (a northern extension of the Wellington Fault) set in the eastern foothills of the Ruahine Range, in western Hawkes Bay, New Zealand, and (b) from a lake at Te Pohue in northwestern Hawkes Bay, are analysed for their pollen and charcoal records to reconstruct the late Holocene vegetational and climatic history of the region.

Western Hawkes Bay lies westward of an obliquely converging plate boundary, the Hikurangi Trough. This oblique convergence has resulted in tectonic strain being partitioned into domains of extension, contraction and strike-slip across Hawkes Bay. Within the study area, strain has resulted dominantly in primary tectonic landforms such as fault scarps and fault lines, and secondary tectonic landforms such as tilted and folded surfaces. Features of movement along the Mohaka Fault in the geomorphology include right-laterally offset streams, ridges with distinctive linear troughs along the line of the fault and the formation of triangular spurs.

The region generally has a warm, dry climate, and suffers from drought periodically, with the drought often being broken by heavy rains in the autumn. These rains may be of cyclonic proportion. Due to both seismic and co-seismic activity in the region, the landscape is both uplifted and broken, and continually subject to mass movement; localised topoclimates are also common. This study determines how the western Hawkes Bay vegetational cover and its composition have changed in response to late Holocene climate changes through analysis of sediment cores. Also addressed is the extent to which tectonism, volcanicity, fire, major storm events and human activity have left a local overprint on the regional vegetational pattern.

Climatically the region may be divided into three sectors: a dry central sector, (Big Hill site); flanked by moister southern and northern sectors.

The regional vegetation in the southern sector was dominated by a *Nothofagus*- mixed podocarp forest in the Kashmir region from c. 800 yrs BP. up to when the site was affected by fire in 1888. In the Hinerua region, 14 kms farther north, *Nothofagus fusca* with a minor *Dacrydium cupressinum*-dominated/ mixed podocarp forest, was established by c. 2790 yrs BP.

The regional vegetation of the central sector from c. 3700 to 3000 yrs BP. was predominantly a *Prumnopitys taxifolia*/mixed podocarp forest. There was also a notable *Nothofagus* component. There is a c 1900 year hiatus in the vegetation record between c. 3000 and 1150 yrs BP when no sediment accumulated at the Big Hill site. The regional forest of the central sector at c. 1150 yrs BP. was still a predominantly *Prumnopitys taxifolia*-dominated/mixed podocarp forest. However, *Nothofagus* was less important in this latter forest. At Willowford, 18 kilometres north of Big Hill, the same *Prumnopitys taxifolia*-dominated/mixed podocarp forest was evident at about 500 yrs BP. At Hawkstone, 10 kms north of Willowford, a *Nothofagus/ P. taxifolia*-dominated mixed podocarp forest was established by 6500 yrs BP. About 3400 yrs BP *Dacrydium cupressinum* became the dominant podocarp, thus placing the Hawkstone region within the northern climatic sector from this date, up to the present.

The regional vegetation of the northern sector from 1850 yrs BP. until European land clearance in the late 19th century at Te Pohue, was a *Dacrydium cupressinum* -dominated/mixed podocarp assemblage with a notable *Prumnopitys taxifolia* component.

Several erosional events have been identified in the stratigraphy of the sites. By estimating the age of these events by sediment accumulation rates, some of these events have been tentatively linked to Grant's (1985) hypothesis of periodic climate-forced erosional events having partially destroyed the forest cover in the western Hawkes Bay region. Using radiocarbon dates from this study, often in conjunction with sediment accumulation rates, it has been possible to identify some erosional events as earthquake generated by linking these events to other known and radiocarbon dated movements along the Mohaka Fault trace in western Hawkes Bay.

Volcanicity has been identified as a factor influencing forest cover in the northern part of western Hawkes Bay. At Hawkstone, microscopic charcoal has been identifed at several levels throughout the 6500 year pollen record of the site. However, the sediment accumulation rate was too low to determine the exact nature of the disturbance, and the forest quickly recovered in each case. Although a 0.20 m layer of reworked lapilli from the Waimihia eruption (3280 ± 20 yrs BP.) was recorded at the site, no fire or disturbance to the vegetation was recorded. However, above the Taupo Tephra (1850 ± 10 yrs BP.) fire is continually recorded at the site. As a result the regional forest did not return. Primary ignimbrite from the Taupo eruption forms the base of the Te Pohue site. The regional forest was destroyed by fire in conjunction with this event. A similar forest to before the event, was re-established within c. 230 years.

Polynesian deforestation is identified by the advent of high frequencies of *Pteridium exculentum* and microscopic charcoal in the pollen record in the Willowford region c. 480 ± 170 yrs BP., and in the Big Hill region c. 435 ± 140 yrs BP.; and are coincident with the decline of indigenous forests in each case.

European settlement, commencing in the mid-nineteenth century at Te Pohue and about 1880 AD. at Hinerua, is identified by the decline of indigenous forests in these areas, coincident with the appearance of exotic pollen types such as *Pinus*, *Taraxacum* and pasture grasses.

ACKNOWLEDGEMENTS

I wish to thank Associate Professor Vince Neall, my chief supervisor, for reading my thesis, and for helpful suggestions on how it could be improved. I would also like to thank Professor John Flenley for reading and commenting on the palynological sections; for permission to use the Geography Department's Zeiss microscope and for making pollen analysis work available to me to pay for one radiocarbon date and some living expenses.

My thanks are also extended to Drs. Clel Wallace and Alan Palmer of the Soil & Earth Sciences group of the Instutute of Natural Resources, Massey University for all their help over the past two years in sorting out many little, and not so little problems involved in my research.

I am also most grateful to Massey University for a Research Fund Grant to cover the cost of some radiocarbon dates, as well as for making available a two-year Graduate Assistantship in Earth Science, which helped with living expenses during the time of my studies.

In the Geography Department of Massey University thanks are also due to David Feek for assistance in the field (at times under very trying conditions); to Miss Leighanne Empson for assistance with the TILIA programme, and other incidental help; to Dr Patrick Hesp for making available copious hours of grain size analysis work that paid for a radiocarbon date and other study related expenses; and to Karen Puklowski, Sandy Robson and Olive Harris for their support and friendship.

Thanks also go to Peter van Essen of the Ecology Group of the Institute of Natural Resourses at Massey University for identifying plant and wood specimens.

I would also like to thank the landowners and farmers of western Hawkes Bay who granted access to the study sites, and at times provided overnight accommodation and helpful knowledge of the local flora.

Table of Contents

Chapter Three - Principles & Methods Employed

Chapter Four - Results

List of Figures

List of Tables

List of Appendices

CHAPTER ONE

1.1 INTRODUCTION

Palynological analysis provides key evidence for climate change during the late Quaternary, particularly in terrestrial environments. This evidence is interpreted as reflecting both latitudinal and altitudinal shifts in vegetation composition in response to varying climates during successive glacial and interglacial periods. Although evidence for changes in humidity is scarce when discussing the overall effects that climate has on vegetation, a link is usually forged between humidity and temperature change. In this respect, cooler temperatures are generally equated with drier conditions and warmer temperatures with wetter conditions in the Quaternary record of New Zealand (McGlone, 1988).

However, at a local level climate change may not be the only forcing mechanism involved in these shifts in vegetation composition. Tectonism, volcanicity, fire, major storm events and human activity are other possibilities which may leave a local overprint on a regional vegetational pattern.

This thesis is a palynological investigation of locations in the eastern foothills of the Ruahine Range in central Hawkes Bay (Figure 1.1). It is an area where intermittent movement along the Mohaka Fault, a major Quaternary fault in the eastern North Island, has formed a series of fault trenches in which clastic sediments, peat and tephra have accumulated.

The region forms part of the axial tectonic belt of the North Island - a belt of active deformation where the Pacific plate is being subducted beneath the Australian plate. Compression oblique to the tectonic belt has resulted in a series of fault-bounded basins and ranges. The Mohaka Fault is a series of active *en echelon* dextral strike-slip faults within the belt. Offsets along these faults have often blocked local drainage off the topographically higher ground immediately to the west, so creating suitable ponding environments for sediment and peat accumulation.

The sediments that are deposited in these ponding environments may reflect instability in the surrounding landscape, or be induced by a tectonic event, but they might also reflect fire or storm events. Given the proximity of the Taupo Volcanic Zone to the study area (Figure 1. 1) and carbonised logs in the Taupo ignimbrite in the region, consideration must also be given to the possible influence of volcanicity, with or without accompanying fire, on vegetation change in the region. The Ruahine Ranges to the west are composed of highly shattered greywacke and there is a history (Grant, 1965; 1966; Grant, et al., 1978; Page et al., 1994) of high intensity, cyclonic rainstorms from the east causing erosion and removal of bush on a large scale. It is expected such events might also be recorded in the pollen record.

No previous palynological investigations have previously been reported from this field area.

1.2 AIMS

The aims of this thesis are:-

1) To establish the nature of the late Holocene palaeoecology of western Hawkes Bay by analysing fossil pollen found in a series of sites situated along the Mohaka Fault.

2) To test whether or not the palynological record in cores obtained along the Mohaka Fault trace can be linked to erosional events which may or may not indicate movement along the fault.

1.3 OBJECTIVES

With the above aims for this study, the following objectives were defined:

1). Sample a representative record of the pollen entrapped in sediments at sites which are fault controlled or fault induced.

2). Prepare pollen diagrams based on pollen abundance obtained from microscopic slides prepared from the sediments recovered at each site.

3) Interpret the data to identify possible climate trends.

4). Obtain radiocarbon dates at selected depths to provide an absolute time frame within which the organic sediments accumulated.

5). Examine the stratigraphy in conjunction with the pollen record and geomorphology of each site to establish any relationships between them.

6). Compare the palynological data with other palynological evidence from the Ruahine Ranges in particular, and New Zealand in general.

1.4 STUDY AREA AND SITES

The field area is specifically located along the trace of the Mohaka Fault, to the east of the axis of the Ruahine Range in western Hawkes Bay. Figure 1. 1 locates the study area with reference to the North Island of New Zealand. This area is bounded to the south by Moorcock Saddle, and in the north by Te Pohue. Within the field area the Mohaka Fault is consistently upthrown to the east. The project centres on five principal sites, chosen because impeded drainage due primarily to movement along the Fault has resulted in water ponding to the west of the fault scarp. At a sixth site, Te Pohue, east of a splinter fault from the Mohaka Fault, a lake has formed behind a massive landslide.

Accessibility was a determinant factor for the sites. They were first selected following examination of aerial photographs and maps of western Hawkes Bay. Following discussion with Ms. J. Hansen, a PhD candidate in the Department of Soil Science at Massey University who was conducting a geological investigation along the Mohaka Fault, the various sites were then visited, and their suitability assessed.

The six chosen sites are a mixture of mires, bogs, ponds, flushes and a lake, as defined by Wardle (1991). Figure 1. 2 shows the location of the pollen sites in relation to the mountain ranges mention in the text. Where appropriate other localities referred to are also shown. Table 1 lists the pollen sites, together with their map reference, height above sea level and type of wetland.

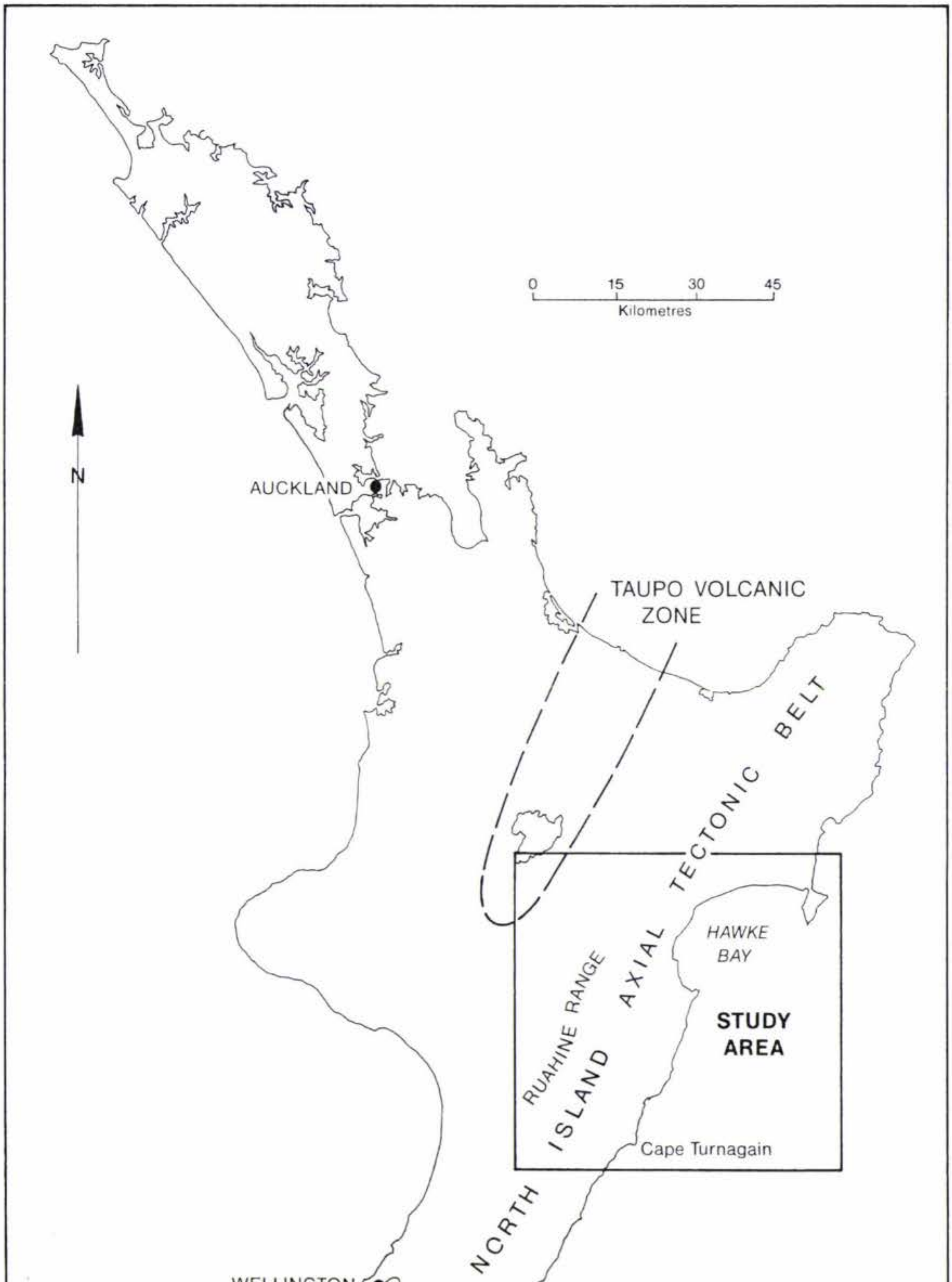


Figure 1. 1 Location of the study area with reference to pertinent physiographical features in the North Island, New Zealand

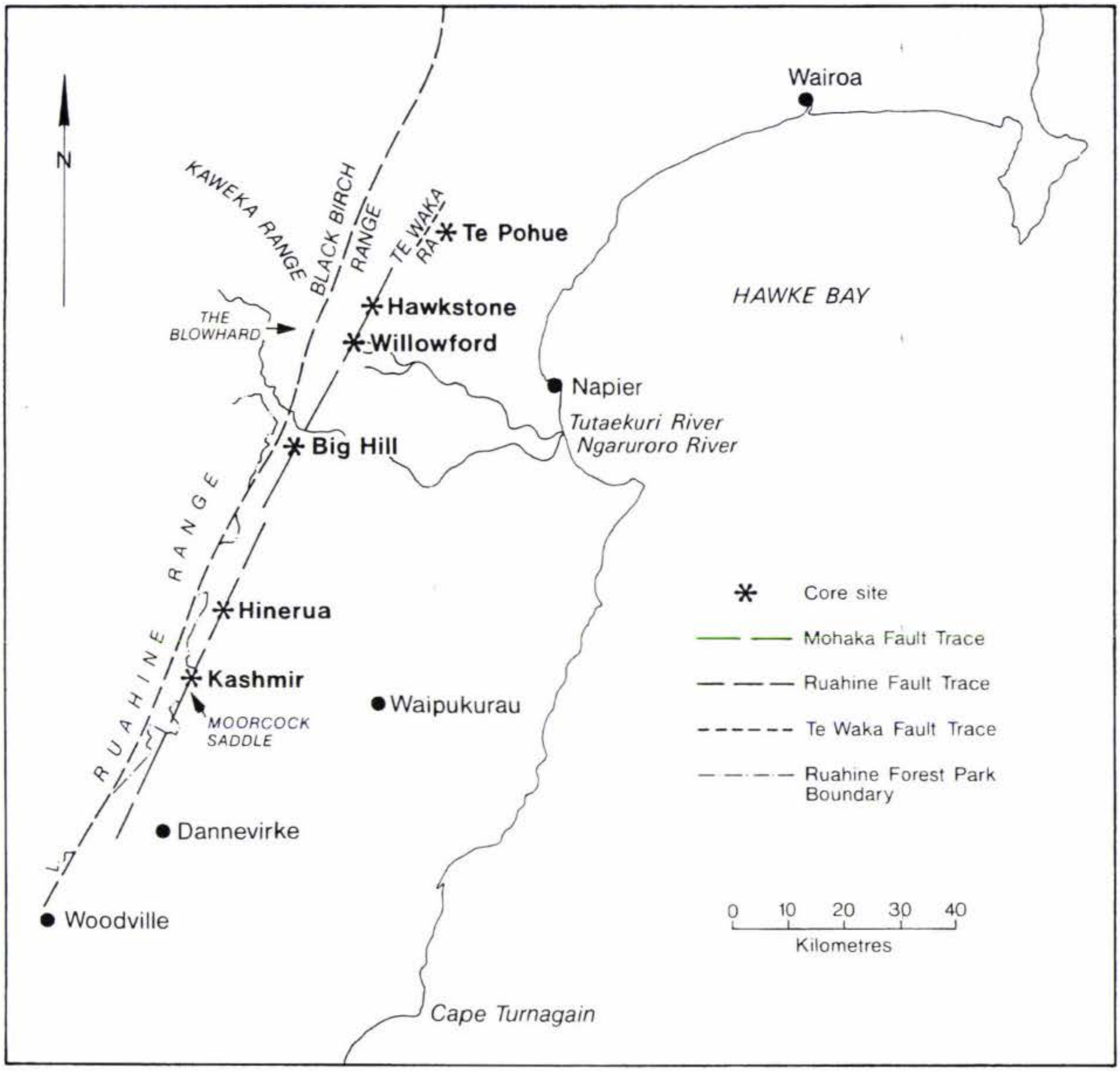


Figure 1. 2 Location of the six sites cored for pollen analysis in western Hawkes Bay

Site	Location	Map Reference NZMS 260	Height asl	Type of site
1. Kashmir	Moorcock Saddle	U22/785 341	700m	flush
2. Hinerua	Hinerua Rd. Extn.	U22/859 456	450 m	mire
3. Big Hill	Big Hill Station	U21/007 960	310 m	pond
4. Willowford	Willowford Station	V20/102 918	350 m	pond
5. Hawkstone	Hawkstone Station	V20/140 995	366 m	mire
6. Te Pohue	Lake at Te Pohue	V20/280 107	c. 550 m	lake

Table 1. Location of pollen sites cored, together with their map reference, height above sea level and type of wetland

1.5 ORGANISATION OF THESIS

Chapter one outlines the research objectives of this thesis. Chapter two provides an overview of previous relative research done in relation to the western Hawkes Bay region. In Chapter three the principles and methods employed in this study are outlined. In Chapter four the results of the research relating to the six sites are individually presented and discussed. Chapter five discusses the research findings of the study area in western Hawkes Bay as a unit, under the headings, geology and tectonic setting, paleoecology, climate implications, fire and anthropogenic impact, erosional influences, and evidence of earthquake influences. Chapter six summarises the research findings presented in this thesis

CHAPTER TWO : LITERATURE REVIEW

2. INTRODUCTION

This chapter aims to provide a general but selective literature review of the physical and environmental factors relative to the development of the western Hawkes Bay landscape. The study area involves the eastern Ruahine Range including the Mohaka Fault zone from the Kashmir region in the south, to Te Pohue in the north. The approach takes the same format as that followed in Chapter Five where the findings of this thesis are presented as a regionally integrated unit.

2.1 GENERAL GEOLOGY, GEOMORPHOLOGY & TECTONIC SETTING

Along the east coast of the North Island of New Zealand, the oceanic Pacific Plate has been obliquely converging with the leading edge of the continental portion of the Australian Plate. Here the tectonic setting is one in which the lighter Australian Plate is overriding the more dense Pacific Plate since the Miocene. This active plate boundary manifests itself offshore as the Hikurangi Trough. Lying to the west, on shore, Hawkes Bay forms part of the East Coast Shear Belt (Lewis, 1980, Cole & Lewis, 1981).

The oblique convergence at the plate boundary has resulted in tectonic strain that is partitioned into domains of extension, contraction and strike-slip, with many of the domains being marked by major faults. (Cashman & Kelsey, 1990; Cashman et al., 1992). From 10 Ma to about 3 Ma this region underwent subsidence and marine deposition. In the latest Pliocene a change to shortening through folding and reverse faulting brought basin filling to an end as the forearc began to contract (Kelsey et al., 1995) During the Plio-Pleistocene oblique subduction and accretion intensified as the Hikurangi margin rotated into a NNE-trending position (Cole & Lewis, 1981). About 1 Ma there was a switch from crustal shortening to dextral shear along major faults (Kelsey et al., 1995) Strain partitioning in the forearc tectonic region, together with underplating of the less dense Pacific Plate as it slides beneath the Australian Plate (Walcott, 1978) has resulted in tectonic uplift and produced the crustal deformational structures now exposed across the Hawkes Bay landscape.

A model comprising four major structural regions has been proposed for this tectonic setting (Cashman & Kelsey, 1990; Cashman et al., 1992; Erdman & Kelsey, 1992; Kelsey et al., 1993). These are,

1. an accretionary slope extending from the offshore Hikurangi Trench to the onshore coastal hills;
2. a forearc basin incorporating the coastal plains and inland hill country west of the plains;
3. a frontal ridge incorporating the fault bounded axial ranges in western Hawkes Bay;
4. a volcanic backarc basin incorporating the Taupo Volcanic Zone.

As that part of this model relative to the study area is the western portion of the forearc basin and the eastern portion of the frontal ridge, only this part of the model will be addressed hereafter. Geomorphic features of this landscape include both direct tectonic landforms such as fault scarps and indirect tectonic landforms such as tilted and folded Neogene and Quaternary surfaces. There is a distinct NNE/SSE alignment to these landforms, suggesting a residual rotational overprint of the crustal movements that occurred during the Plio-Pleistocene. Presently the domain strain regime along the western limit of the forearc basin is one of strike-slip faulting (Kelsey et al., 1995) along this NNE/SSW alignment.

Berryman (1988) has produced a model comparing geomorphic and tectonic features of the entire accretionary ridge system. That part of the model relative to the study area is reproduced as Table 2.1

Tectonic Domain	Tectonic Features	Geomorphic Features
Forearc Basin	• normal faults • tectonic subsidence during the Holocene • moderate, regional uplift during the Pleistocene • broad synclinal structure • stong uplift and formation of asymmetric syncline adjacent to western boundary faults	• low lying coastline • estuaries • barrier bars • low gradient rivers in coastal areas • fluvial terrace sequences caused by aggradation & downcutting inland • large landslides, perhaps triggered by large earthquakes • landslide dammed lakes • abundant superficial mass movement • sparse hot springs
Frontal Ridge	• oblique slip faults bounding region with horizontal to vertical slip ratio commonly 5 : 1 • intra-montane oblique faults • infaulted Neogene rocks along intra-montane faults • down-stepped, faulted western margin	• horizontally offset topography including streams and ridges and shutter ridges • remnants of late Tertiary marine erosion surface • general summit accordance • ignimbrite plateau onlapped at western margin • landforms and deposits of periglacial conditions including solifluction lobes, rock glaciers and shaved surfaces

Table 2.1 Tectonic and geomophic features within the forearc basin and the frontal ridge tectonic domains (reproduced from Berryman, 1988)

Within the study area the major physiographic terrain can be related to two tectonic domains identified above. These physiographic terrains are 1. Mountain Ranges and 2. Western hill country - rolling downland. However, as the following discussion demonstrates, where one zone terminates and the other begins is often hard to define. This is basically due to intra-block faulting, which often trends at right angles to the main fault movements.

1. Mountain Ranges.

Pertinent to this study are the Ruahine and Kaweka Ranges; both form part of the main axial ranges of the North Island. These ranges comprise indurated massive, slightly metamorphosed alternating beds of sandstones and siltstones, of marine origin. Known as greywacke, these rocks form part of the Torlesse Supergroup of Mid-Late Jurrasic age (Kingma, 1962). Uplift of up to 2000 m has occurred along these ranges since the early Pleistocene (Berryman, 1988). Also within the study area the Wakarara Range, a twenty kilometre-long greywacke piercement body, is separated from the main greywacke block of the Ruahine Range by a long narrow graben - the Ohara Depression (Kingma, 1958). In western Hawkes Bay these mountains form the eastern margin of the frontal ridge tectonic domain.

Faulting is most prominent along the eastern margin of the domain. Long faults, principally the Ruahine and Mohaka Faults, are arranged *en echelon* along the margin. The Mohaka Fault and its southern continuation, Wellington Fault, comprise a major dextral-reverse fault extending 300 km from Wellington northeast to Hawkes Bay.

The Ruahine Fault also shows evidence for dextral-reverse slip during the Plio-Pleistocene, in response to the dextral component of oblique convergence along the plate boundary. Current slip is oblique with at least five times more horizontal slip than vertical (Raub et al., 1987).

Deformation has resulted in the differential movement of several of the relatively rigid basement blocks. Strain is partitioned between the two northeast-trending domains that parallel the margin. In the Big Hill area the western domain abuts the axial ranges and is characterised by strike slip faulting. The Ohara Depression has developed within this zone. The eastern domain is undergoing contractual deformation. Here the Wakarara Range is a consequence of block uplift along a reverse fault within this domain (Erdman & Kelsey, 1992). It is likely both these domains accommodate oblique slip at depth where obliquely convergent motion is transferred across the plate interface (Cashman et al., 1992).

Associated effects of all these fault movements on the geomorphology include right-laterally offset streams, ridges with distinctive linear troughs along the line of the fault and the formation of triangular spurs (Berryman, 1988). There are exceptionally well-developed fault facets on the Ruahine Fault near Big Hill produced by the offset of spurs (Kingma, 1957a).

Faulting in the Wakarara block is common but not of major importance. Movement of the block as a whole took place in a southerly direction along the Mohaka Fault after the early Pleistocene (Kingma 1958; 1957a). Immediately north of Wakarara the character of the Mohaka Fault zone changes and becomes less well defined (Grapes et al., 1984). In this area the trace is now found within Neogene sediments (Hammond, 1997)

2. Western Hill-country and rolling downland

The hill-country and rolling downland along the western margin of the forearc basin contains several NE- SW blocks of uplifted greywacke basement. Those pertinent to this study are Maungaharuru, Te Waka, Black Birch, Maniaroa and Don Juan Ranges, and the Blowhard Plateau and Big Hill piercement block.

The northern Ruahine Range is separated from the Kaweka Range by a depression in the vicinity of Kuripapango. This comprises the NE-SW trending Kohurau Graben (a block some 32 kilometres long) which is bounded in the east by the Ruahine Fault Zone and elsewhere by the arcuate Kaweka Fault. Prior to its formation the region was crossed by an earlier southeast-striking graben - the Kuripapanga Graben. During the upper Pliocene both the Kaweka and Ruahine Faults were active (Kingma, 1957b). The block is crossed by two subsidiary faults systems running in a northwesterly (Maniaroa Fault) and a northeasterly direction, with the structure on the floor of the graben complicated by reverse faulting (Browne, 1986). In the area the Ruahine Fault splays into a number of northeast trending splinter faults (Grindley, 1960). In the Blowhard Plateau area these are represented by the Glenross Fault and its subsidiary the Lizard Fault (Browne, 1986). In this domain the Ruahine Fault trace converts to a range-bounding fault separating the Mesozoic greywacke rocks of the mountainland from the Neogene sedimentary rocks in the westen hill-country of the forearc basin (Hammond, 1997).

The Mohaka Fault is classified as active in the area, and crush zones associated with both these major faults are continually subject to mass movement (Lillie, 1953). The fault-controlled structures of the Maniaroa area comprise NE-trending horsts and grabens. This indicates NW-SE compression. There are also small structures with a dominant NE-SW compressional regime. This suggests that elements of both compression and extension are present in the eastern margin of the frontal ridge (Browne, 1986). These less dominant fault lineations may have played a major role in determining local river courses (Kamp, 1992) . For example, the Mohaka Fault is defined by a break in slope along the foot of the Maniaroa Range.

2.2 PALAEOVEGETATION

There have been no palaeovegetation studies reported from within the study area. For this reason the literature review in this section covers studies carried out at sites in the surrounding Hawkes Bay, Ruahine and Tongariro regions.

Lees (1986) reports on five-post glacial sites from along the eastern side of the southern Ruahine Range. In this region a podocarp-broadleaf forest was well established in the foothills as early as 12 900 ± 90 yrs BP. There was a dominance of *Prumnopitys taxifolia* and a notable absence of *Dacrydium cupressinum*, suggesting a cooler and drier climate than at present. By 10 340 ± 100 yrs BP. *Dacrydium* was abundant at all five sites. The frost- and drought-tender species *Ascarina lucida* (McGlone & Moar, 1977) increased, reaching 12 percent of the woody taxa count at the Manawatu site. This was interpreted as indicating a warmer and wetter climate than before.

By about 3400 yrs BP. *Ascarina* was declining and is almost absent from the southern Ruahine region today. *Quintinia* which requires an equable climate (Allen, 1961) was present at all the sites except the West Tamaki area, but is not recorded in the area at present. This pattern is interpreted as indicating frosts are more frequent today than 2000 years ago.

Today *Olearia colensoi*, which survives under frequent cloud cover and high winds, and requires a heavy, well distributed rainfall > 2500 mm/yr $^{-1}$, lies on either side of the Manawatu Gorge at an altitude that usually supports forest elsewhere in the Tararua and Ruahine Ranges (Wardle, 1991). A rise in *Olearia* at two sites on the Delaware Ridge in the southern Ruahine Range suggests a deterioration in climate at these altitudes where there may now be more cloud cover than formerly.

Wilmshurst & McGlone (1997) report on two sites in northern Hawkes Bay, one at Tutira, the other at Putere. Prior to the Taupo Tephra of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990), a tall podocarp/hardwood forest including a wide range of shrubs, climbers and ferns, was established at both sites. At Tutira *Prumnopitys taxifolia* was the dominant podocarp; and at Putere *Dacrydium cupressinum* dominated. Increase in charcoal fragments above the Taupo Tephra indicate that for more than a century after the eruption, fires disturbed the forest. This allowed for the expansion of *Coriaria*, *Aristotelia*, Poaceae, Asteraceae, and *Acaena*, all taxa characteristic of disturbance, but did not retard the expansion of the returning forest at either site.

Abundant charcoal fragments at Tutira at 490 cal yrs BP. and at Putere at 485 cal yr BP., corresponded with an abrupt change to a *Pteridium*-dominated fern-scrubland which included *Coriaria*, *Aristotelia* and *Coprosma*. This has been interpreted as evidence of Polynesian land clearance in northern Hawkes Bay. The fern-scrubland remained the dominant type of vegetation until European settlement when clearance began at both sites c. 1870 AD.

From a Lake Poukawa site, Pocknell & Millener (1984) report that a dense podocarp/ hardwood forest was present in the area throughout the 2000 year period preceding the Taupo eruption. *Prumnopitys taxifolia* and *P. ferruginea* were the most dominant species in this forest, which also contained minor *Dacrydium cupressinum*. *Coprosma*, *Myrsine*, *Plagianthus* and *Lophomyrtus* were also important in the forest understorey, as were the parasitic *Loranthus* and *Cordyline australis*, which is known to be especially abundant near swamps. The strictly lowland coastal species *Alectryon excelsus* and *Dodonaea viscosa* also registered a minor presence.

McGlone (1978) reports *P. taxifolia* continued as the dominant forest species in the Poukawa area following the Taupo eruption, together with a ten percent *Podocarpus totara* component, as well as a small *Dacrydium cupressinum, Dacrycarpus dacrydioides* and *Nestegis* content. McGlone interprets the 10-20 percent *Dacrydium* and *Nothofagus* component as being derived from the Ruahine Range to the west. Pocknall & Millener (1984), on the other hand, believe the source of these two species was from the hill country nearer the site.

Thus the forest at Lake Poukawa, following the Taupo eruption, was essentially similar to that immediately prior to the eruption, but some minor differences exist. McGlone (1978) regularly records the presence of *Nestegis* after the eruption, whereas Pocknall & Millener (1984) report that the only presence of this species before the eruption pre-dates the Waimihia Tephra of 3280 ± 20 yrs BP. (Froggatt & Lowe, 1990). The post-Taupo shrub taxa also differed. Although not contributing much pollen, these included *Alectryon excelsus, Griselinia, Carpodetus serratus, Hoheria, Pseudowintera, Paratrophis, Aristotelia serrata, Rubus, Tetrapathaea tetranda* and *Muehlenbeckia*. McGlone points out that this assemblage is typical of present-day lowland forest in the east of the North Island.

Farther afield, Moar (1961) reporting on sites on the Mokai Patea and Whanahuia Ranges, two ecological areas about 23 kilometres apart in the northern section of the Ruahine Range shows that the vegetation of the region today is very varied. Trunks and roots of *Halocarpus biformis* testify to the presence of a former podocarp forest in an area now characterised by tussock-grassland on both ranges. High frequencies of *Podocarpus* pollen occur during the early post-glacial period. At both sites *Halocarpus* increases in frequency and reaches its maximum between the Taupo and Waimihia

Tephras. The presence of *Halocarpus* wood in peats and soil 160 m above the present timberline also indicates the timberline is not a stable one. Tephra constraints indicate this extension and retreat occurred between 2000 and 3000 years ago. Although not recorded from the Ruahine Range today, *Ascarina lucida* occurs intermittently throughout most of the profiles from these two sites and is interpreted by Moar as indicating a warmer climate in the past than today.

Moar (1967) reports on two further sites from this general area. These are from No Man's Land bog on the western side of the north-eastern plateau of northern Ruahine Range at c. 1450 m a.s.l. *Halocarpus, Phyllocladus* and *Coprosma* are common throughout the profile. There is no increase in *Halocarpus* above the Waimihia Tephra level as in the case of the previous sites discussed (Moar, 1961). *Ascarina lucida* is present in the lower part of the profile. The persistence of this species at this site, and in other Ruahine bogs (Moar, 1961) implies that this species was once a common element in forest communities in this part of the Ruahine Range.

Rogers (1989) and Rogers & McGlone (1989) report on the history of the Moawhango Ecological Region, situated in the northern Ruahine Range/southern Kaimanawa Mountains region. Bogs at an altitude of 1000-1300 m a.s.l. have provided a record of post-glacial vegetation change in this region. The record indicates that by 11 000 yrs BP, podocarp and *Nothofagus* forest stands were well established in lower montane and sheltered upper montane sites. On exposed plateau surfaces just after 11 000 yrs BP., a late glacial lowland forest comprising first, *Halocarpus*, then *Phyllocladus*, was replaced by a *Libocedrus bidwillii* forest. *Nothofagus* expanded diachronously throughout the Holocene in the greywacke mountainlands, while at the same time *Libocedrus* continued to dominate on the sedimentary plateaux. Although there has been a slow inexorable spread of *Nothofagus* from refugia throughout the Holocene, a late Holocene shift to sunnier, less cloudy summers has resulted in an increase in the momentum of this spread.

McGlone & Topping (1977) report that the retreat of glaciers on the Tongariro volcanoes began before 14 000 yrs BP. By this time a podocarp-hardwood forest was replacing the previous scrub and grassland communities and *Nothofagus* existed in scattered pockets of forest in the area. The landscape was a mosaic of grassland, scrubland and isolated but spreading pockets of forest. Three major post-glacial forest zones are recognised:

(i) 14 000 - 10 000 yrs BP. *Prumnopitys taxifolia* forest was dominant in conjunction with *Halocarpus bidwillii*, and the previous grassland/scrubland mosaic was rapidly being replaced by forest more lowland in character. *Alectryon excelsus*, *Dodonaea viscosa* and *Tetrapathaea tetrandra*, which are all adaptable to milder conditions, expanded. Annual temperatures may have been 2 - 3° lower than at present, but the climate was substantially drier.

(ii) 10 000 - 5 000 yrs BP. *Dacrydium cupressinum* forest was dominant. *Ascarina lucida* had a continuous prescence. *Dodonea viscosa* and *Alectryon excelsus* extended their range, and *Halocarpus bidwillii* was replaced by *Leptospermum* and *Lagarostrobos*. The climate was much wetter and milder than at present, and basically frost free.

(iii) 5 000 yrs BP. - Present. Return of *Prumnopitys taxifolia*-dominant forest, increase in *Halocarpus bidwillii* and *Nothofagus*, and a general trend away from the mild climates of (ii) to a more drought- and frost-prone climate.

Only in the last 5 000 years has there been significant expansion of *Nothofagus* forest, but large rhyolitic eruptions of the last 3500 years have tended to delay this spread in the Tongariro region. As a result all species of *Nothofagus* are rare on the Volcanic Plateau, and absent over large areas. However, on the nearby Kaimanawa, Ahimanawa, Urewera and northern Ruahine Ranges, which have been less affected by volcanism, there are well devloped montane *Nothofagus* forests today (McGlone & Topping, 1977).

2.3 CLIMATE

Southern Oscillation conditions, measured by the index SOI, controls the weather pattern in New Zealand. Lower than average rainfall occurs in SOI negative (El Niño) years and higher than average rainfall occurs in SOI positive (La Niña) years (Gordon, 1986). New Zealand experiences warmer temperatures when the SOI is positive, and this is associated with frequent winds from a northerly quarter (Salinger, 1980).

The weather system prevalent over New Zealand incorporates a westerly pattern of anticyclones and depressions associated with eastward-moving warm and cold fronts. Situated in the eastern lee of the axial ranges of the North Island, this westerly weather system controls the mean annual rainfall over most of the Hawkes Bay region. In this respect rainfall decreases from the western ranges, which experience a mean annual rainfall of 2400 mm, to the plains area which experience a mean annual rainfall of 800 - 1200 mm. Throughout the region there is a seasonal variation incorporating a winter maximum and a spring or early summer minimum (de Lisle & Patterson, 1971). The region experiences warm summers and high sunshine hours compared with the rest of New Zealand. Napier, for example, has 2100 - 2200 sunshine hours annually (Thompson, 1987).

The predominant wind directions in the northern sector of Hawkes Bay are from a northerly direction; in the central regions these winds tend to blow from the west or southwest. During periods of strong west to northwest flow Hawkes Bay often experiences warm dry fohn winds (Thompson, 1987).

Fitzharris (1989) in a review of topoclimatology in New Zealand, emphasises that because of the highly varied landscape in New Zealand a wide range of topoclimates are produced that can change rapidly over a short distance. Fifteen distinct macro-scale climate regions have been identifed. The main controls on these topoclimates are elevation, receipt of solar radiation, shelter from wind, distance from the ocean and propensity for cold air to pond. Thompson (1987) reports that the westerly winds in Hawkes Bay tend to be channelled along river valleys. At any time of the year cold winds from a southerly direction can result in snow showers in the hill country, but snow below 500 m is extremely rare.

Due to an easterly aspect Hawkes Bay is strongly influenced by weather systems from this direction. Much of the rain that falls on the plains is from an easterly or southerly quarter (Coulter, 1962). Occasionally deep cyclonic depressions of tropical origin cross Hawkes Bay from a north/northeast quarter. These strong moist fronts are forced to ascend the ranges in the west of the region where they bring extremely heavy rainfalls within a relatively short period of days (Thompson, 1987; Page et al., 1994). Recent examples of these cyclonic fronts are:

- what has been judged, one of the greatest historical cyclonic storms in April 1897. This storm left lasting evidence in the Kuripapango area in the form of large outwash debris fans from very small catchment areas (Grant, 1969);
- the Esk cyclone of 1938 which resulted in severe erosion in the hill country. This cyclone produced more sediment than Bola at Tutira (Page et al., 1994); over a metre of silting in the lower Esk Valley, and widespread silting of c. two metres elsewhere (Grant, 1939);
- a cyclonic storm in October, 1964, which resulted in severe erosion in numerous stream channels of the northern sector of the Kaweka Ranges , but left the southern sector of the range unaffected (Grant, 1969);

- a cyclonic storm in March 1965 in the southeast sector of the Kaweka Range, judged the most intense in the area for many years from the large quantities of rock detritus subsequently moved in streams draining the area, but produced little more than 25 mm in the northern sector of the range (Grant, 1969);

- Cyclone Alison which affected the central Ruahine Range in 1975, and resulted in riparian landsliding, even on forested slopes, and widespread channel widening (Grant et al., 1978). For example the western head of Moorcock Stream towards Pohangina Saddle "... suffered a massive earth movement, with a long consolidated flow of deep shingle extending perhaps a kilometre downstream" (Cunningham, 1975, unpub. listed in Grant et al., 1978);

- and Cyclone Bola which dumped 753 mm of rain on the northern Hawkes Bay hill country within a four day period in 1988, and resulted in severe erosion (Page et al., 1994).

From the above examples it can be seen that rainfall in the Hawkes Bay region can be highly variable and sporadic. As an example mean annual rainfall at Tutira is 1438 mm, however, annual rainfall variability in the area is in excess of 25 percent (Page et al., 1994). Nevertheless, although Hawkes Bay can experience a highly variable and sporadic rainfall pattern, the rain from both easterly and westerly fronts increases towards the western hill country (Thompson, 1987).

Varibility of rainfall also means drought is an important factor in the Hawkes Bay climate. Bondy (1950) in his study of droughts in New Zealand, has found that a partial drought, defined as a period of at least 29 consecutive days, during which the mean daily rainfall does not exceed 0.25 mm, is a better measure of drought than an absolute drought, defined as a period of at least 15 consecutive days during which no more than

0.25 mm of rain has fallen. The rationale is that during periods of deficient rainfall a light shower which is of little practical value, is sufficient to terminate an absolute drought or dry spell - a period of at least 15 consecutive days in which no more than 1 mm of rain has fallen. Thus rainfall effectiveness (R.I.) is a valid measure for defining a drought.

The maximum number of drought days in Hawkes Bay occurs in December and January. In a study of the 64 years prior to 1965 Grant (1968), using R.I. to measure drought severity, reports that partial drought occurred in 37 of these years at both Napier and Gisborne. The average duration per drought year was 56 days at Napier and 54 at Gisborne. At Napier the longest partial droughts were :- 1913 - 1914 (114 days); 1914 - 15 (150 days); 1945-46 (123 days); 1949 - 50 (107 days). Severe drought conditions affected Hawkes Bay in the spring and summer of 1905-6, in the autumn of 1911, in the spring about 1920, and a very droughty period between 1946 and 1958 (Grant, 1968).

Rainfall records and historical observations indicate the central Ruahine Range was affected by the severe drought during 1914-15. As a result, shortly before 1917 abnormally high mortality of canopy trees occurred up to the timberline at c. 1470 m. Despite the drought damage and the impact of deer, the forest regenerated. However forest recovery at the head of the Waipawa Basin produced a timberline 90 m lower that it was before 1915. A recent lowering of the timberline, evident on most of the Ruahine Range today, is thought to be due to the 1914-15 drought. Of interest is the fact that no major source area of coarse sediment developed in the Centre Branch of the Waipawa Basin following the forest dieback in 1917 (Grant, 1984).

The affect of the drought experienced over most of New Zealand in the summer of 1945-46 was so severe in central Hawkes Bay, it was judged the most severe in fifty years. Both exotic and indigenous forest species were affected. *Pinus radiata* suffered severely only on the driest gravel flats where, in one case 75 percent mortality occurred in a forest stand. Elsewhere there was dieback among weaker members of a stand, with plantations about ten years old being most susceptible. Among indigenous species there was some mortality amongst isolated and marginal *Dacrydium cupressinum* in the foothills which experienced an average rainfall of upwards of 1250 mm a year. However, on well drained land on the plains, where the drought was just as severe, second growth *Podocarpus totara* browned off severely, but made good recovery later. In the high country, *Nothofagus solandri* showed some permanent damage (Hocking, 1946). This drought also killed mountain beech growing on deep pumice soils over a distance of 30 kilometres across the southern Kaimanawa Mountains to the Kaweka Range (Elder, 1963).

The drought affecting the whole of Hawkes Bay in the summer and autumn of 1997/8, is one of the worst on record, and did not officially end until July, 1998. There have also been several reports of dieback in the lowland areas as a result of this drought. Desiccation of soils during drought conditions may result in soils cracking, rendering them more vulnerable to erosion during high intensity storms (Hammond, 1997) which, as the rains of July, 1988 indicate, often signal the end of a drought in the Hawkes Bay region.

2.4 EROSION AND RELATED FOREST DISTURBANCE

Erosion within the ranges and hill country of western Hawkes Bay is widespread and well documented. As discussed in section 2.3, climate is identified as a major factor in determining the type of geomorphic processes operating within these high country catchments. There has been a marked increase in the occurrence of debris avalanches and soil slips this century. As a result, the rate of erosion over the entire range is calculated to be about twice the estimated geological "normal" rate for the range. The effect of this accelerated erosion is that gravel is accumulating in river channels, especially around the periphery of the range (Cunningham, 1981) and on the adjacent farmland.

Marden (1977) in a study of the relationship of geology to erosion in the southeastern section of the Ruahine Range, reports that mapping of graded sequences in the West Tamaki catchment indicates seldom, if ever, can slope movement be attributed to a single definite cause. The widespread occurrence of mass movements in the southern Ruahine Range is the result of a combination of natural geologic, geomorphic and climate factors. Although all forms of slope failure in the area are often found in association with faults, triggering mechanisms are principally of climatic origin.

Hubbard & Neall (1980) in a reconstruction of late Quaternary erosional events in the West Tamaki River catchment in the southern Ruahine Range, found that there was a history in this catchment extending back 20 500 yrs BP. They listed erosional periods which alternated with periods of stability when increased rates of soil development and vegetation growth occurred. An interesting point is that Cyclone Alison, a major geomorphic event for the central and northern Ruahine Range area in 1975, had only a lesser effect in the southern portion of the Ruahine Range (Stephens, 1977).

Grant (1965) reports that there is also evidence of more recent widespread erosion along the Tukituki River and its tributaries. The evidence he quotes is a series of depositional terraces composed of banded alluvial gravels, sands and silts which closely resemble deposits that are periodically and locally formed during large floods. By tree-ring dating of podocarps growing within these gravels, Grant has dated this event to about 1650 AD. Pullar (1965) who had made a detailed study of infilling of the Gisborne Plains after the deposition of the Kaharoa Tephra in 615 ± 60 yrs BP. (Lowe, et al., 1998)) has accepted Grant's date, and gave the name Matawhero alluvium to this infilling stage. Grant links this period to an earlier report where he postulates the forests of the Huiarua Range to the north of the study area were greatly modified by gale force winds around 1659 AD. (Grant, 1963), and maintains that a period of increased storminess was the triggering factor.

Several earlier commentators have also remarked on erosion in the eastern sector of the Ruahine Range and its affect on the environment. McKay (1888) observed that the Mangaatua Stream used to spread widely when in flood and deposit large quantities of shingle and boulders over the higher part of the alluvial plains. McKay (1902) described large landslips in the headwaters of the Makaretu River. Kenedy (1914) mentions slips in the mountains as being a source of shingle in the Ngaruroro River, and Aston (1914) noted the presence of extensive shingle slips along the top of the range.

Colenso (1884) was the first to comment on enviromental conditions within the Ruahine Range. Referring to his first crossing of the range by way of the Waipawa and Makaroro Rivers in 1845, Colenso writes that in the upper Makaroro River region narrow, steep stream beds were "partly choked with dead trees and shrubs, and masses of stone ..." . Concerning the same area he continues that there were "... fine forests of Fagus on the top; the trees of which were continually falling down along with the earth into the river beneath. Here and there an immense mass of earth had slipped quietly down the upright cliffs bringing the large trees with it ... in two or three spots during the day I noticed a double slip or subsidence of that nature ...". On his second journey into the Ruahine Range by the same route in 1847, Colenso commented on stumbling over fallen trees and into holes of uprooted trees hidden in undergrowth that was so thick that they sometimes "... passed along on the very edges of extensive landslips, down which it was fearful to look". Of the beech forest below the summit on the western side of the range, Colenso records that the party sank deeply at almost every step "among what seemed to be layers of anciently fallen trees, which were all more or less rotten and lying across each other, and hidden under the long Astelia and Cutting-grass foliage ...".

However, Cunningham (1981) points out that Colenso provided a detailed description of the vegetation on the range and although he mentioned encountering dead, decaying and windthrown trees, and fallen logs in river beds, at no point does Colenso suggest any form of unnatural or spectacular forest debility. On the contrary, at times he wrote of the richness and healthy aspect of the vegetation.

Cunningham (1981) reports that the vegetation on the Ruahine Range is complex and has undergone considerable change during the past century as a result of introduced animals, mainly deer, goats and opossums which have caused considerable damge. In the southern portion of the range the forest has collapsed completely as a result of this damage. Due to root decay the slopes in this area are now more prone to mass movement.

On the northern Ruahine plateau, there was a high deer population by the mid-1920s. At that time the forest floor was bare and roots were exposed. By 1932 the *Nothofagus solandri* var. *cliffortioides* forest was already reduced to a shell on the slopes of the northeastern plateau, and nearly all the undergrowth had been browsed out in some basins. By 1935 deer were to be seen along the whole of the top part of the range from the Ngamoko Range in the north to Keruru in the south (Elder, 1965). Widdowson (1960) in a study of age-class distribution of both mountain and red beech pole stands, concluded that high deer populations during the 1930s arrested beech seedling development in the northeastern sector of the range.

A report by a field officer, following a deer cull in 1938/39, found that certain parts of the bush in the Gull Stream, Big Hill Stream, Koau Stream and the Mangatera River catchment, had been eaten out by deer; as well, the lower part of the bush near Lake Colenso, on the top of the range, was completely bare of any undergrowth. Opossum signs were seen in quantity within the forest as well (Cunningham, 1979).

However, Stephens (1977) notes that although *Weinmannia racemosa* has suffered dieback on exposed sites in the southern Ruahine area, it appears to be quite healthy in sheltered sites. Druce, (1940), however, noted that *Weinmannia* along the track up to Wharite Peak in the southern Ruahine Range appeared to be in poor condition. Stephens (1977) suggests that climate (winds and drought) is a possible causal factor of this dieback, and that possums liberated in the 1930s and deer population peaking about 1962, may not be solely responsible for the large scale mortality of some forest species. Druce (1940) also commented on the presence of *Libocedrus bidwillii* and *Halocarpus biformis* along the Wharite Peak track, but made no comment about these two species suffering any debility.

The importance of natural disturbance in creating opportunities for the growth and establishment of future canopy trees, has been well documented in forest ecosystems (Ogden, 1985). From a study of light environments in two adjacent lowland podocarp forests on the west coast of the South Island, McDonald & Norton (1992) relate less frequent gaps in the canopy to less spatial diversity of light environments, which favours the canopy dominance of one species. In contrast greater spatial diversity of light environments provides a wider range of regeneration sites and thus favours the coexistence of several species in the canopy. A study done on regeneration in the Whirinaki forest region, where a smaller abundance of seedlings may be due to deer browsing, indicates that whatever the origin of these mixed podocarp-hardwood forests, they are potentially capable of maintaining themselves by the gap-regeneration process, from the gap created by the fall of one large tree (Morton et al., 1984).

This review highlights storm erosion as a major factor in creating light environments that subsequently provide regeneration sites for forest species. From Lake Tutira, in northern Hawkes Bay, Eden and Page (1998) have identified a *c* 2250 year storm history in the lake sediments, that predates European settlement. The event-based chronology identifies 340 storms, with a return time of 6.4 years. Based on tephrochronology, the storm record is divided into six periods of high sedimentation as follows :

Mapara 1 period	(2175 - 2155 cal yrs BP) - Annual rainfall = >3000 mm
Mapara 2 period	(2090 - 1855 cal yrs BP) - Annual rainfall = 2000 - 3000 mm
Taupo period	(1455 - 1435 cal yrs BP) - Annual rainfall = 2000 - 3000 mm
Tufa Trig 1 period	(1085 - 935 cal yrs BP) - Annual rainfall = 2000 - 3000 mm
Tufa Trig 2 period	(595 - 500 cal yrs BP) - (onset of Polynesian deforestation)
Burrell period	(375 - 355 cal yrs BP) - Annual rainfall = 2000 - 3000 mm

The above stormy periods are thought to represent wetter than average periods, with increased northerly airflows, frequent incursions of subtropical air masses and positive SOI (Eden & Page, 1998).

The Burrell period is synchronous with Grant's Matawhero Erosional Period. Grant (1989) maintains that during the last 1800 years there have been eight periods of increased erosion and alluvial sedimentation in New Zealand, which have generally increased in magnitude towards the present. In each period there was increased erosion of mountain and hill slopes. Large quantities of sediment were transported into and through drainage systems, raising river beds by up to 20 m, from their headwaters to the coast. Large areas of vegetation along downstream channels and on flood plains were destroyed by alluviation during each erosion period. Between the erosion periods there were longer tranquil intervals when soil formed and fresh surfaces were revegetated. On alluvial sites the vegetation is closely linked to the history of the site - it may grow on an entirely new surface, or be a mixture of survivors and new colonists. Grant also links these accelerated erosional periods to an increased northerly airflow and atmospheric warming, and related increases in major rainstorms and subsequent floods.

Erosion is a natural periodic process. The event which causes the initial movement may be quite trivial, acting as a trigger which reduces slope stability to the critical point at which failure occurs (Stephens, 1977). The above review indicates that prior to (and if Grant's hypothesis is accepted, during) human settlement both macro- and micro- scale climate-forced erosion played a determinant role in the deforestation and subsequent reafforestation history of the western Hawkes Bay region.

2.5 FIRE AND HUMAN DEFORESTATION

Natural fires are usually the result of volcanic activity or lightning strike. Forest damage from volcanic eruptions in historic times has been caused mostly by the force of a blast, burial and burning, with most fires confined to the area around the vent (Clarkson & Clarkson, 1994). Following the eruption of Mt Tarawera in 1886, small localised fires occurred in the area around the mountain (Burke, 1974). In spite of forest destruction by fire following the Taupo eruption of 1850 ± 10 yrs BP. (Froggat & Lowe, 1990), a pollen profile from a site close to the eruption centre indicates that the forest returned to the area within a few hundred years of the eruption (Clarkson et al., 1986).

The forests overwhelmed by the ignimbrite flow of the Taupo eruption were totally destroyed, and forests up to 170 km east of the vent experienced variable amounts of damage from ashfall. Yet reafforestation was completed within 120 - 225 years of the event. This recovery was irrespective of tephra thickness or distance from vent because sites completely overwhelmed by the ignimbrite recovered within this time frame as well. In each case post-eruption forests were similar in character to those existing prior to the eruption (Wilmshurst & McGlone, 1996).

Fires recorded at sites remote from the vent were probably ignited by increased lightning activity due to a large volume of ash in the atmosphere following the event (Wilmshurst & McGlone, 1996). The southernmost records of forest disturbance due to fire associated with the Taupo eruption are recorded from the Reporoa Bog on the Ruahine Range (Rogers & McGlone, 1989), and in the Poukawa basin in central Hawkes Bay (McGlone, 1978; 1989).

Widespread soil charcoal in the pollen record indicates that natural fires have been a recurring feature of the environment (McGlone, 1989). A study of a lowland podocarp/hardwood forest in the Tutira region of northern Hawkes Bay, indicates that these forests were disrupted by lightning strike following the 1850 ± 10 yrs BP. Taupo Eruption. These forests were also frequently disrupted by lightning strike fires associated with drought. But regardless of frequency and intensity of the fire event, rapid forest redevelopment always followed each fire disturbance. A short-term colonisation of the site by seral taxa took place before a forest, with the same composition as before each fire, reestablished in the area (Wilmshurst, et al., 1997).

Destruction of the indigenous forest by anthropogneic burning in historical times is well documented. Following the introduction of the potato to New Zealand, towards the end of the eighteenth century, Maori people underwent an agricultural revolution. This involved a return to ancient Polynesian methods of shifting crop cultivation, in an effort to meet the demand of visiting ships for this valuable item of trade (Taylor, 1958).

There are many eyewitness accounts of Maori fires having destroyed very large areas of forest. Cameron (1964) writing on the destruction of forest for Maori agriculture in the 19th century, reviewed some of these eyewitnesses accounts. A Reverend Yates, an early missionary in New Zealand wrote that the winter potato is always planted on new ground on the side of a wood. First the trees were burnt down, then the potato was planted between the roots. Hochstetter writing in 1867 stated that it was a general custom of the Maori to establish potato gardens in remote and inaccessible places, particularly in large forest areas. Other writers observed that cultivations were established at regular intervals along main tracks and it was customary for travellers to take what they required. The Reverend Chapman writing from the Matamata mission station in 1842 stated that the annual destruction of the timber was a matter of extreme regret. Matamata eight years previously was a fine wooded plain, and in a few years no growing timber would be left nearer than the distant hills. He further wrote that this remark was of general application throughout the whole island. Johnson, an early traveller in New Zealand wrote in 1847 that near the settlement of Matamata hundreds of gigantic trees were in flames from their roots to their topmost branches. Of an area near the present town of Pukekohe, he wrote that hundreds of trees were lying about, charred and blackened or standing deprived of bark and leaves, and some were still burning, many of them far beyond the area being cleared for cultivation. The ongoing consequences of these fires was also commented on. Chapman wrote as early as 1838 of the burnt forest land then being matted with fern and presenting a barrier to extensive cultivation. Bidwilli wrote in 1839 that the potato cultivations were abondoned after the third year's crop and that the land then became covered with fern, and in a few more years was rendered fit for nothing by the constant fires destroying whatever vegetable matter is formed by the decaying plants. Dieffenbach wrote in 1843 of the country around Rotorua being open and covered with fern with blackened tree trunks still standing among the fern.

The anthropogenic burning of the native forests in New Zealand is also recorded in the pollen record. The influx of abundant microscopic charcoal accompanied by a decline in forest species and a spread of bracken (*Pteridium*), seral shrubs and grassland at a site, is considered evidence of initial Polynesian forest clearance. Continual fires, together with the persistence of a shrubland flora at a site until European settlement is indicated, is interpreted as anthropogenic firing of the bracken to assist in the cultivation of this fern root (McGlone, 1978; 1983b; 1989; McGlone et al., 1994; Bussell 1988; Newnham et al., 1989).

Only a dramatic increase in charcoal associated with soil instability and/or replacement of forest by herbaceous communities is indicative of anthropogenic burning (McGlone & Wilmshurst, 1997). This pattern of forest clearance is present in the Tutira and Poutere profiles. Radiocarbon dates place this clearance at 490 cal yrs BP. at Lake Tutira and 485 cal yrs BP. at Lake Rotonuiaha (Poutere) (Wilmshurst, 1997). The only other published palynological record of Polynesian deforestation in Hawkes Bay comes from Poukawa, where a date of later than c. 980 ± 70 yrs BP. is advanced (McGlone, 1978).

Although radiocarbon dating of wood charcoal found in soils in the South Island indicates there were widespread fires in New Zealand from c. 1000 yrs BP. onwards (Molloy, et al., 1963), McGlone (1983b) accepts that Polynesian settlement, identified by anthropogenic burning of the forest, began c. 700 yrs BP. However, Mc Glone points out the pattern of burning by Polynesian settlers c. 700 yrs BP. reflects local rainfall patterns more than the suitability for settlement of the burned areas. This can be seen in the drier eastern parts of the country and the lowlands where until European land clearance, the 1600 mm isohyet separated largely unforested areas from forested areas (Ogden et al., 1998). This pattern was evident in southern Hawkes Bay, where the 1600 mm isohyet coincides with the northern boundary of the former seventy mile bush, which was felled by European settlers in the late nineteenth century.

2.6 EARTHQUAKE HISTORY

The Modified Mercalli Scale in use in New Zealand lists a 7.8 magnitude earthquake as being "very disastrous, where few buildings remain standing, bridges are destroyed and all services, including railways, pipes and cables are out of action, there are also great landslides and floods". In 1931 an earthquake of such a magnitude was felt over most of New Zealand, and destroyed the city of Napier (Hull, 1990). In the vicinity of coastal Napier, a northeast-trending dome c. 90 km in length and some 17 km wide was uplifted, in the course of which the Ahuriri lagoon was drained and 15 km of surface faulting occurred. In spite of this, fifty-five years later only 3 km of fault trace can be confidently recognised in the area (Hull, 1990).

The trace of the Wellington Fault, on the other hand, has been mapped from Cook Strait in the south to Whakatane in the Bay of Plenty. Immediately south of the Manawatu Gorge, the fault bifurcates, the major westward splinter being named the Ruahine Fault and the major eastward splinter is known in the Hawkes Bay region as the Mohaka Fault.

Movement on the Wellington/Mohaka Fault was first described as dextral strike-slip by Wellman (1953) and Stevens (1956; 1957). Lewis (1989) has shown that changes in throw and trend also occur. The recent trace is upthrown to the southeast, whereas long-term movement has been to the northwest. Berryman (1990) and van Dissen et al. (1992) postulate the Wellington-Hutt Valley portion of the fault moves as a single segment. These writers have used the two most recent movements, one between 340-490 years ago, the other between 710-870 years ago to advance a horizontal slip rate on the fault of 5 mm/yr. This is in agreement with the slip rate Stirling (1992) has calculated for fault displaced Holocene beach ridges in the Wellington region.

Based on offset Ohakean river terraces north of Woodville, Marden & Neall (1980) have established a maximum vertical uplift rate of 1. 23 mm/yr for this section of the Mohaka Fault. Marden (1984), from work done in the Ballantrae area of the southern Ruahine Range, reports that both the Mohaka and Ruahine Faults display a large amount of Quaternary horizontal displacement. Horizontal offset on a Porewan terrace displaced by the Mohaka Fault is calculated at 150+ m.

In the Wakarara area Raub et al. (1987) have established an average dextral slip-rate along this segment of the Mohaka Fault of about 3 mm/year for the last 30 000 years, with the vertical slip rate varying between 0.2 and 0.4 mm/year. A radiocarbon dated log, exposed in older units at the base of the fault scarp below the latest surface rupture, indicates the latest movement along this segment of the fault occurred since 1165 ± 50 yrs BP. From trench work done along the Mohaka Fault, Neall & Hanson (1995) report 66.9 m of horizontal movement over 14 000 years in the Wakarara area and a minimum horizontal offset of 60 m in the Hawkstone area. A summary of faulting events along the Wellington/Mohaka Fault together with their established ages (Table 2. 2) has been adapted from Neall & Hanson (1995).

However, the 1931 Hawkes Bay earthquake is evidence that co-seismic activity is not confined to the faults at the western perimeter of the region. Regional co-seismicity and uplift is also reflected in the downcutting of major rivers, such as the Mohaka and the Wairoa, and by the widespread dissection of the Neogene strata (Berryman, 1988).

The first European record of an historical earthquake in the Hawkes Bay region was that of Colenso during his first overland trip to Wellington in 1845. A party of eight left the mission station at Waitangi on 1st March 1845. On the evening of March 13/14th the

Wellington van Dissen et al. [1992]	Pahiatua Beanland Berryman [1987]	Woodville Inglis Farm Trench 3 <--	Woodville Inglis Farm Trench 4 Neall	Nth Woodville Beagley Farm Trench &	Kumeti area Trotter Farm Trench 1 Hanson	Kumeti area Trotter Farm [1995] -->	Wakarara Raub et al [1987]	Big Hill McCool Farm Trench <- Neall &	Hawkstone Syme Farm Trench Hanson	Te Pohue Wedd Farm Trench [1995] ->	Mohaka River Hull [1983]
c.300-450	c. 300	pre 211	EQ	c. 290	c. 257	c. 257		EQ or storm pre 605			
c.800	post 860	EQ						storm c.805			
	1010 - 1160	EQ	post 1105				post 1105				c.1200
								post 1850	post 1850	post 1850	post 1900
					pre 2090	post 3110		pre 3280			
	c.3840	post 4335				EQ		4295 - 5206			
				post 5324	pre 5000	EQ					
					pre 6750	pre 6080					
		pre 9434							8770- 10 000		
			post 10286							post 10 000	
									pre 10 100	pre 11 850	
								pre 14 082			
					post 22 020						
			pre 29 220 EQ EQ								

Table 2.2 Faulting events identified on Wellington (including Mohaka) Fault traces (yrs BP)

party was camped at Waiorongo, a Maori village at Castle Point on the Wairarapa coast. Here early on the 14th, several "...shocks of earthquake lasted about eighty seconds. The posts of the hut in which we were moved about, reeling to and fro. Had the shocks increased in violence ... I should have run out and thrown myself on the ground. My natives sat enjoying the matter as a fine subject of laughter and sport!" (Bagnall & Petersen, 1948). From what Colenso writes it is obvious the Maoris were quite used to earthquakes and thought them nothing out of the usual. Perhaps Colenso soon grew used to them as well, for in his diary of May of 1850 he refers only to "a severe earthquake on the last day of May" (Bagnall & Peterson, 1948).

Early Hawkes Bay settlers must have soon become used to earthquake occurrences as well. A Mary Tod, staying on her Uncle Robert's farm at Braebear House, Kaikora [Otane] wrote to her Uncle John in May 1891 "... the ceilings are of wood, plaster ceilings are unknown, for the earthquakes are so frequent that the people would not be safe if there was brick and plaster about. I haven't felt an earthquake yet but they have them every month or two, and a really bad one once a year or thereabouts (Logan, 1974).

Evidence that co-seismic events were a common occurrence in the Hawkes Bay region towards the end of the nineteenth and early twentieth centuries comes from reports of earthquakes in the Waipawa Times. A list of all earthquakes reported as being felt in Waipawa and surrounding districts between 1878 when the Waipawa Times was first published, up to 1910 has been compiled and is included in appendix 2. This list shows that the late nineteenth century perception that these events occurred every month or two and a bad one every year or so, referred to above, was correct.

Studies show that the Hawkes Bay region has experienced regular seismicity in the late Holocene. Berryman et al. (1989) have identified at least 21 paleoseismic events in coastal areas of the region within the last 2500 years. These writers believe there is evidence of episodic co-seismic activity that has affected Holocene marine terraces along the coast. The episodic nature of events is based on historical evidence of co-seismic deformation in the region, which includes stepped terrace morphology; clustering of ages of terrace deposits within subregions; differential uplift across structures and distinct age variations at subregion boundaries. These episodes occurred 300; 500-600; 900-1000; 1500 - 1600; 2000-2100; and 2300-2400 yrs BP., along different parts of the coast.

Hull (1987) also reports on the formation of a late Holocene marine terrace near Cape Kidnappers as being probably due to a large earthquake c. 2300 yrs BP. Hull further reports on the possibility of one or more post-2300 yrs BP. uplift events.

Cutten et al. (1988) have used offsets and ages of river terraces along the Rangiora Fault in northern Hawkes Bay to identify one faulting event between 3300 and 1900 yrs BP, and two after 1900 yrs BP. They have also identified two events between 3300 and 1900 yrs BP. and two events after 1900 yrs BP. based on road-cut exposures along the fault.

Eden & Page (1998) also believe earthquakes between 2000 and 2300 yrs BP. may have contributed to the magnitude, if not the frequency, of some storm sediment pulses recorded in their Mapara 2 period. These writers also believe evidence of earthquake events may be recorded within their Mapara 1b phase, when four sediment pulses which formed the lake bed surface at the time, have a disrupted wavy aspect.

Co-seismic activity has also been recorded along the Ruahine Fault to the west of the Mohaka Fault. Beanland & Berryman (1987) tentatively suggest an average horizontal slip rate along the segment from the Ohara Depression to the Napier-Taupo highway of 1 to 2 mm/year. From trenches across this fault in the Ohara Depression area, Neall & Hanson (1995) report ten possible rupture events spread over a 12 000 year period, with an average horizontal displacement of 5.5 m per event. These writers estimate a magnitude of between M 7.5 and M 8 is indicated for these co-seismic events. Neall & Hanson also estimate six faulting events recorded along the Mohaka Fault in the same area are indicative of earthquakes of between M 7. 8 and M 8.

CHAPTER THREE : PRINCIPLES AND METHODS EMPLOYED

3.1 FIELD METHODS

The object of the initial sampling of each site was to obtain a core, or cores, suitable for pollen analysis from the variety of sediments found at the six selected sites.

With the exception of the Te Pohue site, which was cored in November 1995, the other cores were obtained in February and April, 1996. At all sites, notes on the local and site vegetation, together with sketches, measurements and photographs were taken at the time of sampling.

3.1.1 CORING METHODS

A wide variety of sediments was found at the various sites; these sediments ranged from soil, to humified and unhumified peat, to lake deposits, with sporadic influxes of colluvial and/or volcanic material. For this reason, apart from Te Pohue and the two ponded sites (Big Hill and Willowford), individual site conditions and/or stratigraphic limitations dictated that no one sampling device sufficed at any one site.

In all, five hand-operated samplers proved suitable to core the sites. These samplers are illustrated in Figure 3.1 and were :-

- a Hiller peat borer with a modified steel-coned head, which takes reasonable samples in fibrous, mossy or woody peat and in fairly stiff muds (West, 1977);
- a D corer, which is effective in peat and mud of a moderate organic nature;

- a Livingstone piston corer, which works best in well decomposed, sloppy peats and lake sediments (Moore & Webb, 1978);
- a Neale piston corer. This sampler, modified by Jim Neale of the Australian National University, has a 10 cm-diameter tube linked to a tripod, both to keep it stationary and to contain the winching gear. The piston is fitted with a self-locking rod/wire device which prevents the piston from moving as the core barrel is driven past the piston during sampling (Neale & Walker, 1996). With this type of sampler a core up to a metre in length at a time can be taken. This sampler is known to be effective up to a depth of 8 metres in peaty sediments (D. Feek pers. comm. 1997);
- a post-hole auger, which is effective in compact sediments of an organic, sand, silt or gravelly nature.

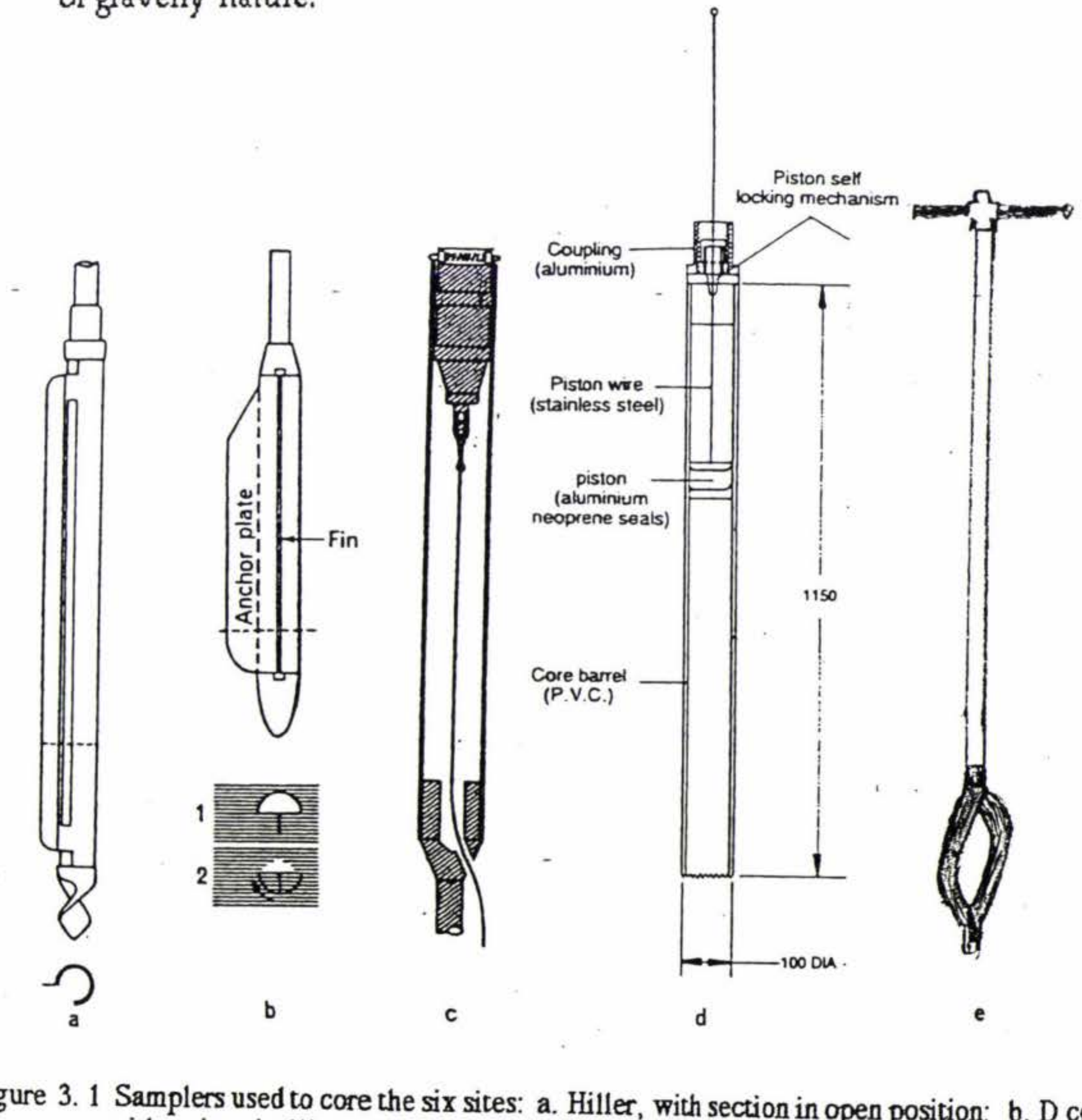


Figure 3. 1 Samplers used to core the six sites: a. Hiller, with section in open position; b. D corer with setions in (1) open and closed (2) positions; c. Livingstone piston corer; d. Neale piston corer, with a rod/wire self-locking mechanism; e. post-hole auger.

Te Pohue and the ponded Big Hill and Willowford sites were cored using a Livingstone piston sampler mounted on an anchored raft through a 10 cm casing. This enabled a core of up to a metre in length to be taken in one drive. At each site coring ceased when coarser material jammed the mouth of the tube and prevented the corer penetrating any deeper. In the case of Te Pohue the coarse sediment was the pumiceous Taupo Ignimbrite; in the case of the Willowford site it was the A horizon of a buried soil. Fine colluvium jammed the mouth of the tube at the base of the Big Hill site.

At each of these three sites the water line was used as the datum plane, and coring was done where the water was assessed to be at its deepest point. This point was ascertained by measuring the depth of the water from the raft by means of metre-long coring rods. Any areas where sediment disturbance was suspected, such as estuaries or outlets, were avoided. The cores from these three sites were extruded into core boxes on site, and were described in the field.

In the case of the Te Pohue and Willowford sites, duplicate cores were taken about five metres from the pollen core so the stratigraphy could be compared. The stratigraphy in the Willowford cores showed both to be black unstratified peat, and as a consequence the second core was discarded. At the Te Pohue site both cores contained well stratified peats. The second core was retained for confirmation of the stratigraphic data.

At the Kashmir site, the Neale piston corer was used initially. The centre of the flush was chosen because it was the wettest area. However, due to the colluvial nature of the sediment only an initial 0.9 m was cored before the mouth of the tube became jammed by an influx of colluvium and a relatively large piece of manuka. Below 0.9 m a post-hole type auger was used and sub-samples were taken at 10 cm intervals from unbroken aggragates of material retrieved from the auger. At 1.90 to 2.05 m depth an AB horizon of a buried soil was encounted. At 2.25 metres depth, within the Bw horizon of the buried soil, the sediment became too compacted for the auger to penetrate.

The sample from the Neale corer was extruded directly into a closed cylindrical container, and so was not described in the field. However, the augered material was described as it was sampled and sealed in plastic bags. A second attempt to retrieve samples of a buried A horizon between 1.82 and 1.90 m depth, immediately above the AB horizon already encounted at 1.90 m depth, was made. This proved unsuccessful because the sediment was too compacted to auger before the buried A horizon was reached.

The Hinerua site, situated along the Mohaka Fault trace, was initially cored with the Neale piston corer to a depth of 1.10 m. At this point roots and coarsening sediment were making coring difficult and at 1.10 m depth a piece of wood jammed the mouth of the tube. Below the wood, a D corer was used until the sediment, which had been grading into mudstone, became too stiff to penetrate at a depth of 1.90 m. The Neale sample was extruded into a closed cylindrical tube. A second Hinerua site was cored. This was a flush (Wardle, 1991) about 100 metres down-slope and one kilometre to the north-east of the first site. Using the Neale piston corer, this site was cored to a depth of 0.95 m, at which point, very angular, sandy siltstone, jammed the mouth of the tube. The first core, of 1.90m, was processed for pollen analysis.

The Hawkstone site is an infilled *Typha*-rich mire. Several preliminary attempts were made to find a suitable undisturbed core site in the vegetation. The site chosen was roughly in the centre of the mire, where surface water was ponding. The top metre was cored using a D corer. As the site was very wet and the recovery rate less than ideal, at a depth of one metre a change was made to the Hiller corer. This method produced excellent core samples using two adjacent holes for the recovery of half-metre lengths from alternative holes to a depth of 1.90 m. At this point a post-hole auger was used to penetrate and sample a compacted 0.20 m tephra layer. Because it was believed that contamination had occurred when the auger unexpectedly pushed through the tephra layer into the peat below, this hole was abandoned and a third hole was started, with sampling starting from immediately below the level of the tephra.

3.1.2 CORE PRESERVATION AND STORAGE

The cores were extruded into plastic casings in the field, sealed, and indelibly labelled, indicating site, depth and which end is uppermost in the stratigraphic sequence. They were then taken intact to the laboratory, where they were fully described, photographed, sub-sampled, and stored at low temperature whenever possible to avoid evaporation, and reduce any chemical changes.

3.2 LABORATORY TECHNIQUES

To minimise risk of contamination, each core box was subsampled as soon as it was described in the laboratory. As a general rule, unless core stratigraphy or site specific factors indicated otherwise, subsampling was done at 10 cm intervals, starting 5 cm from the top of the core, and ending 5 cm above the bottom of the core. Thus, a one metre core would be subsampled ten times, and a 50 cm core five times. Each subsample was given a consecutive number starting from No 1 for the 0.05 cm depth sample. This number was written on the side of the core box with an arrow indicating the exact position of the subsample. In this way, should the core move subsequently in the box, its correct location could always be found by aligning the markings on the core box with the subsampled sites within the core.

3.2.1 Pollen Recovery Techniques

As absolute pollen frequency was required as well as relative pollen frequency, a known volume of an exotic pollen type, which was easy to recognise and unlikely to occur naturally in the sediment under investigation, was suspended in each plastic tube before chemical processing (Benninghoff, 1967). The spore tablets used in each case were exotic *Lycopodium*, with spore concentration determined with an electronic particle counter as described by Stockmarr (1971), with the slight modification that the tablets are based mainly on sodium bicarbonate together with polyvinylpyridon and polyethyleneglycol. Two tablets (which have a spore concentration of 13911 ± 1541 per tablet) were added to each labelled plastic tube and dissolved in a small amount of HCl before subsampling. Then the core surface directly above each subsample site was removed with a spatula to minimise the possibility of contamination. One cm^3 of sample was added to the dissolved *Lycopodium* tablets, the tube topped up with HCl to dissolve any free calcium carbonate in the sediment (Moore & Webb, 1978) and centrifuged down at 3000 rpm for 3 minutes.

The major part of the samples from the field area was extremely rich in detrital clay and silica. This is a reflection of both the local geology, especially the underlying greywacke strata of the nearby Ruahine Range, and the topography. For this reason pollen recovery processes were usually carried out in the order set out below.

3.2.1.1 Potassium hydroxide treatment

This process as described by Faegri and Iversen (1989) and Moore et al. (1991) was used to deflocculate and remove humic colloids, and to break up the peat. The samples were subjected to heat in a hot block at 95° C for up to 10 minutes and stirred occasionally to break up the material. The samples were then poured through a 100 µm gauze (disposable terylene), funnelled into a small flask, and rinsed through with distilled water until the water ran clear. The residual macro-remains were then compared with the description of the stratigraphic column, any necessary corrections made to the description, and the macro-remains discarded. The filtrate was then centrifuged and decanted ready for the next process.

3.2.1.2 Sodium pyrophospate treatment

This process as described by Bates et al. (1978) was used to deflocculate the clays so that inorganic clay was removed. The samples were left in a hot block at 95° C for up to 20 minutes, depending on the amount of clay in each sample.

3.2.1.3 Hydrofluoric acid treatment

This procedure, following the standard hot HF process as described by Faegri and Iversen (1989) and Moore, et al. (1991), was used to remove siliceous material. The samples were left to digest in a hot block at 95° C for 30 minutes. Often one HF treatment was not enough, and the process was repeated. The samples were washed in 10% hot hydrochloric acid each time after the HF treatment to keep the dissolved silicates in solution so they could be disposed of by decanting.

3.2.1.4 Acetolysis

This process, as described by Faegri and Iversen (1989) and Moore et al. (1991), was used to remove cellulose. As it is a reaction that removes organic material, it was also used as a means of removing the inside of the grain. The process was also used as a means of darkening the pollen grains to make identification easier.

3.2.1.5 Fine sieving

In the majority of the cases the sodium pyrophosphate treatment did not fully clean up the clay-rich samples. To remedy this, sieving was done to remove remnant fine matter <6.5 μm using a standard Sartorius filter unit. This unit has been modified by the addition of a vacuum reversal pump system designed by Raine and Tremain (1990). It was often necessary to add a few drops of the detergent, sodium lauryl sulphate (Moore and Webb, 1978) to overcome clumping and assist the sieving process.

3.2.1.6 Oxidation

This process is used to remove lignins. However, it is also extremely corrosive of pollen grains, and for this reason only resorted to if the lignins had not been removed by other processes and were so concentrated that the pollen was uncountable. It was used for most of the Hawkstone samples and the lower 40 cm of the Big Hill samples. The process followed was that of the sodium chlorate method as described in Moore et al. (1991). As the process also bleached the samples, they were reacetolysed.

3.2.2. Mounting

The samples were mounted in silicone oil which, with a low refractive index gives favourable optical results. Chemically, silicone oil is very stable. It also does not appear to cause swelling of the pollen grains over time (Anderson, 1960). A 2000 plus centistokes viscosity was the grade selected. The dehydration process necessary before silicone oil mounting followed that of Moore et al. (1991). The samples were not stained, and were air or oven dried at ≈39.5° C over-night. Two slides were made up for each depth, by placing a droplet of the pollen concentration on a heated slide. When the liquid had spread under the cover slip the slide was sealed with hot wax, named, cleaned up, and the better prepared of the two slides designated as the main slide for each depth.

3.3 MICROSCOPY AND POLLEN IDENTIFICATION

Scanning of the slides was carried out with a Zeiss Axiophot Photo microscope, normally at a magnification of x 600, with taxa difficult to identify requiring magnification of x 1000 and the use of an oil immersion lens. Counts were continued until in excess of 200 dryland taxa, excluding ferns and fern allies were counted at each depth, unless ferns and their allies were the main taxa at any one depth. In this case these spores were included in the 200 dryland count. The added exotic *Lycopodium* marker spores were counted at the same time as the pollen, and the counts recorded at the bottom of each counting sheet.

The taxonomic nomenclature of the fossil pollen follows that of Allen (1961), Moore and Edgar (1976) Connor & Edgar (1987), and Webb et al. (1988).

Fossil pollen identification was made by means of reference slide collections held in both the Geography Department at Massey University and the Geology Department at Victoria University, plus coloured slides made from the latter reference collection. As well, pollen identification keys published by Moar (1993) for Dicotyledon identification; Pocknall (1981a, b & c) for Podocarpaceae identification; McIntyre (1963) for Myrtaceae identification; Cranwell (1952) for general, but more especially for Cyperaceae and Palmae identification; and Large & Braggins (1991) for ferns and fern allies was also referred to. A personal photographic slide collection of most fossil dryland taxa plus some representative wetland taxa found in Hawkes Bay, and identified in the cores of the various field sites, was also compiled to assist in pollen identification.

3.4 POLLEN MORPHOLOGY

Pollen grains from the reference collection of the Massey University Geography Department showing the diagnostic features of the more important grains, that appear in the Hawkes Bay cores, have been electronically scanned and included in the form of a series of figures as Appendix one. The description of the grains basically follows that of Moar (1993), Cranwell (1952) or a combination of these two, and Pocknall (1981a, b, c).

The figures are not idealised perfect views of the individual grains but are intended to demonstrate the salient features used by the writer to identify each pollen type as it appears in the Hawkes Bay samples. As the aim is to show diagnostic grain morphology, magnification has not been strictly adhered to. Sometimes it has been altered so as to fit two views of each grain (usually one polar and one equatorial) on the same page. In this way different morphological aspects of each grain can be discussed as a unit. Apart from the all important *Pteridium*, the ferns or fern allies have not been included.

3. 5 PHOTOGRAPHIC RECORD OF FIELD TECHNIQUES

As well as photographs of the actual pollen sites and the regional flora and topography of each site, photographs were also taken during preparation for, and the actual coring of the sites. Three photographs are included here as Figures 3. 2 to 3. 4 to demonstrate various aspects of the field techniques used.

Figure 3. 2 shows the raft used in coring three of the sites being assembled on the lake at Te Pohue. When assembled the raft was towed into position above the previously determined deepest part of the lake, and moored by three anchor lines, to the nearby shore.

Figure 3. 3 shows the completed raft moored in position. The field assistant is threading a rope through the casings used to keep the metre length rods steady in the water while coring. The rope will be attached to the Kullenberg piston on the Neale corer. The casings are lowered through the water to the bottom of the lake by means of the hole just visible in the centre of the raft. As each metre of sediment is cored and extruded, another rod length is added.

Figure 3. 4 shows the Neale corer being used to core the top metre of the flush at the Kashmir site. The amount of muscle power being exerted by the field workers is an indication of the compacted nature of the sediment being sampled.

Figure 3. 2 The raft used to core the deep water sites being assembled on the lake at Te Pohue

Figure 3. 3 Preparing the Neale corer for use from the raft at a deep water site at Big Hill

Figure 3.4 The Neale corer being used to core compacted sediments at Kashmir

CHAPTER FOUR : THE STUDY AREA

4. SETTING

Both relative and absolute pollen diagrams have been prepared from the six pollen sites in the study area. In the case of a relative diagram, the total pollen and spore frequency is summed to 100 percent and relatively apportioned to each of the taxa and spores identified at a site. In the case of an absolute diagram, total pollen frequency is apportioned according to the number of added exotic pollen types (in this case the exotic *Lycopodium* taxon) counted in each sub-sample.

Since one of the aims of this thesis is to test whether or not the palynological record along the Mohaka Fault trace can be linked to erosional events which may or may not indicate movement along the fault, a further figure has been prepared for each of the six sites. In this figure only pollen counts of taxa of local interpretive importance at each site have been included. These data have been presented under headings such as 'regional forest cover', 'regional ground cover', 'wet site', 'disturbed site', 'exotic forest', and 'site vegetation'. This figure presents the raw pollen counts at each level sampled. In this way it becomes immediately obvious when a taxon indicative of one of the above groupings, enters or leaves the pollen record. The data have then been linked to the sedimentological information in the stratigraphic column. For clarity a separate stratigraphic column has also been prepared for each of the six sites.

To assist in the interpretation of the pollen data, at least one radiocarbon date was obtained for each site. Selection of the level to be dated was made after pollen counting was completed at each site. Radiocarbon dating was carried out at Waikato Radiocarbon Dating Laboratory. The following is a list of the seven radiocarbon dates, (Table 4. 1) together with details of their significance and laboratory determinations .

Event or level being dated	Waikato Reference (Wk-)	dC13	% Modern	Conventional Age
Kashmir site				
An erosional event, possibly earthquake induced, at 1.95 m	5025	-29.1 ± 0.2	90.8 ± 1.5	780 ± 140 BP
Hinerua site				
The base of the mire, when sediment accumulation commenced, at 1.89 m	5026	-29.5 ± 0.2	70.6 ± 1.4	2790 ± 170 BP
Big Hill site				
The resumption of peat formation following an hiatus, at 0.90 m	5488	-29.3 ± 0.2	87.8 ± 1.3	1040 ± 130 BP
The base of the site, when peat formation commenced, at 1.49 m	5027	-24.7 ± 0.2	63.1 ± 0.7	3700 ± 90 BP
Willowford site				
A fire which destroyed the forest in the region, at 1.28 m	5214	-28.9 ± 0.2	94.02 ± 2.0	480 ± 170 BP
Hawkstone site				
Commencement of sediment accumulation after an erosional event 7000 yrs ago, possibly earthquake induced, at 3.12 m	5028	-27.9 ± 0.2	44.4 ± 2.1	6520 ± 390 BP
Te Pohue site				
Influx of bracken following a fire which destroyed the regional forest, at 1.98 m	5029	-29.4 ± 0.2	75.8 ± 1.6	2220 ± 170 BP

Table 4. List of the seven radiocarbon dates obtained for the six sites cored, together with details of their significance and laboratory determinations.

In each case a *c.* 1 cm slice of air-dried sediment from the 3 cm diameter pollen core was submitted.

Each sample was washed in hot 10% HCl, rinsed, dried and submitted for measurement of the ^{14}C activity by the Liquid Scintillation Counting (LSC) method. This is a procedure involving the scintillated counting of benzine and requires at least 5 grams of carbon per sample tested (Hogg, 1982). In preparing the samples three chemical stages are involved. First the oxidation or hydrolysis of the sample carbon to carbon dioxide; then the conversion of this carbon dioxide to acetylene, followed by the catalytic trimerisation of the acetylene to benzene. LSC results are Conventional Age or % Modern, as per Stuiver & Polach (1977). This is based on the Libby half-life of 5568 yr for radiocarbon with correction for isotopic fractionation applied. In the above results the isotopic fractionation, dC13 values (a measure of the remote carbon content) all fall within the set -30 ‰ guidelines, indicating there is little likelihood of contamination from reworked (old) carbon (e.g. calcium carbonate dissolved from limestone) in the samples.

When comparing the raw pollen counts with sedimentological information from the same levels, it became apparent that, in several cases a link could be established between site disturbance, possibly erosional events, and the pollen record. Taking into account the radiocarbon dates from the various sites, an attempt has been made to correlate the palynological and sedimentological evidence obtained with Grant's (1981; 1985; 1996) hypothesis of climate forced-erosional events (periodic gales) being responsible for the destruction of the regional forest both in Hawkes Bay and in fact, the whole central North Island several times in the past 800 years.

Grant's hypothesis maintains that forests suffered repeated natural catastrophic devastation by gales, fire, hillslope erosion, valley floor sedimentation and river channel changes due to natural phenomena such as, solar activity, rainfall, drought, temperature change, wind, storms and sessional vegetation changes. Grant believes Maori only had a minor effect on the extent of the natural forest. By the time of the arrival of Europeans in 1840 AD. half of the forests which had existed in the 16th century had been destroyed by gales and/or fire. Milling and land clearance have resulted in the present natural forests being only a minor remnant of those which covered most of Hawkes Bay in the 13th century. It seems that today at least three remnant forest age groups exist. These age groups have been arrived at by dendrochronological means. Grant (1996) has correlated tree ring data, obtained by means of increment coring of residual forest species in Hawkes Bay carried out by several workers in this field, with his three major and two more recent minor erosional events. Each remnant forest cohort has been linked by Grant with changes which have taken place during the time frame of the first three (major) erosional periods that Grant identified (Grant, 1981; 1985; 1996).

For clarity of argument Grant's Figure 4 (in Parsons, 1997) is reproduced below as Figure 4. 1. Grant has identified five erosional periods that have affected the forest cover of Hawkes Bay to varying degrees over the last 800 years due to the influence of gales, fire, sedimentation and human impact (Figure 4. 1).

However, a study made for the Earthquake and War Damage Commission, to establish a record of past earthquake events in the region between the Manawatu Gorge and the Napier-Taupo highway (Neall & Hanson, 1995), offers a possible alternative to Grant's climate forced erosional hypothesis. For the Neall & Hanson study a series of trenches were excavated across the Wellington (Mohaka) and Ruahine Faults situated along the eastern margin of the axial ranges in western Hawkes Bay. Each time a fault ruptured,

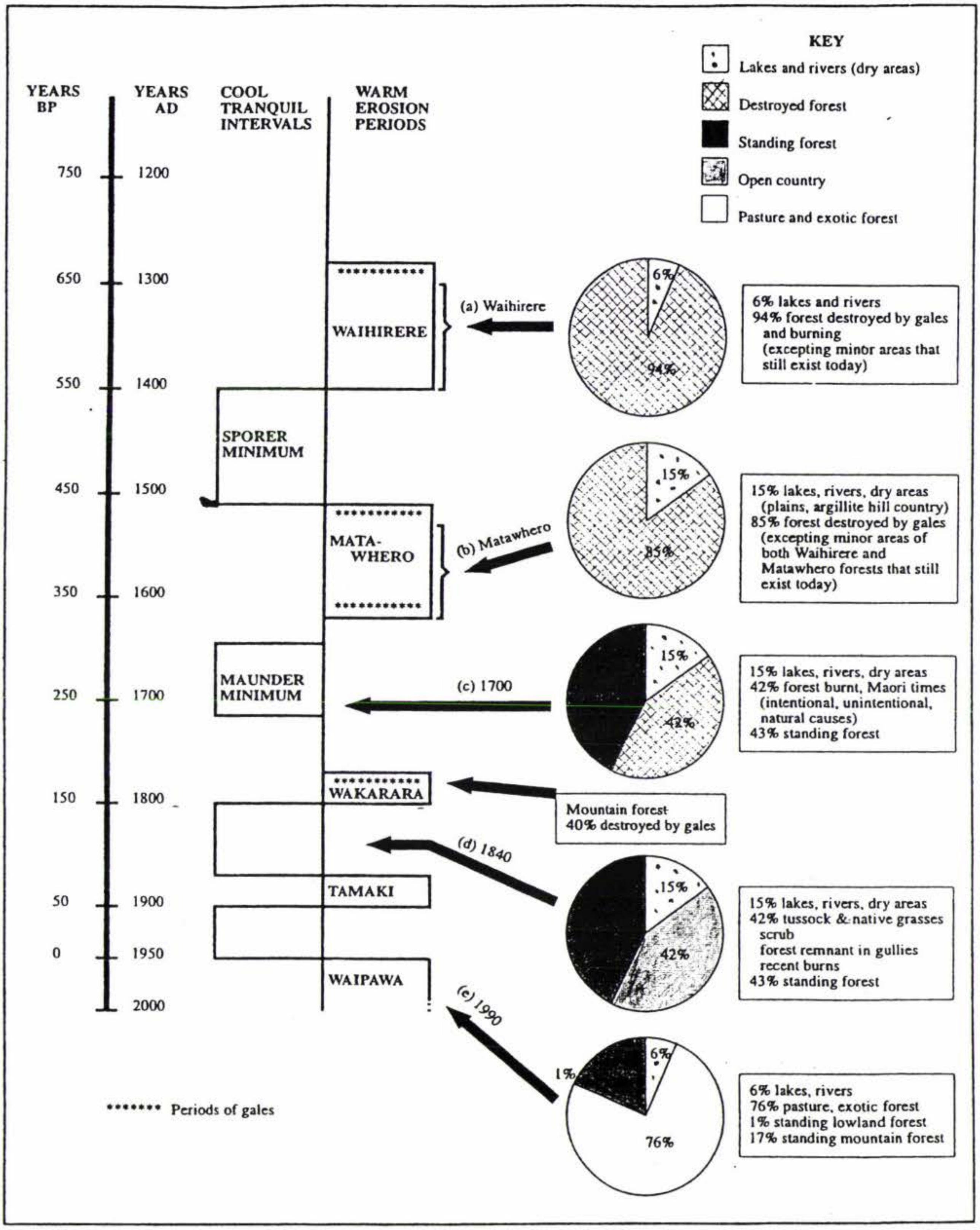


Figure 4.1 Forest cover of Hawkes Bay over the last 800 years as influenced by gales, fire, sedimentation and human impact (reproduced from Grant, *in* Parsons, 1997).

freshly eroded materials from the adjacent fault scarp were rapidly deposited into the fault trench area. In this way a sedimentary record of earthquake debris, deformation and peat layers was built up in the adjacent fault trench. The exposed peat layers were radiocarbon dated to give a time frame for the underlying and overlying earthquake debris. In places, datable volcanic ash layers have provided added time constraints to the fault movements.

Raw pollen data of selected taxa from each site, which are indicative of on, or near site floral disturbance, relative to that specific site, will also be presented for each site. These raw counts, together with absolute pollen data from the same site, will be discussed in relation to both Grant's hypothesis concerning climate forcing, and to possible earthquake events as being the causal factor in the disturbances of both the pollen and/or the sedimentological record at each site. In many cases this discussion will be closely related to the findings of Neall & Hanson (1995).

Where appropriate any site specific evidence which could be interpreted as Maori influence on the local environment will also be discussed.

THE KASHMIR SITE

4.1 INTRODUCTION

The Kashmir site is 150 m within the Ruahine Forest Park in the Moorcock Saddle area (U22/788 341), southwest of Ashley Clinton. Access is by means of Kashmir Road, which stops at the forest park boundary. The cored site is a flush, as defined by Wardle (1991) and is situated at *c.* 700 m above sea level on the edge of a cliff above the Moorcock River Flats. Immediately northwest of the site is the steeply eroded bank of an old creek bed, of which the flush is the modern-day remnant. Southeast of the site is a colluvial fan which has obscured the trace of the Mohaka Fault that lies directly south of the core site. The fault, with a local NNE-SSW strike, is visible on the scrub-covered slope 50 metres north of the site (see Figure 4. 1 6). Offset of the colluvial fan along this fault trace has blocked the drainage of the old creek bed. As a consequence, water draining off the nearby slopes has ponded in the old creek bed and is mixing with greywacke colluvium which is continually being eroded from the loosely consolidated sediments that make up the slopes in the vicinity. The result is a rapidly infilling flush that is periodically flushed by off-slope wash during heavy rainfalls.

Rainfall in the immediate Kashmir area has not been recorded. However, at nearby Mill Farm (509 m a.s.l.) 2120 mm yr^{-1} is recorded and at Ashley Clinton on the plains below (351 m a.s.l.) 1390 mm yr^{-1} is recorded (Anon 1973). As a consequence of the topographical highs to the northwest, the region comes within the eastern rain shadow belt. The soils in the general area are a steepland association of the Brown Soils group

(Hewitt, 1992), and are a reflection of the steep topography and a high rate of erosion in the area. Figure 4. 1. 1 is a map of the Kashmir region, with the core site shown in relation to the trace of the Mohaka Fault which is upthrown to the east in the area.

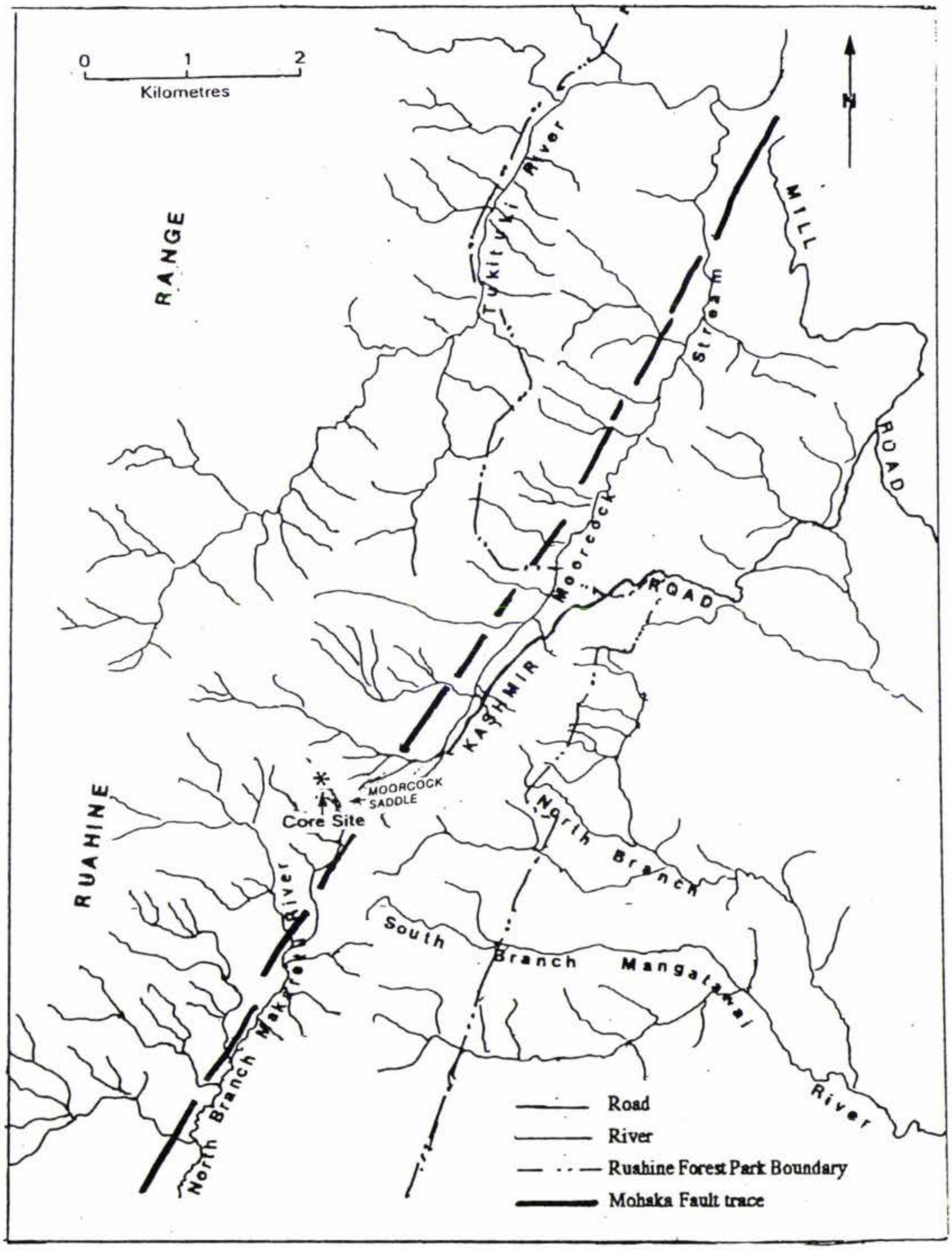


Figure 4.1.1 Map of the Kashmir region in the vicinity of the Mohaka Fault trace, with the core site marked by an *.

4.1.1 GEOLOGY AND GEOMORPHOLOGY

In the general southern Ruahine Range area Spörli & Bell (1976) have recognised three tectonically concordant structural belts: the Kashmir Belt in the east, the Pohangina Mélange in the centre, and the Axial Belt in the west. All three belts have the same northeast trend. The Kashmir site is situated within the Kashmir structural belt. The lithology of this belt comprises relatively thin alternating sandstones and argillites in beds from 10 to 50 cm thick, with occasional concretionary lenses. Conglomerates and grits, up to 5 cm in size, are found in the Moorcock Stream below the pollen site, as well as a few kilometres farther north in the Pukenui area.

The beds in this belt have been affected by either isoclinal folds, sub-horizontal open asymmetric folds, or steeply plunging open folds as a result of faulting and most have been overturned to the northwest. No date can be assigned to the movements which formed these steeply plunging folds as it is possible that the main fault systems in the Kashmir Belt have been in place since the deformation associated with the late Mesozoic Rangitata Orogeny, for there is no evidence that the fold phases represent discrete events, separated in time. It is possible, as Spörli & Bell (1976) point out, that the Torlesse rocks simply changed their mechanical response to faulting from relatively ductile to brittle as they were uplifted.

4.1.2 PRESENT DAY VEGETATION

The present-day vegetation in the Kashmir area is a mix of native lowland small trees and shrubs, and introduced grasses. Aquatic herbs, New Zealand flax and introduced grasses and weeds dominate in the immediate vicinity of the core site. *Cordyline* *indivisa* (the broad-leaved toi tree) is very conspicuous protruding through the low scrub cover on the slope above the core site. Various species of *Coprosma* and manuka (*Leptospermum* sp.) are very numerous on the eastern side of the colluvial fan about 50 metres from the site. On the edges of the flush, young lacebark (*Hoheria populnea*) is common. Farther afield whitey-wood (*Melicytus macrophyllus*) is an obvious component; and the pepper tree (*Pseudowintera colorata*) is found on the fringe of the regenerating bush. A more comprehensive, but not definitive list of native species found within a one hundred metre radius of the site, and identified from cuttings by Mr Peter van Essen of the Ecology Section of the Institute of Natural Resources at Massey University, is presented in Table 4.1

Botanical Name	**Common Name**	**Family**
Ascarina lucida	Hutu	Chloranthaceae
Blechnum sp.	Blechnum fern	
Carpodetus serrata	Putaputaweta	Escalloniaceae
Cassinia vauvilliersii	Mountain cottonwood	Asteraceae
Chionochloa pallens	Tussock	Poaceae
Coprosma foetidissima	Hupiro/Stinkwood	Rubiaceae
Coprosma linariifolia		Rubiaceae
Coprosma lucida	Karamu	Rubiaceae
Coprosma spp.	Small leaved Coprosma	Rubiaceae
Cordyline indivisa	Toi tree (broadleaved)	Asphodelaceae
Cortaderia sp.	Toe toe	Gramineae
Gaultheria oppositifolia	Snowberry	Ericaceae
Gaultheria paniculata	Snowberry	Ericaceae
Gramineae spp.	Native grasses	Gramineae
Griselinia lucida	Kapaka/Broadleaf	Cornaceae
Hebe stricta	Koromiko	Scrophulariaceae
Hoheria populnea	Houhere/Lacebark	Malvaceae
Kunzea ericoides	Kanuka	Myrtaceae
Leucopogon fasciculata	Mingimingi	Epacridaceae
Melicytus macrophyllus	Large-leaved whitey-wood	Violaceae
Metrosideros sp.	Rata vine	Myrtaceae
Nothofagus sp.	Beech	Fagaceae
Phormium tenax	Harakeke/N.Z. flax	Phormiaceae
Plantago sp.	Herb	Plantaginaceae
Pseudopanax arboreum	Pouahoa/Fivefinger	Araliaceae
Pseudowintera colorata	Horopito/Pepper tree	Winteraceae
Rubus cissoiodes	Bush lawyer	Rosaceae
Wahlenbergia gracilis	Rima-roa/Blue harebell	Campanulaceae
Weinmannia racemosa	Kamahi	Cunoniaceae

Table 4.1 Present-day native flora identified at and around the Kashmir site

Along Kashmir Road several kilometres northeast of the Kashmir site, exotic *Pinus radiata* was planted by the New Zealand Forest Service in an attempt both to stabilise the slopes to the south of the access road and to produce a commercial crop. This second aim was later abandoned as uneconomic (R. Black pers. comm. 1996). The stand is now being invaded all along the road by maturing *Hebe stricta*. North of the access road is a stand of rejuvenating forest - with a very noticeable rimu component - fringed by understorey trees. Young lacebark (*Hoheria populnea*) is also growing in the ditch along the access road in several places.

Figures 4. 1. 2 to 4. 1. 5 show various aspects of the environment in the general Kashmir area. Figure 4. 1. 2 is a view of the core site taken from the colluvial fan situated to the south of the site. Figure 4. 1. 3 is a more detailed view of the vegetation in and around the flush. The position of the core site in relation to the figure is indicated by an arrow. The pervasiveness of lacebark (*Hoheria*) and the N.Z. flax at the site is very evident. Figure 4. 1. 4 is a general view of the region to the southwest showing the slopes to be a mix of pasture and rejuvenating bush. Figure 4. 1. 5 is a view to the southeast showing the erosion scared slopes on the Ruahine Range in the region. In the foreground is rejuvenating bush, with an example of the dead standing podocarps which are very evident on the slopes around the site. Figure 4. 1. 6 is a view to the north, of the NNE-SSW trending Mohaka Fault trace (arrowed), indicating the fault is upthrown to the east in the Kashmir area.

4.1.3 RECENT SITE HISTORY

Until the 1880s the general Kashmir area was in native forest. The main species were podocarps, mainly *Dacrydium cupressinum* (rimu), *Prumnopitys ferruginea* (miro),

Figure 4. 1. 2 General view of the vegetation at Kashmir looking north from a colluvial fan situated southeast of the site. X marks the site of the flush cored

Figure 4. 1. 3 A more detailed view of the shrubby nature of the vegetation around the Kashmir site

Figure 4. 1. 4 General view to the southwest of Kashmir showing the uplifted nature of the scrub and pasture clad terrain

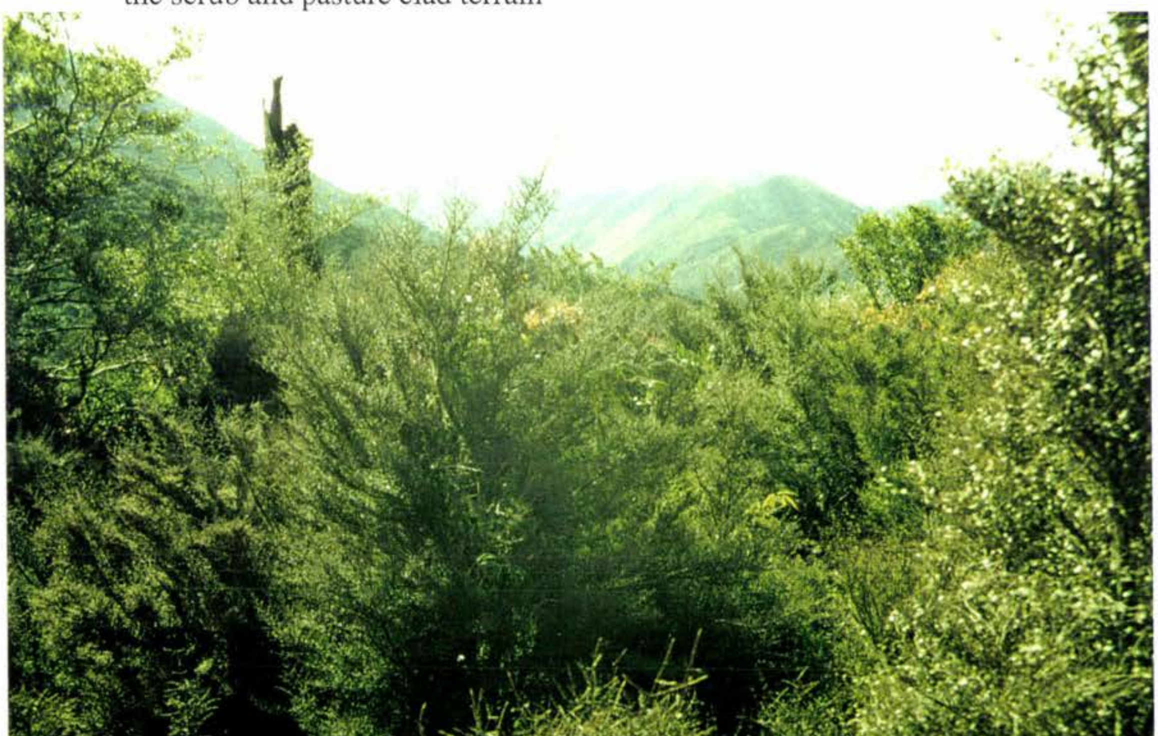


Figure 4. 1. 5 General view to the southeast of Kashmir of the rejuvenating bush near the site and the erosion scarred high country beyond

and to a lesser extent matai *P. taxifolia* (matai) and *Dacrycarpus dacrydioides* (kahikatea). There was also a dense undergrowth of ferns, vines and small trees. *Weinmannia racemosa* (kamahi) was also an important component of the bush. In the 1880s the Moorcock Flats area was cleared for farming. At that time fire was used in an attempt to clear the forest, but it was not very successful. However, the 1888 fire in cutover forest in the 70 Mile Bush at Norsewood is known to have reached the Kashmir area (P. Bonis pers. comm. 1996).

In the early twentieth century several timber mills were set up in the area. Milling began in the Kashmir area in 1918 when C. & F. Thomsen opened their mill on Moorcock Flats, a few kilometres north of the core site. Their aim was to clear the land for farming, when attempts to do so by firing the bush had failed. The Thomsens milled mainly rimu and matai, with some miro and kahikatea, and very minor totara. When felled, much of the forest was found to have a rotten heart and therefore deemed of little commercial value. The last mill in the area was relocated in 1975. At that time one third of the bush on the steeper slopes still remained unmilled because it was deemed of low quality and difficult to reach. This century wild fires and browsing from introduced deer have damaged the remaining bush (Dept. of Conservation pamphlet, 1996).

In 1946 a massive fire burnt 2000 acres of bush from the bush edge to the top of the Ruahine Range above Moorcock Stream. A considerable area of podocarp forest was burnt (Wright, 1985). Figure 4. 1. 5 shows the still standing trunks of some of the fire razed podocarps (identified by P. van Essen as probably miro). Figure 4. 1. 7 shows a cut through one of the large dead rimu trees that litter the slopes in the immediate vicinity of the site. Several attempts to obtain a biscuit cut sample from one of these trunks, in the hope of doing a ring count, were fruitless due to the rotted nature of the heart of the trunks.

Figure 4. 1. 6 The NNE-SSW trending Mohaka Fault trace, upthrown to the east at Kashmir

Figure 4. 1. 7 A cut through a large dead *rimu* lying on a colluvial slope at Kashmir showing evidence of having survived one fire, to be destroyed by another

However, evidence that the area was swept by a fire that did not kill all the forest can be seen in the cut through the dead rimu trunk in Figure 4. 1. 7. The dark line towards the top of the cut is the charcoal outline (arrowed) of the fire singed outer bark of the tree after the fire. The tree then continued growing. A rough tree ring count since the fire indicates the tree continued to grow for about a further sixty years. As most of the rotting fire-singed trees on the slopes in the vicinity of the site appear to have fallen naturally and been left where they fell, it is very likely the charcoal within the dead rimu in Figure 4. 1. 7 is from the 1888 fire in the 70 Mile Bush, and the fire that eventually killed the tree is that of 1946.

4.1.4 PALAEOECOLOGY

The results of the pollen analysis of the Kashmir site are presented in Figures 4. 1. 8 and 4. 1. 9. The stratigraphy is presented separately in Figure 4. 1. 10 (p.78). A sample of organic mud taken from the AB horizon of a buried soil at 1.95 m depth was dated (Wk - 5025) at 780 ± 140 yrs BP.

The pollen diagrams have been zoned using a subjective assessment in conjunction with a visual inspection of the diagrams and to a lesser degree, the CONISS dendrogram provided by the Tiliagraph programme. Three zones have been assigned, namely, Ka1, Ka2 and Ka3; Ka is the code assigned to the Kashmir site.

Zone Ka1 2.00 - 1.80 m

The terrestrial pollen in this zone is dominated by *Nothofagus fusca* with minor *Dacrydium cupressinum*. Also present in substantial numbers are *Prumnopitys*

FIGURE 4. 1. 8 RELATIVE POLLEN DIAGRAM KASHMIR SITE

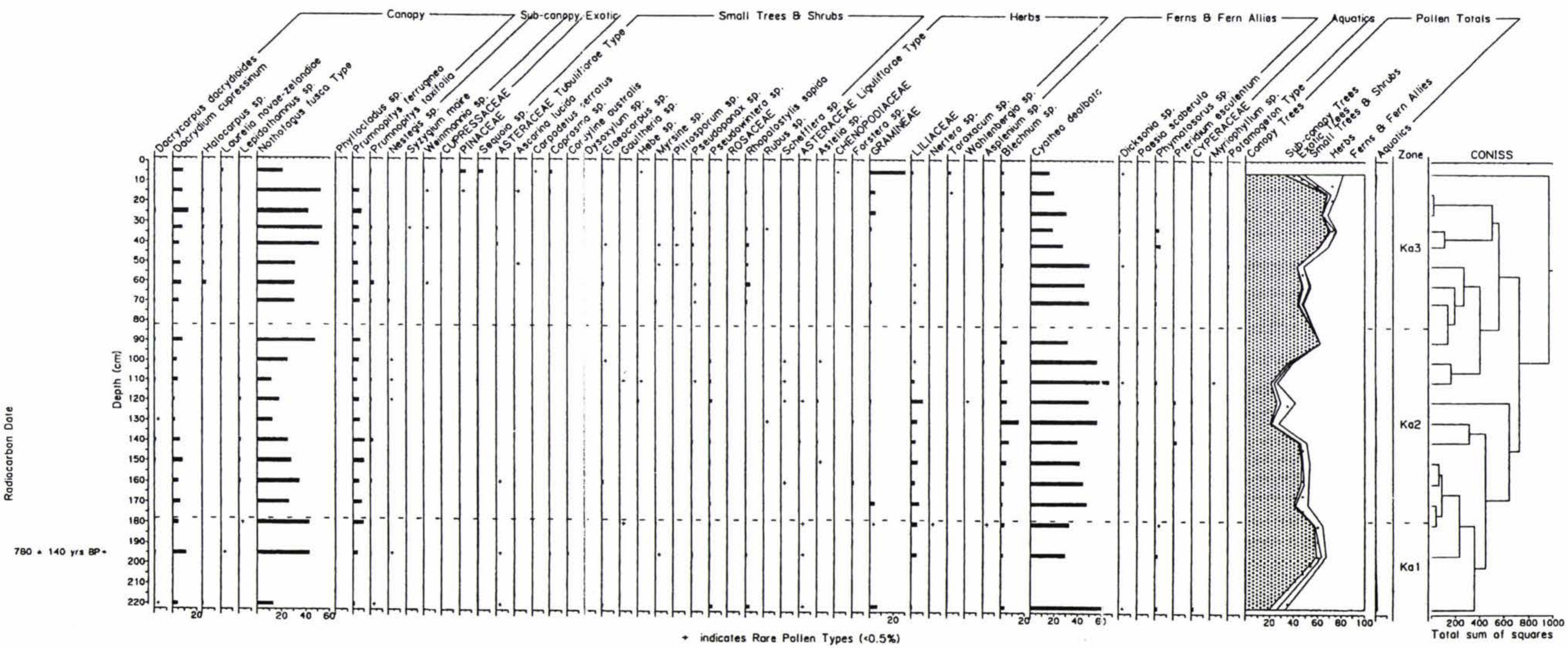
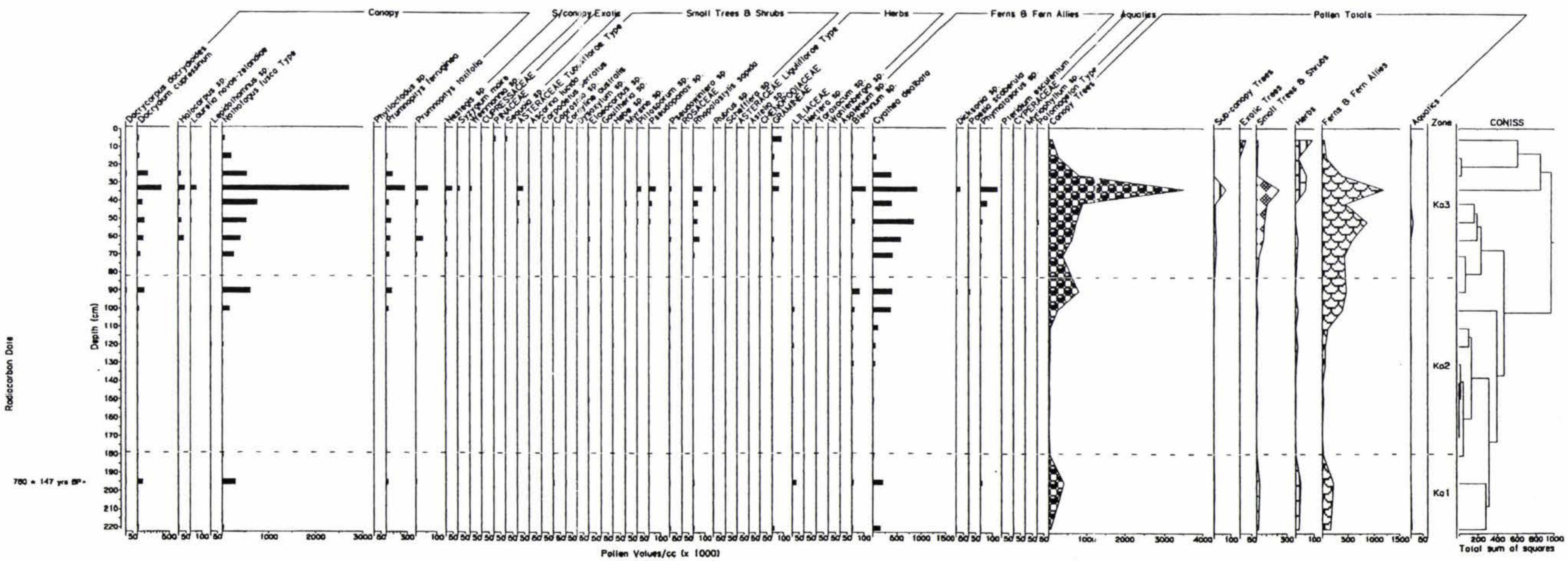


FIGURE 4.1.9 ABSOLUTE POLLEN DIAGRAM KASHMIR SITE



ferruginea and *Rhopalostylis sapida*. *Pseudowintera* also has a notable presence at the base of the zone. This taxon together with *Rhopalostylis* declines upwards, while at the same time, *Nothofagus* expands rapidly to become the dominant forest taxon up to the top of the zone.

The tree fern *Cyathea dealbata* dominates the base of the zone. Native grass forms a conspicuous component of the herbaceous taxa at this level as does the reed Cyperaceae. Both leave the record immediately above, while at the same time *Nothofagus* percentages increase. *Blechnum*, and to a lesser degree Liliaceae, also have a notable presence throughout. The fern, *Phymatosorus*, also appears at the top of the zone, as do Liliaceae species.

High frequencies of fern spores at the base of the zone suggest a fairly abundant pteridophyte flora more associated with moderately dry conditions. However, the high frequencies of grass and Cyperaceae in the basal layer could be related to swamp vegetation expansion in the vicinity of the site.

During the period of time covered by the base of this zone secondary forest taxa, in particular *Pseudowintera*, *Rhopalostylis* and to a lesser extent *Elaeocarpus* together with the tree ferns, and *Blechnum*, expanded. The pollen record indicates that all of these taxa and ferns, which are indicative of an open disturbed site, were able to enjoy an expansion at a time when primary vegetation around the site was establishing, after experiencing a marked degree of instability and disturbance. As this is the base of the site it is very likely the disturbance was earthquake induced.

By the time indicated at the top of the zone, beech forest in the area was well established and *Prumnopitys ferruginea* and to a lesser degree *Dacrydium cupressinum*, formed an important component of this forest. At the same time shrub taxa indicative of open disturbed forest were greatly reduced. The appearance of *Phymatasorus* , a taxon indicative of locally wet conditions, at the top of the zone tends to indicate that water was ponding at the site at this time. This evidence of ponding coincides with marked change in sediment. Within the 1.82 to 1.90 m depth, which was unsampled, is presumably the A horizon of a buried soil (see discussion below). Thus the top of the zone is defined by a major local disturbance which could be storm or earthquake related.

Zone Ka2 1.80 - 0.80 m

The major change that defines this zone is that at the base of the zone all pollen and spore counts are low, although the persentages of the forest taxa are similar to those in the previous zone. The low count is a reflection of clastic input at the site following the major disturbance discussed above. *Nothofagus* is still the dominant forest tree, with *Dacrydium* and *P ferruginea*, continuing as important forest components. *Dacrycarpus dacrydioides* makes a small but consistent appearance towards the middle of the zone. The silver fern (*C. dealbata*) continues to dominate the understorey throughout. Monolete fern spores are very common. *Blechnum*, indicative of a disturbed site, is very prominent. *Asplenium* (hen & chicken fern), *Paesia scaberula* (ring fern) and *Pteridium* (bracken) all appear towards the top of the zone in small percentages.

Liliaceae forms a conspicuous component of the herb taxa, with native grasses still present in small numbers and *Forstera* appearing intermittently throughout the zone, albeit in small percentages. Liliaceae appears in moderate numbers at the base of the zone and increases to maintain high levels towards the top of the zone. The aquatic plant, Cyperaceae also makes an appearance towards the top of the zone.

Pseudowintera is still present, but in much reduced percentages. However, many of the small tree and shrub pollen types which were present in the previous zone, are either absent or have become much reduced in numbers. This marked decline in the frequency of secondary forest taxa tends to indicate the primary vegetation around the site was becoming established, and as the canopy closed in, the secondary taxa became much reduced due to unsuitable ecological conditions.

Nearly all the tree pollen and spores in this zone are corroded. This suggests they are a consequence of inwash from eroding soils within the catchment. This would indicate that the site acted as a pollen trap for vegetation on the surrounding slopes. The corroded state of the pollen would help account for the generally low pollen and spore counts thoughout the zone.

The high frequencies of fern spores suggest a fairly abundant pteridophyte flora more associated with open conditions. This, together with Liliaceae, and to a lesser extent native grasses, *Pteridium* and Cyperaceae all suggest the site was a wet open flush acting as a trap for both the on site and the regional pollen and spores. This abundance of both pteridophyte and bog land flora is especially noticeable at the 0.90 to 1.40 m depth. However, the apparent presence of wetland and herb taxa in higher frequencies could all be related to very localised site vegetation expansion, not forest reduction in the region. In this way any apparent decline in percentage of forest taxa would be just a reflection of the dramatic increase in percentages of vegetation in and around the site.

The appearance of *Dacrycarpus dacrydioides* towards the middle of the zone, which coincides with the increase in wetland and herb taxa lends support to the conclusion that local conditions were becoming damper and perhaps more disturbed, from mid-zone to near the top of the zone.

Zone Ka3 0.80 - 0 m

The major change that defines this zone is an abrupt reduction in wetland taxa and herbs. *Nothofagus* continues to dominate the primary forest in the zone, albeit with initially reduced percentages. The abrupt reduction in wetland taxa indicates the site was drier than at the top of the previous zone. This, together with the initial reduction in beech percentages, suggests there was an erosional event at the site at this time. A coarse sandy lens in the sediments at 0.80 - 0.81 m depth supports this. *Dacrydium* and *P. ferruginea*, continue to have the low but stable presence they had in the previous zone. *Dacrycarpus dacrydioides* is present in very small percentages. About mid-zone both *Halocarpus biformis* (pink pine) and *Nestegis* (maire) enter the record and maintain a continual, if small presence to the top of the zone.

Cyathea dealbata initially has a very high presence, but declines in frequency towards the top of the zone, while at the same time beech percentages increase. As beech expands small tree and shrub taxa also appear in the record. Understorey species such as *Pittosporum*, *Pseudopanax*, *Myrsine*, *Coprosma*, and *Elaeocarpus* have a small but constant presence almost to the top of the zone. *Rhopalostylis* returns to the site at the base of the zone and maintains a moderate, but fairly steady presence, almost to the top of the zone. The expansion of *Nothofagus* and understorey species indicates the canopy was relatively open at this time, and coincided with the entry of *Halocarpus* and *Nestegis* into the record.

This expansion also comes at a point when the stratigraphy indicates continual sediment input into the site had slowed and soil formation was occurring. This soil formation was intermittent, being continually interrupted by influxes of gravelly sand and clastic material. These influxes indicate site disturbance continued until the present.

Grass is the main herb in this zone. This taxon has an initially minor input at the base of the zone, but increases dramatically at the top. *Pinus radiata* and *Sequoia* also enter the record at the top of the zone, as does *Tararacum*. The appearance of these exotic taxa is attributed to European land clearance in the early twentieth century.

Aquatic plant taxa are greatly reduced throughout the zone, with *Potomageton* making only intermittent, minor appearances. However, the appearance of this swampland taxa, together with the herb Liliaceae at the top of the zone, suggests the site is wetter now than it was at any time during the period covered by the zone. As this change coincides with forest clearance in the Kashmir area, this increase in wetness could be due to increased overland flow from the surrounding hills into the site following forest clearance.

4.1.5 DISCUSSION

Sediments at the Kashmir site range from coarsely fibrous peat in the top layers of the stratigraphic column, to sand with a generally weakly developed crumb or fine nut structure in the horizons below. At 0.21 m depth here is the A horizon of a buried soil (S1) and again at 1.90 -2.05 m depth there is the AB horizon of a further buried soil (S2). The texture of this buried soil is that of a silt loam with a fine crumb structure. A sample from the AB horizon at 2.05 m depth returned a radiocarbon date of 780 ± 140 yrs BP. A stratigraphic description of the site is set out in Figure 4.1.10.

The pollen record at the Kashmir site extends back about 800 years. The stratigraphy indicates there have been three episodes of soil development during this time. The event that terminated soil development of the buried soil S3 is not recorded as it is contained within the unsampled section between 1.82 and 1.90 m depth. However, in the sediment above 1.82 m up to 0.51 m depth (S2) coarse sand, grit and gravel are continually recorded. These coarse sediments are a reflection of a period of instability at the site. In the case of the buried soil S1, soil development has been terminated by a further input of very gritty sand into the site at 0.21 m depth. As the site is situated in a greywacke terrain and within the Mohaka Fault Zone, it is accepted that the influxes of these coarse sediments have come off the loosely compacted topographical highs surrounding the site. This influx is due to either storm- or earthquake-induced erosion.

The overall pollen record at the Kashmir site indicates that for at least the past 800 years the region has been covered in *Nothofagus fusca*-type forest in association with podocarps, mainly *Dacrydium cupressinum* and *P. ferruginea*. *Dacrycarpus dacrydioides* and *P. taxifolia*, although present, have only a minor role in this association. A notable absence from the record is *Podocarpus totara*.

This record is in reasonably good accordance with what Elder (1965) found in his study of the vegetation of the central Ruahine Range region. Elder found that a fringe of podocarps, mainly *Dacrydium* with a little *P. taxifolia* and *Dacrycarpus dacridioides* occur either scattered throughout the lower red beech forest which predominates in the region, or in small pockets on favourable sites. Scattered *P. ferruginea* also occurs to somewhat higher altitudes and *Halocarpus biformis* is present over most of the range

KASHMIR SITE

m	Horizon	Description
0	Of 1	Very dark greyish brown (10YR 3/2) coarsely fibrous peat with very fine muddy sand; many fine and coarse roots c 2 mm; many stalks c 1 mm; distinct boundary
0.07		
0.12	Of 2	Dark greyish brown (10YR4/2) coarsely fibrous peat with very fine gravelly sand; many 1 mm and 5 mm roots; sharp boundary.
0.14	Cw	Black charcoal rich gleyed layer; moderately developed fine nut texture; few very angular greywacke clasts c 4mm; sharp wavy boundary.
	Cg	Very dark greyish brown (2.5 Y 3/2); very gritty fine sand; gleyed; distinct boundary.
0.21		
	2Ahb	Very dark olive brown (2.5Y 3/3) very fine sand; weakly developed fine nut structure; many very angular greywacke clasts c 3 mm; wavy distinct boundary.
0.30		
	2A/B	Very dark olive brown (2.5Y 3/3) and light olive brown 2.5Y 4/3) very fine sand; weakly to moderately developed fine nut structure; many 3-4 mm angular clasts; 5mm charcoal layer at base; distinct wavy boundary.
0.42		
0.51	2C	Brownish black (10YR 3/1) gravel lens; abundant angular clasts c 4 mm; abrupt, distinct, wavy boundary.
	3Bw 1	Olive brown (2.5Y 4/4) fine sandy loam; weakly developed crumb structure; many 3 mm angular greywacke clasts; coarse sandy lens at 0.80-0.81 m; wood at 0.90 m; sand component coarsening and increasing below 0.90 m; many clasts c 4 mm and a few quartz grains c 2 mm; pebbles c 6 mm at 1.00 m; pebbles c 8 mm at 1.10 m; coarse sand c 2 mm at 1.20 m and profile becoming grittier; gravel lens lens at 1.30-1.31m ; gradational boundary over 30mm.
1.34		
	3Bw2	Dark greyish brown (2.5Y 4/2) gritty sandy loam; weakly developed crumb structure; some clasts c 3 mm; gradational boundary.
1.60		
	3Bw 3	Greyish brown (2.5Y 5/2) fine sand; moderately developed fine crumb structure; loose; dry; few clasts c 3 mm; moisture content increasing down profile; by 1.75 m structure is a fine nut; grit and coarse sand content c 2 mm increasing.
1.82		NOT SAMPLED
1.90		
14C date 780 ± 140 yrs BP. 2.05	4AB	Olive Brown (2.5Y 3/3) silt loam; fine crumb structure; slightly firm; some fine roots c1 mm; some organic matter; profile moist; gradual indistinct boundary;
	4Bw	Olive brown (2.5Y 4/3) silt loam; fine crumb structure; friable; few fine roots; profile drying out.
2.22		Base of site

Figure 4. 1. 10 Stratigraphic column. Top 0.80 m cored using the Neale corer; below 0.80 m site was sampled by auger, due to gravelly nature of the sediment.

in the mountain beech forest, but most commonly below 1300 m. Although Elder found *Podocarpus totara* was present on the rolling country from Ashley Clinton to Kereru to the northeast, this podocarp has not been seen within the boundary of the range in this vicinity.

Rhopalostylis sapida (nikau palm) does not appear to be present on the range proper. However, Grant (1997) records many sightings of this lowland forest palm in the general Hawkes Bay area. Some sightings near to the Kashmir site occur in the Otamaroho Bush just south of Kashmir, at Te Uri near Dannevirke, in the Awapikopiko Reserve near Woodville, within the Manawatu Scenic Reserve, and in the McLean's Bush Scenic Reserve near Cape Turnagain (Grant, 1996). Its appearance in the pollen record at Kashmir as far back as 800 years ago indicates this palm has been a component of the lowland bush in Hawkes Bay for at least that long.

The main subalpine scrub species identified in the pollen sequence at Kashmir also accord well with what Elder (1965) found at lower altitudes on the eastern side of the Ruahine Range. *Pittosporum*, *Myrsine*, several *Coprosma* and *Pseudopanax*, plus minor *Gaultheria*, *Pseudowintera*, *Schefflera*, and *Rubus cissoides*, are all found at various levels at the Kashmir site during its 800 years history. All are lowland scrub taxa identified by Elder as growing on the lower slopes of the eastern portion of the Ruahine Forest today.

Comparison of the 800 year pollen record at Kashmir with rejuvenating native species growing in the vicinity of the site today indicates that, until forest clearance in the early twentieth century, there have been no major changes in the regional flora within this 800 year time. Any changes in pollen percentages and/or pollen types in the Kashmir record must, therefore, relate to site-specific conditions at the time of the change.

The conditions that initiated these changes have been identified as storm- or earthquake-induced erosional events.

As mentioned above, this aspect will be addressed by selecting some important taxa of local (site) interpretive importance and presenting the raw pollen counts of these taxa in diagram form (Figure 4. 1. 11). These raw counts in conjunction with absolute pollen data will then be discussed in relation to changes in the sediments accumulating at the site. The reason for choosing the raw data relating to these selected taxa (as opposed to processed data) is that only taxa of interpretive importance are required. By using this raw data it becomes immediately apparent when any of these species enter or leave the pollen record. It is this type of change that is important, as the aim of the exercise is to discuss whether or not there is any evidence in the overall record of changes that can be attributed to climate-induced forcing (Grant's hypothesis) and/or earthquake-induced erosional events (Neall & Hanson's hypothesis).

However, to do this some sort of time frame has to be adhered to. It is known that there were fires at the site both in 1888 and 1946 (see above), as well as more recent minor fires in the area. There is a charcoal layer in the stratigraphy at 0.12 - 0.14 m depth. Large charcoal pieces were also identified in the pollen samples at both 0.15 m and 0.41 - 0.42 m depths. As minor *Pinus radiata*, and *Sequoia* as well as grass were also in the pollen record at 0.15 m depth, the 1946 fire has been assigned to this level, and the charcoal at 0.41 - 0.42 m depth assigned to the 1888 fire. For this reason the gravel lens in the stratigraphic column at 0.43 - 0.44 m depth could be evidence of Grant's Tamaki Erosional Period of 1870 to 1900 AD (see Figure 4. 1) as this disturbance is just below the charcoal layer assigned to the 1888 fire.

Interpretive Stratigraphic Data based on sediment accumulation rates & pollen information	Depth sampled (m)	Regional Forest: Beech	Rimu	Matai	Miro	Coprosma	Nikau palm	Exotics: Pinus radiata	Regional G. cover: Grass	Silver fern	Disturbed Site: Blechnum	Cyperaceae	Liliaceae
Minor fire in area	0.05	56	22	2		5		13	81	42	5		3
Charcoal = Fire at site (1946)	0.15	156	23		19	2	3	1	13	57	7		1
	0.25	151	44		31				17	108	1		
	0.33	195	27	4	22	2	5		4	65	8		
Charcoal = Fire at site (1888)	0.41	215	21	3	12	2	11			112	2		
Earthquake (1863 AD) (0.43-	0.44m)			Gravel		lens	at		site				
	0.51	150	30	1	21		10			240	7		1
	0.61	141	31	12	22		18		5	210			
	0.70	165	26	4	33		8		6	266	5		
?Wakarara Erosional Period	0.80			Detrital		sand	at		site	- No	pollen	accumulated	
	0.90	174	29		23					113	18		
	1.00	151	19	2	32					341	17	5	5
	1.10	42	16	3	13					250	19	5	
	1.20	69	6	3	20				3	190	19	23	
?Matawhero Erosional Period	1.30	44	7		22				2	203	53	16	
(gravel lens at 1.31 m)	1.40	66	15	5	26					104	17	9	
	1.50	72	21		25					107	11	11	
	1.60	84	11	2	13				1	108	6		5
?Waihirere Erosional Period	1.70	38	9		11				6	69	2		8
(gravel at 1.75m)	1.80	155	17	2	34				2	118	10		12
				Site		not			sampled				
AB horizon of a paleosol -->	1.95	166	42	2	12	3	4			114	7		12
(14C date 780 ± 140 yrs BP)	2.20	82	26	2	8		21		40	390	21	11	4

* 2cc sampled at each depth

* 220 primary forest taxa and /or grass taxa counted at each depth or 4 slides fully scanned where dryland taxa did not accumulate

Figure 4.1.11 Interpretive stratigraphy of the Kashmir site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995).

However, in 1863 AD. there was an earthquake measuring M7.5 on the Richter Scale centred midway between Waipukurau and Ashley Clinton (C. Wallace pers. comm. 1998). As an event of such magnitude would have affected the Kashmir area situated in the foothills of the Ruahine Range above, it would be recorded in the stratigraphy of the Kashmir site. For this reason the erosional event signalled in the sediments at Kashmir by a gravel with abundant angular clasts between 0.44 and 0.51m depth, could reflect this event. This possibility is based on assigning the 5 mm charcoal layer at 0.42 m depth to the 1888 Norsewood fire that is known to have swept through the whole area.

Inspection of the stratigraphic column (Figure 4. 1. 10) indicates that above 1.82 m depth, there have been no major depositional breaks in the sediment record until the gravel lens at 0.51 m depth assigned to the 1863 earthquake. For this reason, and solely for the purposes of the exercise, it has been assumed that sediment accumulation rates have been more-or-less constant at the site from the disturbance identified at 1.82 m depth, up to 0.51 m depth.

The 780 ± 170 yrs BP. radiocarbon date (Wk - 5025) for the 1.95 m depth corresponds to 1170 AD ± 140 yrs BP. With the 0.51 m depth assigned to 1863 AD. this provides the time parameters for an assumed constant accumulation rate of 2.08 mm/yr. between these two dates. Based on this time frame the site disturbance recorded at *c* 1.75 m depth by coarse gritty sand in the stratigraphic column, is assigned a date of *c*. 1270 AD. ± 140 years; the site disturbance recorded at 1.31 m depth by a gravel lens in the stratigraphic column is assigned a date of *c*. 1480 AD. ± 140 years; and the site disturbance recorded at 0.80 m depth by a coarse sandy lens in the stratigraphic column is assigned a date of *c*. 1725 AD. ± 140 years.

Although the evidence to support Grant's hypothesis is very tenuous, the time frame for his three main erosional periods, namely the Waihirere, the Matawhero and Wakarara Erosional Periods, have been added (as a tentative hypothesis) to Figure 4. 1. 11, with reasons, as follows:

The Wakarara Erosional Period - 1770 - 1800 AD. (180 to 150 yrs BP.)

This period is tentatively assigned to the 0.80 m depth. This is based on the sediment accumulation rate and the fact that at this depth there was an input of detrital sand into the site. Apart from five corroded part pollen grains, no pollen was found at this depth. Instead, the processed pollen sample consisted almost entirely of very weathered silica grains. This is evidence of a local erosional event. From the raw pollen counts of the regional forest both above and below this level, as shown in Figure 4. 1. 11, it is obvious there is absolutely no change to this forest composition. However, following this erosional event at 0.80 m depth there was a large increase in silver fern (*C. dealbata*) in the area. Counts of this tree fern remained high until the next erosional event at the site which has been assigned to the 1863 earthquake. Following this event the tree fern gradually declined in importance.

The Matawhero Erosional Period - 1510 - 1620 AD . (440 - 330 yrs BP.)

This period is tentatively assigned to the 1.31 m depth. This is based on sediment accumulation rates and the fact that there is a gravel lens at this depth followed by a gradational boundary over 30 mm to a Bw horizon below. There is also a temporary dip in the regional beech pollen counts at this depth, while at the same time there is a large increase in silver fern. Counts of this tree fern remain high until the base of the next erosional period above. As well there is a very large increase in *Blechnum* spores at 1.30 m depth (53 spores counted). This is indicative of site disturbance on a large scale. Counts of this monolete fern also remain moderately high until the next erosional period. Cyperaceae counts also increase markedly following the gravel input into the site. Grant's hypothesis maintains this erosional period lasted for about 100 years. Pollen and spore counts between 1.10 and 1.30 m depth do not discount this possibility. Coarse sand and grit in the profile also indicate the site was disturbed at this time.

The Waihirere Erosional Period - 1280 - 1400 AD. (670 - 550 yrs BP.)

This period has been assigned to the 1.75 m depth. This is based on accumulation rates, a drastic reduction in all pollen and spores in the record at this point and grit and coarse sand in the sediments at this level. Raw beech counts drop from 155 at 1.80 m depth to 38 at 1.70 m depth. The podocarp counts are also greatly reduced at this time, as are the ferns. Regional forest pollen counts climb only slowly during the interval up to the next erosional period above. However, podocarp species, a minor component in the pre-disturbance forest, recovered relatively more quickly than the beech forest. When disturbed, beech forest is known to take longer than podocarp forest to reestablish in an area (Elder, 1965). The evidence here of forest regression does tend to support Grant's scenario of almost total forest destruction during the gales of his Waihirere Erosional Period. But it is also possible that, following an erosional event that terminated soil development at the site, sediment accumulation rates from 1.75 m to 1.60 m depth were greater than the average 2.08 mm/yr. calculated for the site, with the low pollen counts recorded at this level just a reflection of this increase in sediment accumulation.

It is evident that small trees and shrubs had virtually disappeared from the Kashmir record by 1.80 m. depth. That is, in temporal terms, between the date of 780 ± 140 yrs BP. and the 670 to 550 yrs BP., when the gales of the Waihirere Erosional Period are purported to have destroyed 94 percent of forests in New Zealand Also, below 1.80 m depth, and within the 8 cm non-sampled section, is presumably the A horizon of a paleosol together with its contact with the overlying Bw horizon, where the sedimentological evidence that may support Grant's hypothesis for the commencement of his Waihirere Erosional Period should lie.

Another major problem that needs to be addressed is that Grant maintains that fires accompanied the Waihirere age gales. There is absolutely no charcoal in the stratigraphy at Kashmir below 0.42 m level to support Grant's hypothesis that the forest in the Kashmir area was destroyed by fire. The first fire recorded at the Kashmir site is at 0.42 m depth, and this has been assigned to the 1888 AD. fire, which began in cut-over forest at Norsewood, on the plains below the Kashmir site. It must also be noted here that there is no evidence of fire-induced changes at Kashmir that can be attributed to Polynesian settlement either.

Nevertheless, with the above site disturbances tentatively assigned to Grant's hypothesis, this leaves an erosional event dated around 800 yrs BP. in the Moorcock Saddle area unaccounted for in Grant's hypothesis. Hubbard and Neall (1980) discuss several major erosional events that have taken place in the West Tamaki Catchment of the central Ruhine Range. One of these events is dated at *c.* 770 ± 60 yrs BP. Neall and Hanson (1995) believe it is possible this event may have been initiated by movement along the Mohaka Fault which traverses that catchment. Also a radiocarbon date from a trench dug farther north in the vicinity of the Mohaka Fault on McCool's farm at the end of Nelsons Road (U21/010764) by Neall & Hanson, has returned a radiocarbon date of 805 ± 58 yrs BP. This date was taken from a wood sample folded between a sandy silt loam and a gravel unit and is interpreted by Neall & Hanson as recording an earthquake event that displaced deposits of both the Waimihia Tephra (3280 ± 20 yrs BP. (Froggat & Lowe 1990)) and the Taupo Tephra (1850 ± 10 yrs BP. (Froggatt & Lowe 1990)) layers below.

As the Mohaka Fault trace, in both the Kashmir region and the area covered by the McCool trench, forms part of the same segment of the Mohaka Fault trace (J. Hanson pers. comm.), it is possible, given the close temporal proximity of these two radiocarbon dates that they are a record of the same erosional event. That being so, it is concluded that this same event is recorded in the sediments of the Kashmir stratigraphic column not long after 780 yrs ± 140 yrs BP. and at least one hundred years before 650 yrs BP., which is the start of Grant's storm-induced Waihirere Erosional Period. This 30 year period from 780 to 750 yrs BP. is based on sediment accumulation rates in the Kashmir stratigraphic column. Based on the above evidence it is concluded that the erosional event that buried the topsoil at the Kashmir site between 780 and 750 yrs BP. was the result of an earthquake induced movement along the Mohaka fault in the Kashmir region.

Neall & Hanson (1995) also report on a further erosional event that deposited fine sandy gravel into the McCool 1 trench. This event is dated at 605 ± 35 yrs BP., from a sample taken from the underlying peat. This event is interpreted by Neall & Hanson as a possible earthquake or storm event. Based on the accumulation rates in the Kashmir stratigraphy, this event may correspond to the Kashmir erosional event indicated by a gravel layer at 1.75 m depth and tentatively assigned to Grant's Waihirere Erosional Period. As one of the reasons for linking this erosional event to Grant's scenario, was the palynological evidence of a general forest regression in the Kashmir area immediately following the deposition of the gravel layer, the 605 ± 35 yrs BP. event recorded by Neall & Hanson is accepted here as more likely to be evidence of a storm-induced erosional event, than of an earthquake.

Bearing in mind the original aim of the above exercise, which was to test first, whether there was any evidence in the palynological and/or sedimentological record of the Kashmir site to support Grant's hypothesis of periodic storm events having greatly reduced the forest cover in the central North Island, and second, whether there was any evidence in the same record for earthquake erosional events, the following sedimentological history is tentatively concluded.

- At a date unknown but, based on sediment accumulation rates, no earlier than 1000 - 1150 yrs BP. and no later than 880 ± 140 yrs BP. an earthquake event formed the topographical depression at the site.

- At *c*. 880 yrs BP. (at 2.10 m depth) the Kashmir site was damp, possibly boggy.

- At about 780 yrs BP. (between 1.82 - 1.90 m depth) the site was strongly influenced by an earthquake-induced erosional event which infilled the swampland.

- At *c*. 600 yrs BP. (at 1.75 m) the site was again affected by an influx of gritty sand, signalling an erosional event (possibly related to the Waihirere Erosional Period).

- At *c*. 400 yrs BP. (at 1.31 m) gravel was deposited at the site, indicating another erosional event (possibly related to the Matawhero Erosional Period).

- At *c*. 160 yrs BP. (at 0.80 m) coarse sand was deposited at the site, signalling a further erosional event (possibly related to the Wakarara Erosional Period).

- In 1863 AD. (0.51 m) the site was influenced by a large earthquake-induced erosional event, gravel and clastic material were deposited at the site.

- At *c.* 1863AD. (0.43-0.44 m) gravel was again deposited at the site, evidence of a further erosional event (probably related to an historical earthquake in the region; alternatively the event could be related to Grant's Tamaki Erosional Period)

- In 1888 AD. (0.42 m) the site was burnt as a consequence of the fire in the 70 Mile Bush, which spread up into the Kashmir area

- In 1946 AD. (0.12 -0.14 m) the site was again affected by fire in the Ruahine Range to the west of Kashmir and resulted in a charcoal rich gleyed deposit at the site

The above was concluded by linking the palynological record extracted from 10 cm subsampling of the site, to the sedimentological record of the site, and underpinning the data with a radiocarbon date at the base of the record, and historical dates of known fires and an earthquake event at the top of the record.

THE HINERUA SITE

4. 2 INTRODUCTION

The Hinerua site is situated along the Mohaka Fault on Peter Oakley's property at Hinerua, west of Ongaonga in western Hawkes Bay (U22/859 456). Access to the site is from the end of Hinerua Road where the road converts to Hinerua Road Extension and is closed to public access. The pollen core site is a mire, as defined by Wardle (1991), situated immediately west of the fault scarp at *c.*450 m above sea level. Immediately to the west of the site is a hill with a steep face. The mire has formed in the depression between this hill and the fault scarp, due to ponded drainage. The Mohaka Fault at Hinerua retains the NNE-SSW trend of farther south, and is still upthrown to the east. To the south of the mire is a small fan formed from down-slope debris off the western topographical high. To the northeast the landscape is more undulating, as the terrain falls away to the valley farther east. The fault scarp is clearly visible in the foothills of the steeper land to the north, appearing as a break in slope (see Figure 4. 2. 2.)

Rainfall in the Hinerua area has been recorded at 1876 mm yr^{-1} at a station on nearby Brentwood Road (Anon., 1973). As with the Kashmir region, Hinerua is within the eastern rain shadow belt produced by the topographical highs to the northwest. The soils in the general area are Brown Soils and their associated steepland variants (Hewitt, 1992), with some alluvial clay soils in the vicinity of the local creeks. Generally, the soils are a reflection of the rainfall regime, the steep topography and a high rate of erosion.

Figure 4. 2. 1 is map of the Hinerua region in the vicinity of the Mohaka Fault. It shows the site in relation to the western topographical high (Hinerua Ridge), and the trace of the Mohaka Fault scarp to the east. Also shown is the relationship of the site to the Hinerua Thrust, a structural feature which dominates the landscape to the southeast of the site. Figure 4. 2. 2 is a view of the core site with the Mohaka Fault trace on the right and encroaching manuka scrubland visible on the steepening topography in the background to the left.

4.2.1 GEOLOGY AND GEOMORPHOLOGY

The geological units exposed in the general Hinerua area can be assigned to three main groups: (1) Mesozoic basement, equivalent to the Kashmir Belt described at the previous site; (2) Tertiary sedimentary units, consisting of a lower mudstone unit and an upper rudite-dominated molasse deposit associated with the uplift of the Axial Ranges during the mid-Pleistocene; and (3) surficial deposits to the north of the site in the form of aggradational river gravels which have produced locally extensive river terraces immediately south of the Waipawa Reentrant structural zone (Raub, 1985).

The Tertiary mudstone exposed in the Hinerua area is the lower mudstone unit belonging to the Ashley member of the Kumeroa Formation. This unit consists of 1600 m of light grey to light bluish grey, weakly consolidated sandy mudstone to siltstone, and in places silty sandstone (Raub, 1985). In the study area the rudite sequence is associated with the Hinerua Thrust, lying immediately southeast of the site (see Figure 4. 2. 4).

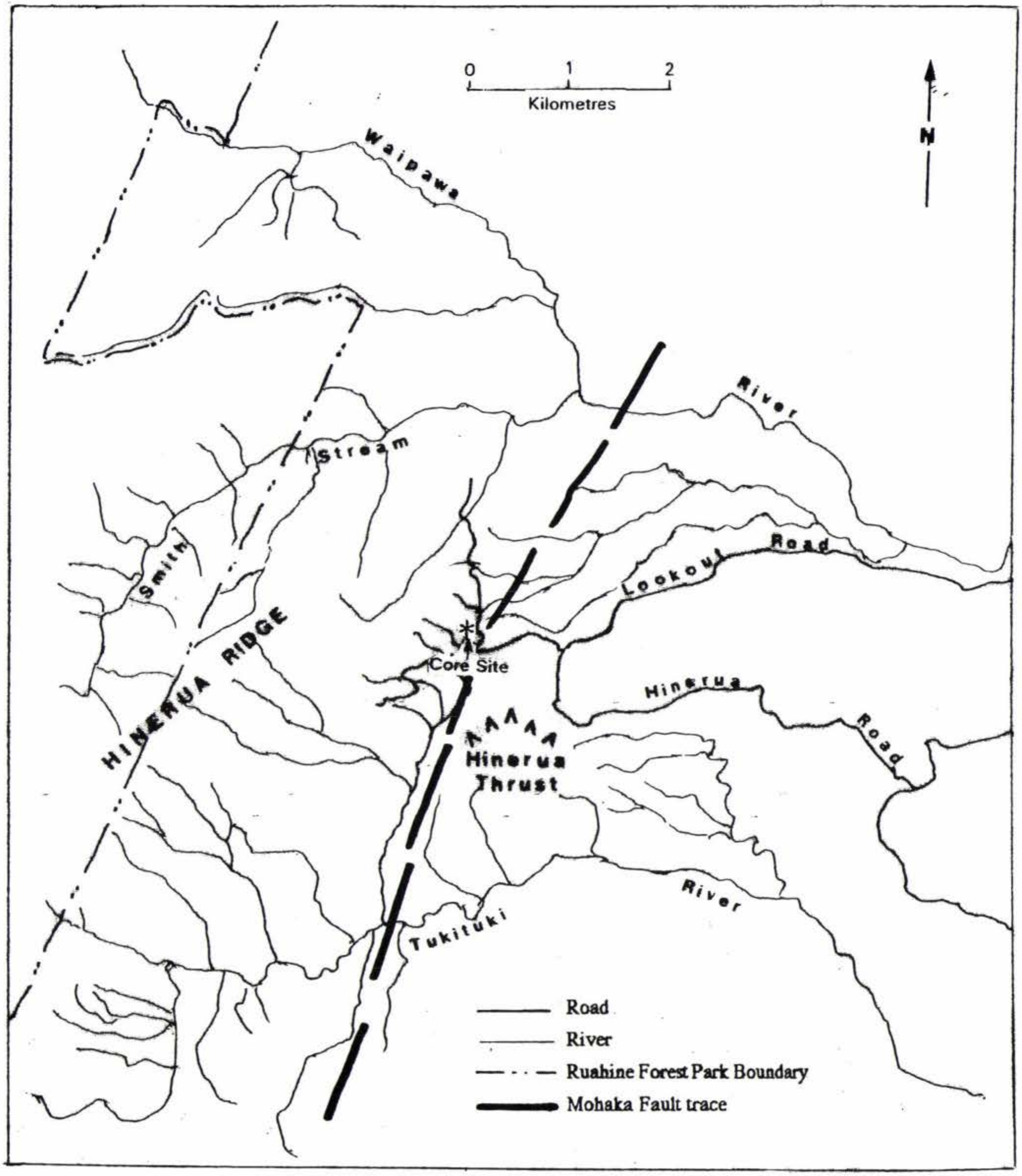


Figure 4. 2. 1 Map of the Hinerua region in the vicinity of the Mohaka Fault trace. The site cored is indicated by an *

Figure 4. 2. 2 Detailed view of the core site at Hinerua with the Mohaka Fault scarp to the right and encroaching manuka scrubland on the steepening topography to the left

4.2.2 PRESENT DAY VEGETATION

The present day vegetation in the Hinerua area consists mainly of introduced pasture grasses and weeds. Figure 4. 2. 3, which is a general view of the core site, shows the generally grass-covered rolling hills to the northeast of the site. Between the scarp of the Mohaka Fault and the Hinerua Thrust there is a stand of introduced Douglas fir trees. Figure 4. 2. 4 of the Thrust taken from the Mohaka Fault scarp, shows this stand of Douglas fir in the middle ground, and the exotic weed, ragwort, on the scarp itself.

Along Hinerua Road, on the eastern side of the fault scarp, native understorey trees are becoming dominant. Taxa identified are *Olearia rani* (tree daisy), *Gaultheria* (snowberry), a *Coprosma*, *Carpodetus serrata* (putaputaweta), *Leucopogon fasciculata* (mingimingi), *Hebe stricta*, *Rubus cissoides* (bush lawyer), *Leptospermum* (manuka), *Cyathodes juniperina* (common mingmingi), and *Fuchsia excorticata*. This latter has only just returned to the area following the eradication of possums (Mr. Maulder pers. comm. 1996). Ecologically all these species are found in lowland and montane forest (especially along forest margins); in forest clearings and in second-growth forest; and in damp places.

Vegetation on the mire site consists mainly of grasses, both native and introduced, *Taraxacum* (dandelion) and other introduced weeds, especially ragwort, and native rushes, reeds, sedges and herb plants.

Farther afield towards Hinerua Ridge in the west, *Leptospermum/Kunzea* is more pervasive (Figure 4. 2. 2). Young *Dacrydium* (rimu) and *Prumnopitys taxifolia* (matai) are recolonising the area, as well as some young *P. ferruginea* (miro), but no totara.

Figure 4. 2. 3 Panoramic view of the Hinerua site looking north, with the Mohaka Fault scarp on the right and grass covered rolling hills with a minor manuka scrub cover in the background to the northeast

Figure 4. 2. 4 The Hinerua Thrust taken from the scarp of the Mohaka Fault at Hinerua

There are many fallen logs of *Libocedrus bidwillii*, (mountain cedar) but no living specimens have been found. Neither *Nothofagus fusca* (red beech) nor *Nothofagus solandri* (black beech) have regenerated in the area, even though these two beech species were the main forest species in the Hinerua area prior to forest clearance (H.N. Swinburn pers. comm. 1996).

4.2.3. RECENT SITE HISTORY

Until the turn of the century the Hinerua area was covered in Nothofagus forest. Both *Nothofagus fusca* and *Nothofagus solandri* were present. *N. fusca* grew in the hollows and more sheltered areas, and *N. solandri* grew on the more exposed ridges (H.M. Swinburn pers. comm. 1996).

At the end of the nineteenth century the area was opened up for settlement. The original plan was to divide the area into side by side "100 acre blocks", with a 'settlement line' running along the foot of the steepland. This acreage proved uneconomical to farm and the early settlers appealed to the Right Honourable Hunter, the then Minister of Lands, to extend the settlement line up into the steeper lands. In this way the area of each farm was increased to 200 acres (A. Wilmott pers. comm. 1996).

The *Nothofagus* forest was cleared by burning. The method favoured by the early settlers was to fell a few beech trees, stack them together tepee style, and when the logs were dry, fire the pile. Many attempts failed because the pile was fired too soon. Blackened beech logs that lay scattered over the tops and slopes for decades after firing attest the this fact. One such failure earned the immediate area involved the local name of Black Burn ridge (H.M. Swinburn pers. comm. 1996).

Many fires, especially docking fires, got out of control and swept the area as wild fires. One such fire in 1926 burned over the whole of Hinerua Ridge, leaving charred forest in its wake. An entry in the Wakarara School Log Book dated February 23, 1926 records 'Fires are spreading fast and the school has been full of smoke today' (Wakarara School 75th Jubilee Booklet, 1972). The charred logs of red beech from all the the Hinerua area were later used for fence posts. Miss Swinburn recollects her father exchanging a horse for a load of these posts (H.M. Swinburn pers. comm. 1996).

Arthur Wilmott recalls that when he purchased the 500 acres that include the Hinerua site of this study, in 1934, there were so many burnt beech trees lying around his and the adjacent 600 acres property, that it was dangerous to travel around on horseback. He too utilised the beech as fence stays (A. Wilmott pers. comm. 1996).

No timber mills were set up in the Hinerua district. The closest was McCullough's Mill which opened in 1930 farther north on the Silverstream property now farmed by John Tatam. Timber was hauled to the mill across the Waipawa River by steam winch. Three years later the mill was shifted to the bed of the Waipawa River, and from there milled much of the area now farmed by Mr W. Cullen (Wakarara School 75th Jubilee Booklet, 1972). The mill finally closed in 1942. During the twelve years of its existence small amounts of timber were taken from the Hinerua area to be milled at McCullough's Mill (A. Wilmott pers. comm. 1996).

4.2.4 PALAEOECOLOGY

The results of the pollen analysis of the Hinerua site are presented in Figures 4. 2. 5 and 4. 2. 6. The stratigraphy is presented separately in Figure 4. 2. 7 (p.105). A sample of organic sediment from the base of the core at 1.89 m depth was dated (Wk - 5026) at 2790 ± 170 yrs BP.

The pollen diagrams have been zoned using a subjective assessment in conjunction with a visual inspection of the diagrams and to a lesser extent, the CONISS dendrogram provided by the Tiliagraph programme. Three zones have been assigned, namely Hi1, Hi2, and Hi3; Hi is the code assigned to the Hinerua site.

Zone Hi1 1.89 - 1.00 m

The terrestrial pollen in this zone is dominated by *Nothofagus fusca*, with minor *Dacrydium cupressinum*, *Prumnopitys taxifolia*, *Prumnopitys ferruginea*, *Halocarpus biformis*, *Dacrycarpus dacrydioides* and *Rhopalostylis sapida*. All these minor taxa have a low but stable presence throughout the zone. Relative pollen counts (Figure 4. 2. 5) indicate the region has a stable beech forest with a minor mixed podocarp component, during the period covered by this zone. Minor percentages of small trees such as *Coprosma*, Asteraceae and *Lophomyrtus* are also present intermittently throughout the whole zone.

However, absolute pollen counts (Figure 4. 2. 6) indicate that, although *Nothofagus* forest with minor *Dacrydium cupressinum* was well established at the base of the zone, from the 1.60 m depth upwards there is a general decline in regional forest pollen accumulation rates, and there is an apparent severe forest regression signalled at the top of the zone at 1.00 m depth.

FIGURE 4. 2. 5. RELATIVE POLLEN DIAGRAM HINERUA SITE

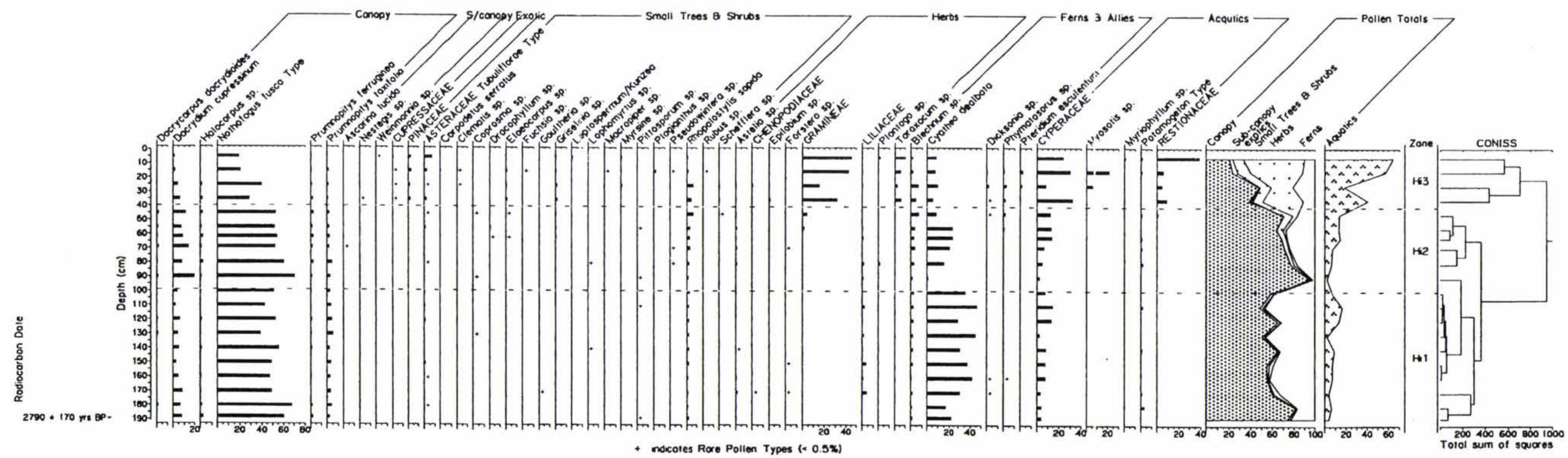
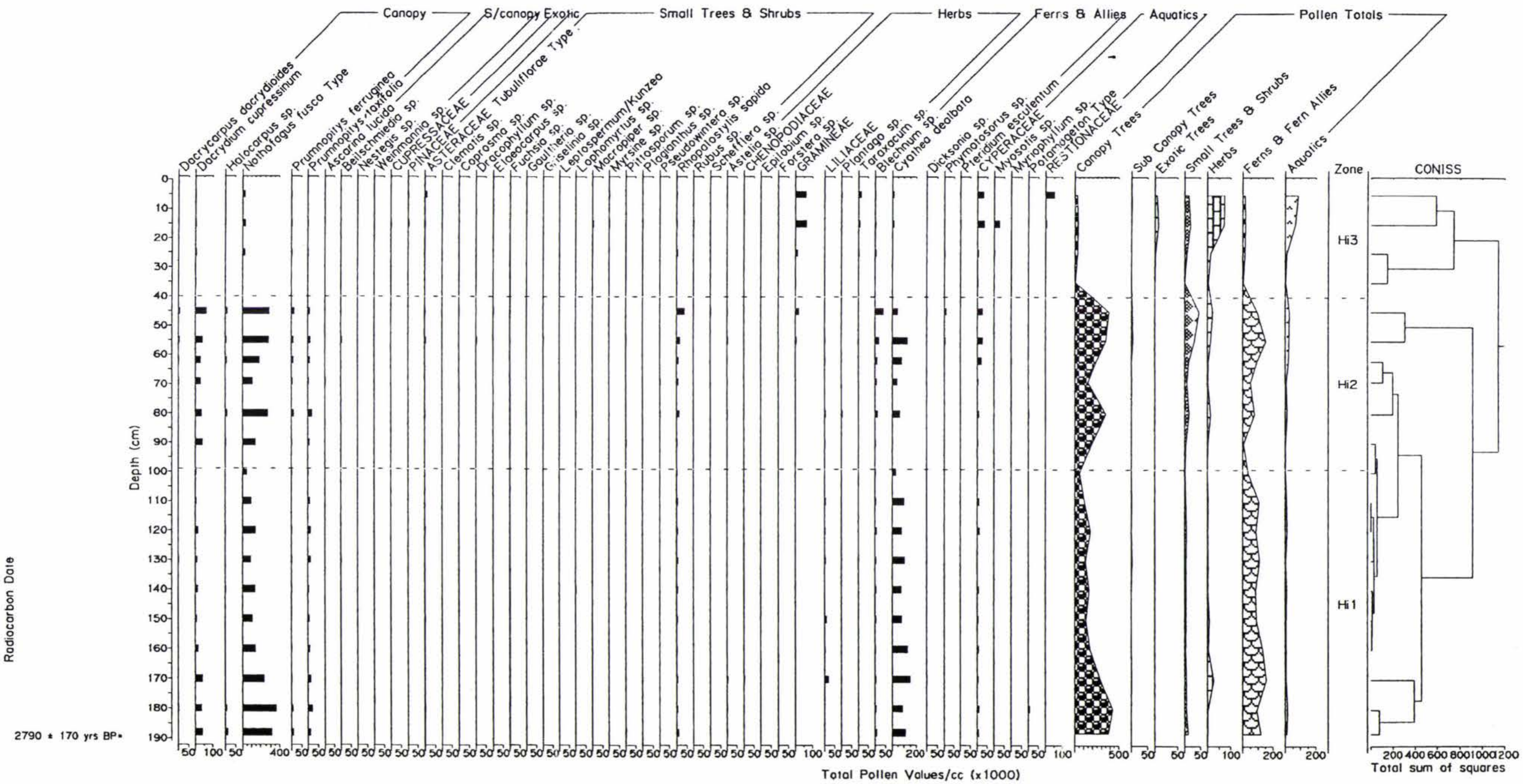


FIGURE 4. 2. 6 ABSOLUTE POLLEN DIAGRAM HINERUA SITE



The tree fern *Cyathea dealbata* is present in high but fluctuating amounts in this zone. This fern follows the trend of the regional *Nothofagus* forest and regresses suddenly and severely at the top of the zone. *Potamogeton* has a notable presence at 1.80 m depth and reappears intermittently up to the top of the zone. Minor but constant amounts of reeds (Cyperaceae) are present throughout, as is also the herb Liliaceae. The *Blechnum* fern is present, but in very small percentages.

High percentages of tree fern spores suggest an abundant pteriodophyte flora throughout the zone. Low but persistent percentages of Cyperaceae is indicative of damp conditions, and the presence of *Potamogeton* at 1.80 m depth and intermittently above, indicates that at times there was open water at the site. However, the absence of secondary forest taxa such as *Elaeocarpus, Pseudowintera* or *Leptospermum /Kunzea,* together with low *Blechnum* counts, all suggest the site, although persistently damp, and at times wet, was not a particularly disturbed one.

Zone H12 1.00 m - 0.40 m

At the base of this zone there is a notable increase in *Nothofagus fusca* percentages. That this is not an ephemeral situation due a marked decrease in *Cyathea dealbata*, which temporarily, all but disappears from the record at this point, is evident from the absolute pollen counts which show that both *Nothofagus* and *Dacrydium* recover quickly from the regression at the top of the previous zone. Cyperaceae, which had been increasing at the top of the previous zone, undergoes a temporary reduction in importance (see Figure 4. 2. 8).

Thus the main division between zones Hi1 and Hi2 is where the percentage of pollen from pteridophyte flora decreases markedly, and the primary forest recovers dramatically from the regression signalled at the top of the previous zone. The temporary reduction in *Cyathea dealbata* occurs immediately above a minor site disturbance at 1.00 m depth. This disturbance was identified by a slight change in texture and colour of the sediment and the presence of an 8 mm pebble at this depth. A 50 mm *Nothofagus* log at 0.90 to 0.95 m depth, which jammed the Neale corer, may be linked to the disturbance and could indicate the temporary forest regression at the top of the previous zone was real.

As in the previous zone *Nothofagus fusca* continues to dominate the forest taxa throughout, although absolute pollen counts indicate this species either suffers a temporary mid-zone set back, or there was a change in sedimentation rate. However, *Dacrydium cupressinum* now plays a more important role than earlier, with *Prumnopitys ferruginea*, *P. taxifolia* and *Halocarpus* only present in very minor amounts. *Rhopalostylis sapida* continues to have a low but stable presence, increasing slightly in importance towards the top of the zone. *Blechnum* continues to have a minor presence throughout, also with a gradual expansion evident towards the top of the zone. Small trees and shrubs such as *Coprosma* and Asteraceae continue to be present intermittently as in the previous zone, with the addition of very minor amounts of *Elaeocarpus*, *Pittosporum* and *Griselinia*.

Wetland taxa vary in importance throughout the zone. After nearly disappearing from the record at the base of the zone, Cyperaceae steadily increases in importance to the top of the zone. Both *Plantago* and *Potamogeton* appear following the inferred site disturbance near the bottom of the zone, with *Potamogeton* continuing to play a minor but constant role until it disappears at the top of the zone. The fern *Phymatosorus* also makes a very minor appearance towards the top of the zone. The herbs *Astelia* and Liliaceae are present in a minor way thoughout the zone.

Reduced wetland taxa counts at the base of this zone indicate the site was relatively dry following the disturbance that greatly reduced the presence of *Cyathea dealbata* in the area. Increasing percentages of Cyperaceae, *Potamogeton*, and *Plantago* (a herb that grows on the margins of streams, ponds and flushes, and sometimes submerged in 1 - 2 metre deep ponds (Johnson & Brooke, 1989) by 0.80 m depth, suggest that by this depth moisture had returned to the site and that water may, in fact, have begun ponding there. The minor increase in *Rhopalostylis sapida* and *Lophomyrtus* at this same depth also suggest dampness at the site and secondary forest taxa exploiting an opening in the forest canopy due to forest disturbance in the immediate area. Relatively stable *Nothofagus fusca* frequencies throughout the zone indicate the ecological disturbance recorded at the site was not widespread, but limited to the area around the site.

Zone Hi3 0.40 - 0.0 m

This zone is characterised by the introduction of grasses at the site. *Taraxacum* also forms a conspicuous component of the herbaceous taxa, and Restionaceae (sedge) also enter the record for the first time. Pollen from *Pinus radiata* and Cupressaceae also make their appearance in this zone. *Nothofagus fusca* still dominates the primary forest taxa as in the previous zones, with *Dacrydium cupressinum* and other podocarps having a reduced role upwards to the present.

Although high frequencies of grass could be related to swamp vegetation expansion, or may be a reflection of uphill transport, the overall decline in primary forest taxa that accompanied the expansion of grass suggests forest clearance. Pollen derived from small trees and shrubs, and herbs, although not abundant, are most diverse in this zone, with *Elaeocarpus*, an arboreal swamp taxon that may be indicative of site disturbance, having a consistent, if small presence throughout, as does the shrub Asteraceae. This also suggests some type of forest disturbance.

The introduction of wetland taxa such as the forget-me-not *Myosotis* (Johnson & Brook, 1989), *Myriophyllum*, and Restionaceae, plus the return of *Potamogeton* and *Plantago* to the site suggest the site was then currently accumulating water off the topographical high to the west, due to increased overland flow following forest clearance.

4.2.5 DISCUSSION

Sediments at the Hinerua site range from a sandy loam with minimal soil development at the top of the stratigraphic column to silt and clay loams below, which have minimal soil development or are structureless. Between 0.65 and 0.75 m depth there is the A horizon of a buried soil. This soil is a silty clay loam with a moderately developed very fine crumb structure. Immediately below is a Bw horizon, followed by a C horizon. Between 1.46 and 1.50 m depth there is a further buried A horizon. This soil is a clay loam with a weakly developed very fine crumb structure. Immediately below there is a 3C horizon with a silty clay texture. Between 1.65 and 1.71 m depth there are many well rounded 4 mm pebbles in the sediment. This 60 mm layer forms a distinct, discontinuous boundary between the 3C and 4C horizons, with a clay loam texture, below. The coarser sediment and well rounded pebbles at the base of the 3C horizon, could be evidence of an earthquake event or a debris fall. However, the presence of well rounded pebbles tends to suggest that water-introduced sediment entered the site at that point. This raises the possibility there may be some sediment lost due to erosion at this depth. The base of the column returned a radiocarbon date of 2790 ± 170 yrs BP. A stratigraphic description of this site is presented in Figure 4. 2. 7.

The pollen record at the Hinerua site, therefore, extends back about 2800 years. The stratigraphic data indicates there have been three episodes of soil development during this time. The event that terminated soil development of the first buried soil is recorded by a charcoal-rich layer at the top of the 3Ahb horizon and a change to a lighter coloured structureless 2C horizon above. It is possible there is time lost in the stratigraphy following the deposition of this charcoal-rich layer. In the case of the second buried soil, evidence that soil development has been terminated is indicated by a change from a dark olive grey 2Ahb horizon with a gleyed silty clay loam texture to a dark grey accumulating soil with a fine sandy loam texture above. Again there may be a hiatus in deposition between the top of the 2Ahb horizon and the base of the Ah3 horizon above, but given the accumulating nature of the soil at this depth, it is more likely a change in site conditions is indicated. The coarser texture and lack of gleying in the Ah3 horizon suggests the site was drier, or better drained, than in the horizon directly below.

The pollen record at the Hinerua site indicates that for the past 2800 years, up until European forest clearance in the late 19th century, the region was covered in beech (*Nothofagus fusca*-type) forest in association with podocarps, mainly *Dacrydium* and to a lesser extent, *P. taxifolia*. *P. ferruginea* and *Halocarpus biformis*, although present have only a minor role in this association. *Dacrycarpus dacrydioides* is also present intermittently in very minor amount. As the presence of this species before European forest clearance tends to coincide with increases in Cyperaceae at the site, this is interpreted as an indication of wetter conditions. As in the case of the Kashmir site, totara is notably absent from the record.

HINERUA SITE

	m		
	0	Ah1	Dark olive grey (5GY 3/1) organic rich, fine sandy loam; minimal soil development; many fine to coarse roots; wood (60x30x15 mm) at base; gradual boundary.
	0.46	Ah2	Black (10YR 2/1) fine silty clay loam; well developed fine nut and crumb structure; wood (80x15x15 mm) at base; gradual boundary.
	0.61 – 0.65	Ah3	Dark grey (N 3/0) fine sandy loam; moderately developed fine nut structure; some medium to coarse roots; distinct wavy boundary.
	0.65 – 0.75	2Ahb	Dark olive grey (2.5 GY 4/1)) silty clay loam; moderately developed very fine crumb structure; Gleyed; many greenish black (7.5GY) peds (2mm); some very fine to medium roots; gradual boundary.
	0.75	2Bw	Dark olive grey (2.5 GY 4/1) silty clay loam; minimal soil development; some fine to medium roots; 50 mmlog at 0.90 - 0.95 m; indistinct boundary.
	1.00	2C	Dark olive grey (2.5 GY 4/1); silty clay loam; structureless; plastic; well rounded pebble (8 mm) at 1.03 m; many fine to medium roots at top, root content decreasing down profile; indistinct boundary.
	1.46 – 1.50	3Ahb	Olive black (5 GY 2/1) clay loam; weakly developed very fine crumb structure 50 x 10mm root; charcoal rich; indistinct boundary
	1.50	3C	Dark olive grey (5 GY 4/1) silty clay loam; weakly developed structure; some fine roots; some well rounded 4mm pebbles from 1.65 to 1.71 m; distinct discontinuous boundary.
	1.71	4C	Dark grey (N 3/0) clay loam; structureless; some very fine roots; rounded quartz pebble (10 mm) at 1.81 m; sharp wavy boundary denoted by a discontinuous root mat into the silty fine sandstone below.
14C date 2790 ± 170 yrs BP.	1.89 - 1.90	R	Purplish grey (5RP 7/1) silty fine sandstone - Base of site

Figure 4.2.7 Stratigraphic column. Top 1.10 m cored using the Neale corer; below 1.10 m the site was cored using a D corer.

This record is in reasonably good accordance with what Elder (1965) found in his study of present vegetation of the central Ruahine Range region. That is, red beech forest predominates on the lower slopes in the region, with a fringe of podocarps, mainly *Dacrydium* plus some *P. taxifolia* scattered throughout in pockets on favourable sites; with *Halocarpus biformis* scattered throughout the *Nothofagus* forest below 1300 m; and scattered *P. ferruginea* within the *Nothofagus*, mostly at higher altitudes.

Absolute pollen counts of *Nothofagus* taxa (Figure 4. 2. 6) indicate that until forest clearance, a *Nothofagus* forest had been stable and well established in the Hinerua region for at least the last 2800 years. The absolute podocarp pollen counts (Figure 4. 2. 6) also indicate that mixed podocarp stands, comprising mainly *Dacrydium* with minor *P. taxifolia* and some *P. ferruginea*, had also been a minor component of this forest for equally as long.

The silver fern (*C. dealbata*) was the major understorey component of the forest throughout the 2800 year history covered by the Hinerua site. Apart from the base of the site, spore counts of this species suggest that numbers of this tree fern may have been consistently high. Exceptions occur when there was disturbance to the site. This disturbance is reflected in the stratigraphy of the site. At 1.46 - 1.50 m depth there is a paleosol plus charcoal recorded. Silver fern numbers in the pollen sample at 1.45 m depth above, dip as a consequence of the fire, but immediately recover. At 0.90 - 0.95 m depth a 5 cm *Nothofagus* log is recorded in the stratigraphy. Raw pollen counts (Figure 4. 2. 8) indicate silver fern numbers at that point are reduced to 2. Recovery is slow, and although the tree fern remains an important component of the forest, counts never return to what they were before (Fgure 4. 2. 8). With European forest clearance the silver fern again becomes negligible (Figure 4. 2. 8). The demise of this species is attributed to it being the main understore component of the *Nothofagus* forest. This

Interpretive Stratigraphic	Depth	Regional Forest				Locally Wet Site			Disturbed Site						
Data based on sediment accumulation rates & pollen information	sampled (m)	Beech	Rimu	Matai	Miro	Kahikatea	Cyperaceae	Sedges	Pinus radiata	Grass	Blechnum	Bracken	Daisies	Tree ferns	Taraxacum
	0.05	52	3		1		65	106	6	125	4		9	23	27
Charcoal-Fire at site in 1946	0.15	61	5	4	1		69	12	8	138	5	6	6	22	16
	0.25	67	7	2	2		10	5	2	26	13	2	1	16	4
Forest clearance in 1880s	0.35	83	18	2	5		53	14	5	92	14		5	16	16
at 0.40m	0.45	166	35	5		4	14	1		12	23		1	26	
	0.55	173	21	6	5	3	15			4	12			79	
Paleosol = c. 600 yrs BP	0.62	149	23	6	6	2	16				8			66	
	0.69	148	39	5	4	4	7				6			58	
	0.80	166	21	12	6	1	5				7			40	
Disturbed site 1100 yrs BP	0.90	165	46	6	2	2	2				3			2	
	1.00	170	13	9	4		8				4			119	
	1.10	179	8	15		1	17				5			192	
	1.20	171	19	14	6	2	15				4			96	
	1.30	162	18	21	5	4	2				4			187	
Paleosol & charcoal at 1.46-	1.40	173	16	6	6	1	9				5			98	
1.50 m = c. 2050 yrs BP	1.50	186	10	12		1	8				3			141	
	1.60	173	17	10	3		8				2			153	
Disturbed site - pebble lens	1.70	174	29	10	2		3				4			112	
at 1.70 m = c. 2500 yrs BP	1.80	169	16	9	6	2	4				2			42	
	1.88	167	21	6	11						5			61	
Base of site -->	1.89														
14C date 2790 ± 170 yrs BP															

* 1cc sampled at each depth
* 220 primary forest taxa and/or grass taxa counted at each depth, or 4 slides fully scanned where enough dryland taxa did not accumulate

Figure 4.2.8 Interpretive stratigraphy of the Hinerua site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995) can be compared with what has been found inparts of the Ruahine Range and the northern port of the Kaweka Range today, where ferns (*Dicksonia* and *Blechnum*) is the only understorey cover under the scattered red beech stands in these areas (Elder, 1965).

Rhopalostylis sapida is the most dominant understorey tree in the 2800 history covered by the Hinerua site. Starting as a very minor understorey component 2800 years ago, this lowland forest palm maintains a steady presence throughout until the time covered by the 0.80 m depth. At this point, following the site disturbance recorded at 0.90 m, this species gradually increases in importance to form a conspicuous understorey component at the time of the commencement of European forest clearance in the 1880s. Following forest clearance its presence declines sharply and it is not recorded in the top layer. Grant (1976) does not record any present day sightings of this palm in the Hinerua region, and Miss Swinburn, who has farmed at Hinerua for many decades, reports she has never seen any growing in the area (H.M. Swinburn pers. comm. 1996). Its absence from the record today is attributed to the forest clearance.

Very few subalpine shrub taxa signalled more than a minor presence in the pollen sequence at Hinerua. This is attributed to the fact that the forest in the region comprised mainly beech species, with silver fern making up the understorey component. Nevertheless, the shrub taxa *Clematis*, *Coprosma*, *Gaultheria*, *Griselinia*, *Myrsine* *Lophomyrtus*, *Macropiper*, *Pittosporum*, *Plagianthus*, *Pseudowintera* and *Schefflera* have all been found, usually as discrete taxa, at various levels throughout the 2800 years recorded at Hinerua. Thus these small trees and shrubs may, in fact, have been present in the forest. These genera have all been identified by Elder (1965) as part of the flora in the forests at lower altitudes on the eastern side of the Ruahine Range today.

Comparison of the 2800 year pollen record at Hinerua with rejuvenating or growing native species in the region or in the eastern Ruahine Range today indicates there has been no major change in flora in the region within this time. Any changes in pollen percentages and/or pollen type in the Hinerua record must therefore, relate to on- or near-site changes. As in the case of the Kashmir site, this aspect will be addressed by selecting some taxa of local interpretive importance in relation to the stratigraphy of the Hinerua site. The raw pollen counts of these taxa are presented in diagram form (Figure 4. 2. 8). Also, as with the Kashmir site, the aim of the exercise is to discuss whether or not there is any evidence in the record of changes that can be attributed to climate-induced forcing (Grant's hypothesis) and/or to earthquake-induced erosional events (Neall & Hanson's hypothesis).

Inspection of the stratigraphic column (Figure 4. 2. 7) shows that the three Ahb horizons at the top of the column all have gradual boundaries. The two uppermost horizons grade into the horizon immediately below to form an accumulating soil. the Ah3 horizon has a distinct wavy boundary at 0.65 m depth. There may be some sediment lost at this point due to erosion. All other horizons, including the 3Ahb horizon discussed above, have indistinct and at times discontinuous boundaries. This tends to indicate there have been no major depositional breaks in the sediment record. For this reason and solely for the purposes of the exercise, it has been assumed that sediment accumulation rates have been relatively constant at the site up to 0.40 m depth when absolute pollen counts indicate forest clearance took place.

It is known that the site was burnt in 1926 when fire ranged all over the Hinerua Ridge immediately above the site, destroying much of the remaining forest on the ridge (Wakarara 75th Jubilee Booklet, 1972). There was a further fire in the area in 1946

(H.M. Swinburn pers. comm. 1996). This is the same fire that affected the Kashmir site (see above). Charcoal found at 0.15 and 0.25 m depths is attributed to these two fires. On the basis of the greatly reduced *Nothofagus* and silver fern pollen counts and the expansion of grass counts above, the 0.40 m depth is attributed to forest clearance by early European settlers at the end of the 19th century.

In fitting the remaining *c.*2700 year pollen record at Hinerua into the lower 1.50 m of the stratigraphic record it is recognised that the margin of error could be significant. Nevertheless, because five distinct disturbance events are signalled in the stratigraphy some attempt has been made to correlate and date them, not least of all so that these events can be compared with the evidence from other sites in this study. A correlation of the five disturbances is attempted in Figure 4. 2. 8.

For the purposes of the exercise the disturbance due to European forest clearance at 0.40 m depth has been assigned to 70 yrs BP. (1880 AD). Based on assumed constant accumulation rates below this depth of 0.56 mm/yr. the site disturbance recorded at 1.71 m depth (inferred by the presence of 4 mm pebbles in the core) is assigned to *c.* 2500 yrs BP. Immediately above this level silver fern counts increase markedly, while at the same time there is no change in *Nothofagus* counts. *Dacrydium* and *P. ferruginea* do show a slight reduction in pollen counts at this level. In the case of *Dacrydium* this may be only a a reflection of percentage increases in other forest taxa. *P. ferruginea*, on the other hand, does not fully recover the relatively minor importance it had at the base of the site. But as this species is found on the higher slopes within the eastern Ruahine Range today (Elder 1965), the evidence tends to indicate the site disturbance was local and affected the mostly understorey species only, in this case the silver fern. As there is no increase in the presence of the monolete fern spores of *Blechnum* nor in pollen of Cyperaceae, the disturbance does not seem to be site specific, but appears to relate to the area in general.

Again, based on sediment accumulation rates the site disturbance at 1.46 - 1.50 m depth, indicated by a paleosol with a charcoal layer above, is assigned to *c.*2050 yrs BP. At this level silver fern counts decrease greatly while at the same time there is no significant change in the regional forest percentages. *Blechnum* and Cyperaceae counts show no change either. The evidence at this level suggests the disturbance is not just site specific but related to a fire that affected the ferns in the understorey in the general area.

The major palynological disturbance above 1.00 m depth, indicated by the almost total disappearance of silver fern from the record immediately above this depth (Figure 4. 2. 8) and the presence of a 5 cm diameter log in the stratigraphy from 0.90 to 0.95 m depth (Figure 4. 2. 7) is assigned to *c.* 1100 yrs BP., also on the basis of constant sediment accumulation rates. Again there is no change in the regional *Nothofagus* forest; however, there is a notable temporary increase in the *Dacrydium* percentage following the disturbance. This increase could be a reflection of wetter conditions near the site. *Blechnum* and Cyperaceae are almost totally absent at this level. As with the two previous disturbances, the silver fern appears to be most affected. This tree fern suffered a major set back at this point, and it never recovered its former importance. At this level the understorey trees become marginally more important at the expense of *Cyathea dealbata*. This tends to indicate a slightly more open canopy at this level than previously, with these small trees benefitting from the increased sunlight reaching parts of the forest floor. At 0.80 m depth the presence of the wetland taxa *Potamogeton* (and possibly the herb *Plantago*) indicates a wetter site than below. This could be due to increased overland flow following the reduction of the understorey cover during the disturbance recorded at 1.00 m depth.

A further basis for assigning 1100 yrs BP. to this disturbance is that Raub et al., (1987) report that a surface rupture across the Mohaka Fault in the Wakarara area, a few kilometres north of Hinerua, has occurred since 1165 ± 50 yrs BP. This date is based on the radiocarbon dating of wood fragments in a unit predating the offset event, indicating surface rupture occurred later than this date. For this reason the site disturbance at 1.00 m depth is attributed to an earthquake event. The affect of this event will be expanded on in the discussion of the Big Hill site which follows this site.

The fourth site disturbance at 0.65 m depth, indicated by the disruption of a paleosol and a coarsening in sediment type from a dark olive grey silty clay loam to a dark grey fine sandy loam above the disturbance, is assigned to *c.* 600 yrs BP.; again this is on the basis of accumulation rates. At this depth there is no change in the understorey component of the forest: silver fern if anything increases its percentage and *Rhopalostylis sapida* shows no change. There is no indication of any reduction in primary forest cover in the region. *Nothofagus fusca* still dominates the primary forest. There is, however, a moderate, but temporary decrease in the *Dacrydium* percentages. What is different in this disturbance, is the increase in both *Blechnum* and Cyperaceae at the site. Relatively high counts of these two species are recorded from the time indicated by this level up the the present day. As well, the fern *Phymatosorus* appears and *Potamogeton* is present. This evidence tends to suggest the disturbance is major and site specific, with water ponding at the site following the disturbance.

Based on the above rationale, the disturbance at 0.65 m depth is amore likely to be due to an earthquake event, than to Grant's Waihirere Erosional Period. It is possible, given the 170 year ± factor that is built into all the date calculations at Hinerua, that this event at Hinerua could be correlated with the earthquake event recorded in the McCool farm trench that returned a radiocarbon date of 805 ± 58 yrs BP. (Neall & Hanson 1995). The event at Hinerua may also be a correlative of the earthquake event that infilled the swampland at the Kashmir site *c.* 780 yrs BP., as well as the large erosional event in the West Tamaki Catchment of the central Ruahine Range *c.* 770 ± 60 yrs BP. reported by Hubbard & Neall (1980) (see above).

Above the paleosol at 0.65 - 0.61 m depth there is no further major disturbance recorded, either to the stratigraphy of the Hinerua site or to the regional forest, until European forest clearance in the 1880s. From this evidence it would appear that the later storm induced erosional events reported as occurring elsewhere in the North Island by Grant (1996), have not been recorded at the Hinerua site. It is quite possible that Hinerua Ridge, the topographical high immediately to the west and northwest of Hinerua, protected the area from the worst of gales and/or accompanying fires, during the storm-induced erosional periods of Grant's hypothesis. Another possibility is that the stratigraphic resolution at Hinerua is too coarse to record the erosional events Grant discuses.

Based on the above discussion, the following sedimentological history is concluded for the Hinerua site.

- About 2790 ± 170 yrs BP. the Hinerua site formed, probably due to an earthquake event. The site was slightly disturbed, but not significantly wet.

- At *c.* 2500 yrs BP. (1.70 m) the site was affected by an influx of pebbles, signalling a disturbance, possibly an erosional event; water may have flowed through the site.

- At *c.* 2060 yrs BP. (1.45 m) the site was affected by fire and the top soil was buried by an erosional event. The understorey of the surrounding forest was greatly reduced.

- At *c.* 1100 yrs BP. (1.00 m) the site was affected by an earthquake-induced erosional event large enough to destroy the understorey in the surrounding forest and deposit a log with a 50 mm diameter at the site.

- At *c.* 600 yrs BP. (65 m) the site was affected by an erosional event (possibly earthquake-induced) that buried the then current top soil.

- The site remained periodically disturbed and damp, with a reduced understorey forest cover, until the 1880s when forest clearance by European settlers commenced. From this time on the dominant vegetation at the site has been grasses, sedges, reeds, ferns and introduced weeds.

The above site history was concluded by linking the palynological record of the site to the sedimentological record, and underpinning the data with a radiocarbon date at the base of the record and historical dates of known European forest clearance and known fires in the Hinerua area.

BIG HILL SITE

4.3.1 INTRODUCTION

The Big Hill site is situated on Big Hill Station, northwest of Kereru in central Hawkes Bay (U21/007 960). Access is by means of Big Hill Road which leads off Kereru Road. The trace of the Mohaka Fault is along the lower eastern slopes of the Big Hill topographical high. The fault trends NNE-SSW and is upthrown to the east, as at the previous two sites. The site is *c.* 305 m above sea level.

Rainfall in the Big Hill area is approximately 1416 mm yr^{-1} (Anon., 1973). This rainfall places Big Hill well within the eastern rain shadow belt. The soils in the area are eroding Pallic soils and their associated steepland variants (Hewitt, 1992), with minor accumulating soils in gullies. The soils are a reflection of both the steep topography and rainfall regime.

Extending northeast immediately west of the fault trace for about 3 km from the station homestead at the end of Big Hill Road, is a series of sag ponds. These ponds have formed due to blockage of the natural drainage off the topographical high to the west (Big Hill) by the scarp of the upthrown fault. Since the late 1970s the water level of these ponds has been artificially raised due to damming by the current owner.

Four of these ponded drainage sites were cored. Three sites produced cores ranging from 0.30 to 0.75 m in length. The first site cored, that closest to the Ngaruroro River, produced a core 1.49 m in length. This core was processed and the pollen analysed.

Figure 4. 3. 1 is a map of the Big Hill region in the vicinity of the Mohaka Fault trace showing the core site in relation to the western topographical high, the trace of the fault scarp, and the Ngaruroro River to the north of the Big Hill area. Drainage off the high to the west is also indicated.

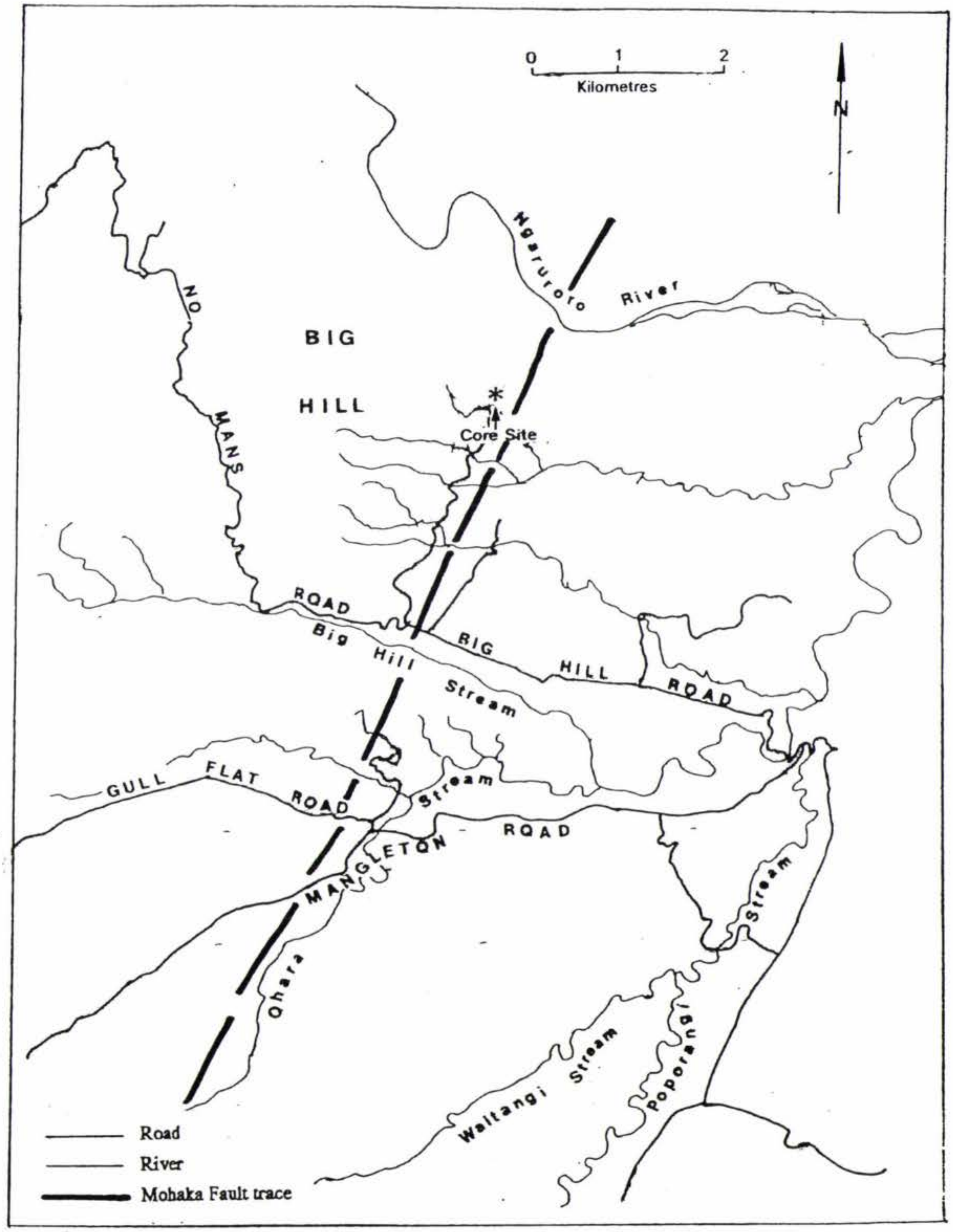


Figure 4. 3. 1 Map of the Big Hill region in the vicinity of the Mohaka Fault. The core site is indicated by an *

4.3.1 GEOLOGY & GEOMORPHOLOGY

The geological units of the Big Hill area can be assigned to two main groups; Mesozoic basement, in the form of greywacke belonging to the Torlesse Supergroup, described above, and a late Tertiary mudstone. The Tertiary mudstone exposed in the area is the Waitangi member of the Ohara Mudstone, of early-middle Nukumaruan age. This sequence is a *c* 320 m thick, dominantly blue grey, micaceous, calcareous, very fine sandy mudstone (Erdman & Kelsey, 1992).

Structurally the Big Hill Block is a major basement block, bounded on the east by the Mohaka Fault which trends c. 030°. The dip of the beds where the mudstone unconformably overlies the basement immediately east of the Mohaka Fault, is about 35° to the east, the dip flattens to 16° to 20° farther east, to steepen again in the vicinity of the Wakarara monocline about 1 km east of the Mohaka Fault.

4.3.2 PRESENT DAY VEGETATION

The present day vegetation on Big Hill river flats and the topographical high is mainly introduced pasture grasses. Some native bush and kanuka scrub remain in the steep gullies. A stand of introduced Cupressaceae has been planted at the end of Big Hill Road. Native and exotic grasses, introduced weeds, kanuka and isolated cabbage trees grow in the vicinity of the sag ponds along the Mohaka Fault trace. Figure 4. 3. 2 is a view of the core site at Big Hill showing the vegetation around the site to be mainly native and introduced grasses, and kanuka scrub. Figure 4. 3. 3 is a view of the NNE-trending Mohaka Fault scarp at Big Hill with the fault trace appearing as a break in slope and upthrown to the east.

Figure 4. 3. 2 The sag pond cored along the Mohaka fault at Big Hill. Vegetation on the scarp is Kanuka. The Ngaruroro River is visible in the distance on the right

Figure 4. 3. 3 The Mohaka Fault trace at Big Hill. The trace appears as a break in a grass-covered slope and is upthrown to the east

To the west and northwest of Big Hill the northern Ruahine Range divides into three blocks - a northeast and a northwest plateau, with the Pohokura basin in between. At low altitudes, vestiges of podocarp forest remain at several points around the margins of this area and *Nothofagus* forest tends to dominate from 610 m to the treeline at about 1400 m. On the slopes at the northern extremity of the range *Libocedrus bidwillii* (cedar) is found in association with the beech. The cedar is not in great quantity and appears to be dying out. In the northeastern extremity of the range fire-induced *Leptospermum* (manuka) scrub is common up to about 1165 m. Behind Big Hill Station the manuka is heavily defoliated, presumably by possums. On the tops, especially in the bogs, *Halocarpus biformis* is being replaced by tussock. In general both the *Libocedrus* and *Halocarpus biformis* communities have shown a consistent pattern of deterioration over several generations. However, they do show some pioneering vigour in limestone terrain and where the canopy is more open (Elder, 1965).

At 560 m altitude south of Big Hill and west of Poporangi Station, where *Dacrydium cupressinum*. *Prumnopitys taxifolia*. *P. ferruginea Dacrycarpus dacrydioides* and some *Podocarpus totara* were milled earlier this century, Elder counted the growth rings on the stumps of ten of the felled trees. Counts showed the *Dacrydium* varied from 310 to 540 years old. *Nothofagus fusca* (red beech) in the same area was tree ring dated at 340 years old and black beech and mountain-red beech hybrids ranged up to 180 years old (Grant, 1996).

Between the Makaroro and Waipawa Rivers, south of Big Hill, knolls and spurs exposed to the wind stand out from a canopy of *Nothofagus solandri* and *N. fusca* on the surrounding lower ground. Large *N. fusca* logs and beheaded trees, some still living, merge with the mountain beech canopy. Such a pattern can be attributed to wind effect (Elder, 1965). At lower levels decaying *N. fusca* is dominant and large *N. fusca* stumps underlie standing *N. fusca* and *Dacrydium* poles which have been tree ring dated from a little before 1800 AD. (Grant, 1991).

In the gorges of the Ngaruroro River in the vicinity of Big Hill, there are several pockets of lowland species. A typical association of these species is *Myoporum laetum*. *Dodonaea viscosa*, *Rubus squarrosaus* and *Hebe angustifolia*. To the north and east, in addition, there is a notable Hawkes Bay coastal component including *Senecio banksii*. *Pittosporum ralphii*. *Teucridium parvifolium*, *Angelica rosaefolia*. *Cheilanthes sieberi* and *C. distans*. mixed with such Mokai Patea endemics as *Hebe colensoi* and *Myosotis exima* (Elder, 1965).

4.3.3 RECENT SITE HISTORY

Originally the land comprising Big Hill Station formed part of the larger Keruru Station, a 8100 ha leasehold farm situated 43 kilometres west of Hastings. Keruru was part of the 20250 ha Otaranga Block purchased by the Government in 1857. Leased by J. N. Williams, son of the Rev William Williams, Keruru was carrying 3200 sheep by 1860. Parts of the block changed hands over the years and in 1905 the Big Hill portion of 2835 ha was sold to Owen Monckton.

In 1911 the remainder of Keruru was sold to Robert McGregor Turnbull. At the time the station comprised 2349 ha freehold and about 2025 ha pastoral lease. In 1944 Keruru was sold to Mrs Gwen Malden and her sister Miss Ruth Nelson. They also took over the Big Hill property and developed it along with Keruru, until they sold it on to the present owner in 1965 (Macgregor, 1970).

At the time of European settlement both the eastern and western plateaux in the northern Ruahine Range west of Big Hill, were covered by a mosaic of mountain beech and red tussock; and the Pohokura basin carried an induced cover of tall kanuka scrub with islands of matai-dominated forest. Almost all the red-tussock grassland on the eastern plateau has been grazed by sheep and for the most part burnt from the mid 1880s onwards. More recently cattle have been run on parts of the eastern plateau; it was the first part of the Range to be browsed by deer. As a result both the forest and tussock have been greatly modified (Elder, 1965).

Immediately south of Big Hill is Poporangi situated 50 kilometres west of Hastings. This land was first taken up when James Alexander applied for the lease of 2074 ha of grassy plains and fern (i.e. bracken covered) hills, which he stocked with 500 sheep. On the north and east the run was bounded by the Poporangi Stream (see Figure 4.3.1.) from Patakura to the Kereru bush. In 1857 Alexander extended his holding to 6124 ha. By 1872 the land had changed hands again and was running 9468 sheep. The land was very rough; it took 3 days to muster the run. Few cattle were grazed as they were inclined to disappear into the bush and become wild (Macgregor, 1970).

In the early 1860s it took a week to drove 200 head of merino sheep from Olrig Station near the Ngaruroro River in the north, up the Poporangi Stream to Wakarara Station, a 7290 ha block lying between the Wakarara and the Ruahine Ranges. The Poporangi Stream had bush and scrub to the water's edge on both sides, and the bush had to be broken down to get the sheep along the creek. It took two days for the sheep, en route to Wakarara, to travel up the stream (Magregor, 1970). Very little timber was milled from the Keruru/Big Hill area, the only record being that of white pine (Kahikatea) cut from along the banks of the Poporangi Stream in 1932 and used for fruit cases and tallow casks (Wright, 1985).

Poporangi Station became one of the show places in Hawkes Bay. But a shortage of labour, created by the draw on manpower for World War I, allowed the increase of rabbits and growth of manuka scrub. Eventually the grazing of the Mangleton and Ellis Whare blocks was discontinued before 1940 owing to the encroachment of fern and manuka. Following World War II these blocks were split into six farms for soldier settlement, and the land has since been recleared of scrub, although there are some remnants of native bush containing good specimens still standing (Macgregor, 1970).

When W.A. Glazebrook took over Big Hill in 1965 the land was covered in manuka and kanuka scrub, estimated to be at least 50 years old. Since the 1970s most of the land was gradually cleared by means of burning, and then sown in introduced pasture (W.A. Glazebrook pers. comm. 1997). Mr. Glazebrook has also artificially raised the water level in some of the sag ponds by means of dams to provide water for stock.

4.3.4 PALAEOECOLOGY

The results of the pollen analysis of the Big Hill site are presented in Figures 4. 3. 4 and 4. 3. 5. The Stratigraphy is presented separately in Figure 4. 3. 6 (p.132). A sample of organic silt from the base of the core at 1.49 m depth was dated (Wk - 5027) at 3700 ± 90 yrs BP. A sample of organic mud from a depth of 0.88 - 0.89 m was dated (Wk - 5488) at 1040 ± 130 yrs BP.

The pollen diagrams have been zoned using a subjective assessment in conjunction with stratigraphy, a visual inspection of the diagrams and the CONISS dendrogram provided by the Tiliagraph programme. Three zones have been assigned, namely, BH1, BH2, and BH3; BH is the code assigned to the Big Hill site.

FIGURE 4. 3. 4 RELATIVE POLLEN DIAGRAM BIG HILL SITE

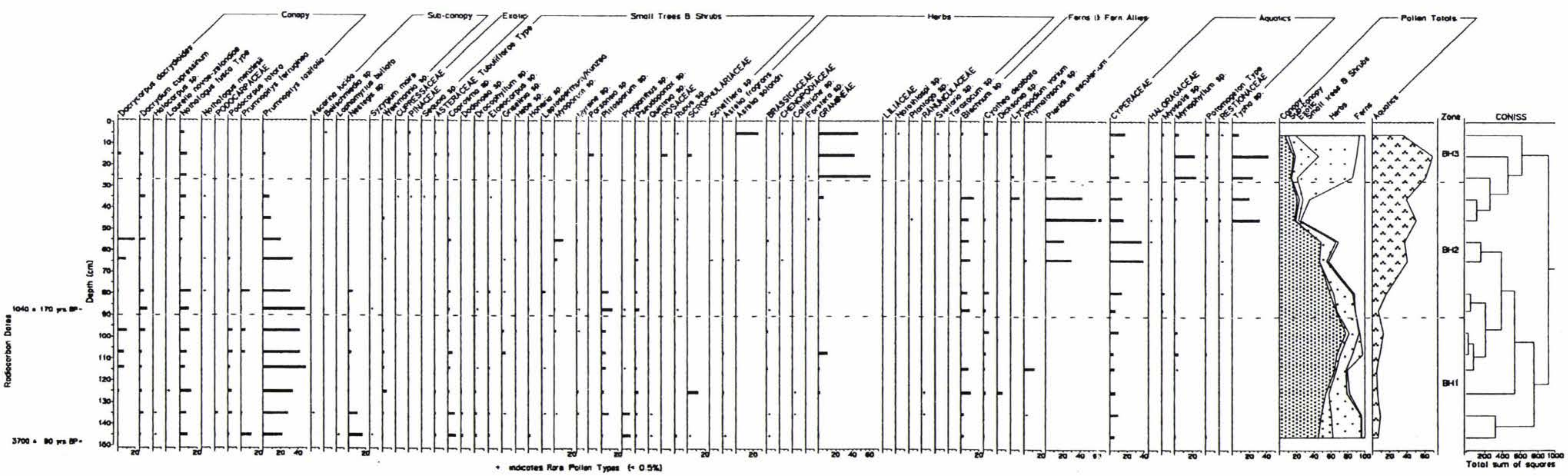
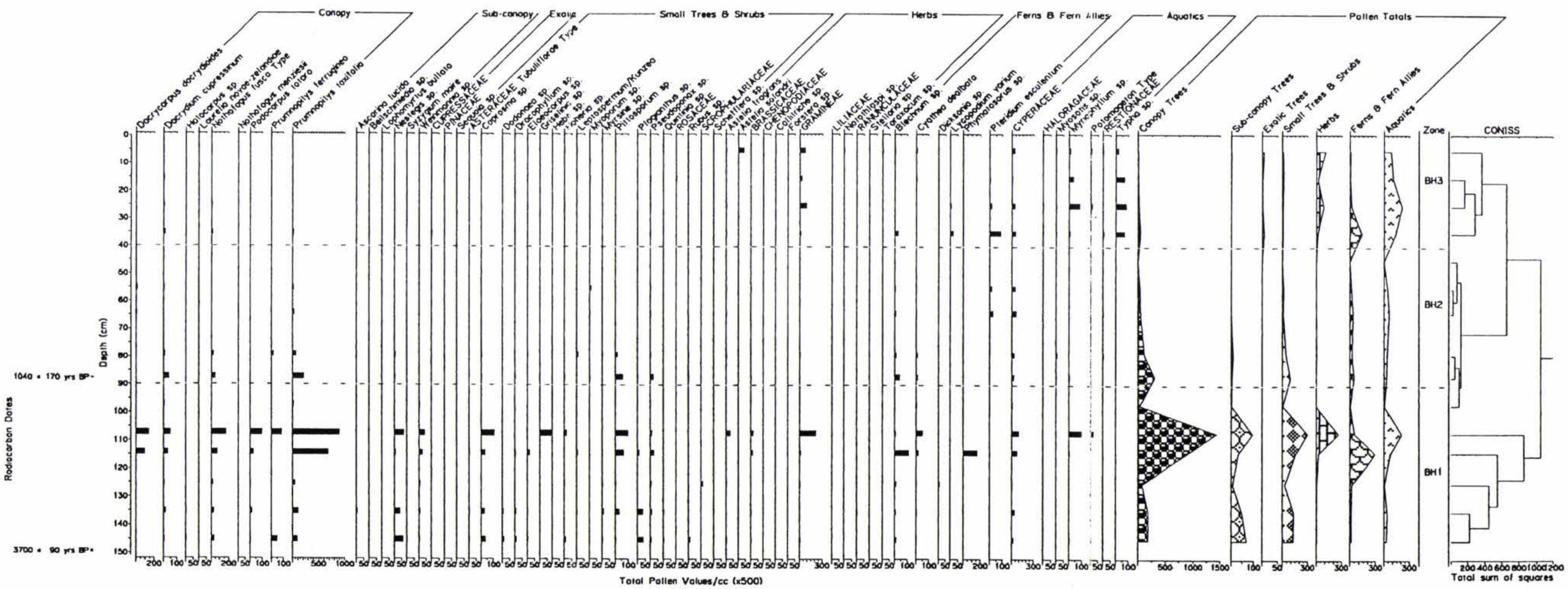


FIGURE 4. 3. 6 ABSOLUTE POLLEN DIAGRAM BIG HIL SITE



The pollen diagram is subdivided on the basis of a very evident reduction in forest cover at 0.90 m depth. As well as an almost totat elimination of forest species immediately below this depth, radiocarbon dates and sediment type indicate an hiatus in the record at 0.90 m depth, following an erosional event recorded between 0.90 and 1.09 m depth. A further subdivision has been made at 0.26 m. depth. At this point the primary forest is greatly reduced and grasses dominate the pollen diagram from this depth to the top of the column. The failure of the forest to regenerate has been interpreted as evidence of European land clearance.

Zone BH1 1.49 - 0.90 m

The terrestrial pollen in this zone is dominated by *Prumnopitys taxifolia* (matai) in conjunction with *Nothofagus fusca* (beech). The podocarps *Dacrydium cupressinum* (rimu), *Podocarpus totara* and *Prumnopitys ferruginea* (miro) are also present as a minor component of the primary forest taxa. *Dacrycarpus dacrydioides* (kahikatea) enters the record at the time covered by the 1.15 m depth, following mid-zone site disturbance. The sub-canopy tree, *Nestegis*, (Maire) is an important component of the forest at the base of the zone but is absent from the record in the middle of the zone, to return again with a greatly reduced importance towards the top of the zone. *Weinmannia* has a small presence at the base of the zone, but increases in importance from mid-zone upwards, as the importance of *Nestegis* is reduced. *Ascarina* has a notable presence just before the site was disturbed towards the middle of the zone.

Small trees and shrubs play an important part in the pollen spectra of this zone. The shrubs *Coprosma*. *Pittosporum*. *Plagianthus* and, to a lesser extent *Hoheria*, follow the same pattern as *Nestegis*, in that they are an important component of the forest at the base of the zone, and counts are greatly reduced during the mid-zone disturbance. Above the disturbance, *Plagianthus* and *Hoheria* are of minor importance. However, *Coprosma* and *Pittosporum*, together with *Griselinia* and *Myoporum* are important components of the understorey. *Pseudowintera*, *Hebe* and *Myrsine* are also present towards the top of the zone.

Below the mid-zone disturbance, which, on the evidence of volcanic ash in the stratigraphy at this level, is attributed to volcanic activity, secondary forest taxa expand at a time when primary vegetation in the region is experiencing a marked degree of instability. During the mid-zone disturbance both primary and secondary forest undergo a regression. Following the disturbance both primary and secondary forest expand very quickly, with an increased diversity of small trees and shrubs very evident.

At the site monolete ferns, mainly *Blechnum* and *Phymatosorus* increase rapidly following the mid-zone disturbance, with *C. dealbata*, having a minor but increasingly important presence towards the top of the zone. First Cyperaceae then *Myriophyllum* and *Potamogeton* also become established as important wetland taxa following the disturbance. Grasses are also a very important component of the pollen assemblage immediately following the disturbance, but disappear from the record immediately above when *C. dealbata* becomes established. The pollen record here suggests a fairly abundant pteridophyte flora associated with a swamp environment became established at the site after the disturbance.

Zone BH2 0.90 - 0.26 m

At the base of this zone arboreal pollen is mainly derived from primary forest taxa, with a small percentage of secondary forest taxa. These latter are in the form of *Pittosporum* and, to a lesser degree, *Plagianthus* which are present in relatively high frequencies. As in the previous zone *P. taxifolia* dominates the primary forest component, with both *Nothofagus* and *Dacrydium* present as minor components. *P. ferruginea* and *Podocarpus totara* appear in only very small frequencies. *Nestegis*, *Coprosma*, *Griselinia* and *Pseudopanax* re-enter the record just above the base, signalling a return to the arboreal diversity of the previous zone.

At the time covered by 0.72 - 0.73 m depth a coarse sandy lens in the stratigraphy signals a further disturbance. Minor amounts of microscopic charcoal were also found at this level. Pollen percentages above this depth indicate *Prumnopitys taxifolia* is not affected by this disturbance, but *Nothofagus* and *Dacrydium cupressinum* pollen percentages decline rapidly. These taxa recover only very slowly towards the top of the zone. Following this disturbance *Dacrycarpus dacrydioides* enters the record and maintains a high profile until the next site disturbance in the zone, when this taxon temporarily disppears from the record. Small trees and shrubs are most affected. Most leave the record or undergo a marked decline. Exceptions are *Pseudopanax* and *Myoporum*. These are both forest regrowth species, their presence at this point suggests they were able to exploit a gap in the canopy following primary forest decline. Very minor traces of microscopic charcoal at this depth of c. 5 μm indicate the disturbance may be fire related.

At 0.65 m depth *Pteridium* (bracken) enters the record. The appearance of *Pteridium* may be in response to the minor fire recorded at 0.72 - 0.73 m depth. Percentages of this fern increase steadily until near the top of the zone, after which a dramatic decline in this species occurs. This decline coincides with a further episode of site disturbance and coincides with a change from very fibrous peat to organic rich silt in the stratigraphy at 0.26 m depth.

However, before this decline there is evidence of continual forest disturbance at 0.55m, 0.45 m and 0.35 m depths. At these depths extremely high frequencies of *Pteridium* (bracken) suggest severe forest disturbance occurred. Minor, large (>65 μm) flakes of charcoal at 0.55 m depth, increasing amounts at 0.45 m depth, and abundant amounts of these large flakes at 0.35 m depth indicate the area around the site was continually subject to fire during the time covered by these depths.

During this disturbance all primary forest taxa register low percentages. *P. taxifolia* is still the dominant forest species in conjunction with *Nothofagus* which is slowly becoming re-established following a severe decline after the previous disturbance. At 0.45 m depth *Typha* (raupo) enters the record and undergoes a rapid expansion which lasts almost to the present day. *Potamogeton* continues to be present, as does Cyperaceae. The above is evidence of an expanded wetland taxa at the site and indicates that from the 0.45 m depth to the present, the site was continually under water. Native grasses also re-enter the record at this point.

At 0.37 - 0.39 m depth a coarse sandy lens in the stratigraphy indicates there was further disturbance at the site. At this point pollen percentages indicate the podocarp forest had declined and the *Nothofagus* forest in the region was registering a very minor, but steady presence. At the same time *Pteridium* counts continued to be exceptionally high. This decline in the frequency of primary forest taxa coupled with the high bracken counts suggests a general recession of forest in the region. Wetland taxa continue be an important part of the pollen spectra at this point, with the raupo continuing as the dominant aquatic. Grass counts increased slightly, but small trees and shrubs occurred only in very small frequencies.

Zone BH3 0.26 - 0.0 m

The main division between this zone and the zone immediately below is where the percentages of grass pollen increase rapidly, while at the same time those of *Pteridium* decrease equally as rapidly. Primary forest taxa are all but eliminated from the zone, with *Nothofagus* present in very minor frequencies in conjunction with a minimal podocarp presence. Wetland taxa maintain the importance they had below, with *Myriophyllum* joining *Typha* as an important aquatic in this zone. *Potamogeton* also continues as a minor component of the wetland taxa. *Pinus*, *Sequoia* and Cupressaceae, all introduced forest species, are present in small percentages throughout the zone.

At the top of the zone the wetland taxa decrease in importance and the herb *Astelia solandri*, a grass-like perching lily, joins the grasses to dominate the pollen record. Of the primary forest species, *Nothofagus* is still present in small frequencies at the top of the zone, and *P. taxifolia* still registers a very minor presence. The small trees *Elaeocarpus* and *Hoheria* register a presence, as does the shrub Asteraceae Tubuliflorae type. These secondary growth taxa are an indication of disturbance in the area. This is attributed to European land clearance. Throughout the zone *Leptospermum* spp barely registers a presence, although kanuka and manuka are known to have been widespread in the area even following scrub clearance for farming (see above). Although the current land owner began clearing the surrounding land of kanuka scrub in the 1970s, there is no evidence of macro- or microscopic charcoal in this zone to reflect this burning.

4.3.5 DISCUSSION

Sediments at the Big Hill site range from an organic rich silt at the top of the stratigraphic column to fibrous and sandy peat below, with several sandy lenses at discrete levels, identified as resulting from erosional events. At 0.90 m depth there is a sharp natural break in the column. A sample between 0.87 - 0.88 m depth returned a radiocarbon date of (Wk - 5488) 1040 ± 140 yrs BP. From 0.90 to 1.09 m depth a coarse sandy layer of sediment containing many angular clasts, some 5 mm in length, is interpreted as colluvial greywacke which entered the site following an erosional event. Hard fine white rhyolitic ash is dispersed throughout this colluvium. The layer below is humic peat, becoming sandy towards the base before it grades into an organic rich sandy silt. There is hard, fine, white ash scattered throughout this humic peat as well. The base of the column returned a radiocarbon date (Wk - 5027) of 3700 ± 90 yrs BP. A stratigraphic description of this site is presented in figure 4. 3. 6.

On the basis of the basal radiocarbon date of 3700 ± 90 yrs BP., description of the ash and known tephrochronology of volcanic ash deposits in the region, the white ash scattered throughout the organic peat above the basal layer, that is, between 1.09 and 1.31 m. depth, is identified as the Waimihia Tephra dated at 3280 ± 20 yrs BP. (Froggatt and Lowe 1990). The greywacke colluvium deposited in the layer immediately above the peat, between 0.90 and 1.09 m depth, is attributed to a major erosional event occurring soon after the above date. The fine white ash in this colluvial deposit is therefore, reworked Waimihia Tephra. There is a sharp break in the stratigraphy at 0.90 m depth, before the resumption of organic-rich fine sandy mud accumulation. This mud has been radiocarbon dated (Wk - 5488) at 1040 ± 140 yrs BP. at 0.87 - 0.88 m depth.

BIG HILL SITE

14C date	m	Unit	Description
	0 – 0.08	C1	Very dark greyish brown (2.5 YR 3/2) organic rich silt; structureless; some fine roots; distinct boundary.
	0.08 – 0.26	C2	Reddish brown (2.5 Y 3/1) organic rich silt; structureless; many fine and medium roots; gradual boundary over 30 mm.
	0.26 – 0.65	2Of1	Brownish black (2.5 YR 3/1) very fibrous peat; coarse sandy lens 0.37 - 0.39 m; gradual darkening of colour below 0.46 m; coarsening of fibres towards the base; gradual boundary.
	0.65 – 0.73	2Of2	Black (10 YR 2/1) sandy peat; coarse sandy lens 0.72 - 0.73 m; indistinct boundary.
14C date 1040 ± 140 - Yrs BP. (0.89)	0.73 – 0.90	3C	Brownish black (7.5YR 2/2) organic rich fine sandy mud; some fine roots; sharp boundary, (depositional unconformity).
			HIATUS
	0.90 – 1.09	4C	Olive grey (10 YR 4/2) sandy silt; minor fibrous organic matter; scattered fine (1 mm) white ash throughout; some angular clasts *c* 4mm; concentration of angular *c* 5 mm clasts at 1.06 m; distinct wavy boundary.
	1.09 – 1.31	5Oh	Black (10 YR 2/1) humic peat; texture becoming silty towards the base; scattered fine white ash; gradual boundary over 50 mm.
	1.31 – 1.48	6C	Black (10 YR 2/2) organic rich sandy silt; structureless; few fine roots; 8mm root at 1.48 m; indistinct boundary grades into silt below.
14C date 3700 ± 90 - yrs BP. (1.48)	1.49	7C	Brownish grey (5 YR 4/1) silt; structureless. Base of site.

Figure 4. 3. 6 Stratigraphic column. Site cored with the Livingstone piston corer.

The termination of peat accumulation at 0.26 m depth is assigned a date of c. 1800 AD.. This date is based primarily on palynological evidence. At 0.25 m depth the *Dacrydium cupressinum* and *P. taxifolia* percentages dip sharply indicating a sudden forest regression, while at the same time grass counts increase dramatically, and manuka/kanuka, a known poor pollen disperser, enters the record. This description of the flora is identical to that noted by the early leaseholders who first grazed the area in the 1860s. This date is also in agreement with Grant's date for the end of his Wakarara Erosional Period. By this date, according to Grant's hypothesis, 34 percent of mountain forest in New Zealand had been destroyed by gales (Grant, *in* Parsons, 1997).

Using the radiocarbon date of 1040 ± 140 yrs BP. and the 1800 AD (150 yrs BP.) date as parameters gives an assumed constant sediment accumulation rate, between 0.26 and 87.5 m depth, of 0.69 mm/yr. Based on this accumulation rate the resumption of sediment accumulation at 0.90 m depth is dated at *c*. 1075 ± 140 yrs BP. These dates indicate that following the major erosional event that occurred soon after the deposition of the Waimihia Tephra, there is an hiatus of up to *c*. 2000 years (*c* 3075-1075 BP.) during which no sediment accumulated at the site. This hiatus is signalled by a depositional unconformity in the stratigraphy at 0.90 m (Figure 4. 3. 6). The lack of sediment accumulation during this period would also account for the absence at the site of ash from the Taupo eruption of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990).

Of relevance Elder, in his discussion of the present day flora of the Ruahine Ranges, notes that the depth of the ash from the Taupo eruption on the hills to the west of Big Hill was reduced to less than one inch (2.5 cm), and that there was no accompanying charcoal (Elder, 1965).

Thus the pollen record at Big Hill records two distinct stages. The first began about 3700 BP. and lasted for about 625 years until c 3075 BP. Then there is a diastem in the record of about 2000 years before the second stage commenced about 1075 yrs BP. and continued until the present. Thus the main division between zones BH1 and BH2 is the diastem. This is indicated by an abrupt textural change from greywake colluvium containing minor fibrous organic matter, to organic rich fine sandy mud at 0.90 m. The division is also where the percentage of pollen from primary forest taxa gradually declines and pollen from wetland species gradually increases to dominate the interpretive pollen diagram (Figure 4. 3. 7).

The pollen record at the Big Hill site (Figure 4. 3. 4) indicates that 3700 years ago the region was covered in a mixed podocarp forest of mainly *P. taxifolia* (matai) in conjunction with *Nestegis* (maire), *P. ferruginea*, and minor *Dacrydium cupressinum* and *Podocarpus totara*. *Nothofagus* was also an important component of the primary forest. Secondary forest taxa included minor percentages of *Weinmannia* (kamahi), *Ascarina* (hutu) and *Lophomyrtus* (ramarama). Small trees and shrubs were mainly limited to *Coprosma*, *Pittosporum*, *Plagianthus* and minor amounts of *Dodonaea*, *Hoheria*, *Myrsine* and Asteraceae (Tubuliflorae).

With the exception of *P. ferruginea* which temporarily disappears from the record during the major disturbance, the primary forest shows no sign of being affected by the Waimihia eruption. *Nothofagus* percentages do drop slightly but soon recover, and *P. taxifolia* percentages increase markedly. However, this may be just a reflection of minor decreases in *Dacrydium cupressinum* and *Podocarpus totara* pollen counts, and the absence of *P. ferruginea* from the record at this point. Immediately following the eruption *Dacrycarpus dacrydioides* makes a notable appearance. This could be due to a more open canopy as much as to the wetter conditions this species usually signals.

Interpretive Stratigraphic Data based on sediment accumulation rates & pollen information		Depth sampled (m)	Regional Forest				Wet Site				Site Disturbed				
			Beech	Rimu	Matai	Maire	Kahikatea	Cyperaceae	Sedges	Raupo	Kamahi	Manuka	Grass	Blechnum	Bracken
		0.05	15	1	3		2	97	4	41		6	60	7	
	Silt	0.15	8	4	2		3	14		143		2	44		7
?Wakarara Erosional Period	Silt	0.25	19	6	2		1	71		165		1	164	1	9
Textural Change	Peat	0.35	36	31	38		1	122	9	173			32	71	222
?Matawhero Erosional Period	Peat	0.45	19	10	34			126	10	257	7		6	29	260
	Peat	0.55	2	6	20		19	58						8	21
?Waihirere Erosional Period	Peat	0.64	4	3	98		25	192	2		1			28	87
	Sand	0.72	No Pollen at Site												
Slight forest regression	Peat	0.79	44	16	107	15	2	55	1			13	1	22	
C14 date 1040 ±140 yrs BP	Peat	0.87	33	27	145	2	2	20					1	29	
Hiatus - created by large erosional		0.90	Site destroyed by earth quake event												
event - colluvial greywacke at site		0.97	26	14	99	5		26			4				
plus fine white lapilli		1.07	24	7	128	9		13			5			1	
	Peat	1.14	17	7	158	2		16			5	1	38*	25	
Fine white lapilli in sandy silt at Site		1.25	44	7	111			21			13			33	
Waimihia Eruption 3280 ± 20 yrs BP		1.35	24	13	93	33		33			4	2		8	
		1.45	31	4	76	56		17			2			10	
Base of site 14C date 3700±90 yrs BP		1.49													

* Phymata soris

* 1cc sampled at each depth

* 200 dryland taxa and/or grass taxa counted at each depth, or 4 slides fully scanned where enough dryland taxa did not accumulate

Figure 4.3.7 Interpretive stratigraphy of the Big Hill site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995)

In the disturbance following the deposition of volcanic ash the secondary forest taxa *Weinmannia* and *Coprosma* are quick to recover, as does *Nestegis* to a lesser degree. *Elaeocarpus, Griselinia* and *Myoporum* enter the record. *Ascarina* and *Myrsine* do not return. Although there is no evidence in the stratigraphic column of any major volcanic ash deposition at this time, the secondary forest that established following the ash deposition is well adapted for rapid colonisation of clearings and disturbed sites as they are all relatively quick growing. This may be an indication that the thickness of the ash in the region was greater than is indicated by the physical evidence of the ash recorded at the site.

The pollen record of this site indicates that during the 625 year span covered by this zone, forest in the Big Hill region was a mosaic of vegetation types similar to those described by Elder (1965) as existing in the eastern Ruahine Range today, and in particular in the gorges of the Ngaruroro River in the vicinity of Big Hill.

Pollen counts of primary forest at the base of zone BH2, from the level immediately above the hiatus at 0.90 m depth, also indicate that the forest that was established in the region around 1075 yrs BP, when sediment accumulation resumed at the site, was almost identical to that of 2000 years before, i.e., forest species both before and after the hiatus are similar to those in the eastern Ruahine Range today. This indicates that there have been no major climate changes recorded at this site during the past 3700 years. Any major changes in pollen percentages or pollen types in the record must, therefore, be due to other factors. There are several site disturbances recorded in the BH2 zone. Each disturbance is identified by an influx of coarse material into the site and a change in site vegetation percentages. Each of these disturbances has been interpreted as an erosional event.

As with the previous two sites discussed, an attempt is also made to see whether or not there is any evidence in the record of changes that can be attributed to climate-induced forcing (Grant's hypothesis) and/or earthquake-induced erosional events (Neall & Hanson's hypothesis).

As has been said, the base of the Big Hill site has a radiocarbon date of 3700 ± 90 yrs BP. The event that formed the site is most likely an earthquake about or not long before this date. Neall and Hanson (1995) make no mention of an earthquake or erosional event about this time. However, they do record an earthquake event in their McCool 1 trench, situated south of Big Hill, at 4295 ± 56 yrs BP.

At 1.31 m depth humic peat accumulated at the site until the first disturbance in the core (unit 4C) occurred and is represented by the sediments from 1.09 to 0.90 m depth. This disturbance is believed to have taken place subsequent to 3280 ± 20 yrs BP. on the grounds that the fine ash in the core below this disturbance is the Waimihia Tephra (Froggatt & Lowe 1990). The disturbance is limited to prior to 1075 ± 140 yrs BP. when the site began reaccumulating peat following the hiatus. Based on an average accumulation rate of 0.43 mm/yr., calculated on the basis the time it took for sediment to accumulate from the base of the site up to the first record of the Waimihia Tephra at 1.31 m depth, the peat containing the Waimihia (unit 5Oh) and the erosional event (unit 4C) that temporarily destroyed the site at 90 m depth was laid down within a maximum of 950 years. This would date the termination of the erosional event to as late as 2330 yrs BP. However, the colluvial nature of the sediment suggests the whole of unit 4C was deposited within a much shorter time, for example, being dumped as one major event, or as a series of short term repetitive events. A concentration of angular 5 mm clasts at 1.04 - 1.06 m depth suggests there was more than one event involved. For this reason a date of 3075 yrs BP. is advanced here as a more realistic date for the termination of the erosional event.

Neall and Hanson (1995) report no earthquake or erosional events from their trenches on McCool's farm south of Big Hill to fit this 3280 - 3075 yrs BP. period. However, in their Inglis 3 trench (on Inglis farm just north of Woodville) there is a record of an earthquake event between 4335 ± 66 yrs BP. and 3000 yrs BP. Neall and Hanson further report evidence of an earthquake event in their Trotter 2 trench (on Trotter's farm, 8 km north of Inglis farm) prior to 3110 ± 60 yrs BP. when peat begins accumulating in the trench. On the above evidence it is postulated that the Big Hill site was strongly influenced by an earthquake event probably around 3125 years ago (3075 yrs BP.). An hiatus in deposition followed, which lasted for c. 2000 years until sediment began accumulating again at the site about 1075 ± 140 yrs BP. and corresponds to the bottom of zone two.

Of relevance are observations from trenches crossing the Mohaka Fault in the Wakarara area, immediately south of Big Hill. Here offset units indicate a surface rupture has occurred no earlier that 1165 ± 50 yrs BP. (Raub et al., 1987). Neall and Hanson report a similar date from their Inglis site no. 4 (on Inglis farm) near Woodville. Here a new soil formed in silty material following a faulting or storm event that resulted in the deposition of a lens of compact breccia into the fault trench. This breccia contained charcoal dated at 1105 ± 65 yrs BP. (Neall & Hanson, 1995). They do not report on any events in their McCool trenches about this time. As the material dated was charcoal and as such may possess an error due to "inbuilt age effect" (McFadgen, 1982), the actual time represented by this date may in fact be younger than 1105 ± 65 yrs BP. Nevertheless, on the evidence of the movement north of Big Hill identified by Raub et al. (1987) and the established date of *c* 1075 ± 140 yrs BP. for the resumption of sediment acumulation at the Big Hill site, it is postulated that there was a movement along the Big Hill segment of the Mohaka Fault about 1075 ± 140 years ago. The event of 1105 ± 65 yrs BP.

recorded by Neall & Hanson (1995) near Woodville, may be related to this event. The erosional event at the Hinerua site, dated by sediment accumulation rates to 1100 yrs BP. (see 4. 2. 5 above) may also be related to this movement.

This event is not recorded in Neall and Hanson's McCool trench. As the gorge of the Big Hill Stream separates that part of the Mohaka Fault containing the Big Hill site, from the McCool trench site, it is also possible the McCool site did not move during the event recorded both at the Big Hill site and by Raub et al. (1987) farther south in the Wakarara area. Other possibilities are, no datable material was found in the McCool trench at the appropriate level, or, subsequent erosion has removed all trace of any such movement.

The first sedimentological disturbance after the hiatus occurs at the base of 2Of2 between 0.72 and 0.73 m depth. The evidence of this disturbance is a coarse sandy lens in the stratigraphy - indicative of an erosional event. Apart from a few broken and corroded *Cyathea dealbata* (silver fern) spores and one broken *P. ferruginea* grain, no pollen accumulated at the site at this depth. Rather, the sub-sample comprised almost pure detrital silica. Based on sediment acumulation rates of 0.69 mm/yr., for this part of the core, the 0.72 - 0.73 m depth is equal to *c* 831 ± 140 yrs BP. (1119 ± 140 AD.). This disturbance is too old to be attributed to Grant's Waihirere Erosional Period (1280 - 1400 AD.). Eden and Page (1998) reporting on sediment pulses in Lake Tutira in Northern Hawkes Bay, estimate a pulse of c. 12 mm is the result of a c. 450 mm storm event. But the estimated date for the disturbance at Big Hill does not fall within any of the storm periods identified by these writers. It is possible this disturbance was due to an isolated, localised cyclonic storm.

However, the 831 ± 140 yrs. BP. date does accord well with the disturbance identified by Neall and Hanson (1995) in the McCool trench at the end of Nelsons Road which returned a radiocarbon date of 805 ± 58 yrs BP., as well as with the major erosional event in the West Tamaki Catchment of the central Ruahine Range dated at *c* 770 ± 60 yrs BP. (Hubbard & Neall, 1980). Both these events have been accepted by Neall and Hanson (1995) as recording an earthquake event along the Mohaka Fault. The 831 ± 140 yrs BP. date also accords with the evidence at the Kashmir site of an 800 yrs BP. erosional event in the Moorcock Saddle area (discussed above in 4. 1. 5) which is accepted in this work as recording an earthquake event along the Mohaka Fault.

The second depositional disturbance following the hiatus occurs at 0.65 m depth. At this point the sandy peat found below this depth becomes very fibrous. At 0.64 m depth there is a very minor amount of microscopic charcoal < 5 μm recorded. 5 μm is the ash fragment size that is transported over distance by the wind (Patterson et al., 1987) At this same depth there is an influx of *Pteridium* and Cyperaceae, but the main regional forest species, *Prumnopitys taxifolia* is not affected. On the other hand *Nothofagus*, whose pollen source would have been the central Ruahine Range to the north-west of Big Hill, is notably reduced. (see Figure 4. 3. 7). Based on the very minor amounts of charcoal and its smallness of size, at this depth, plus the evident reduction in *Nothofagus* percentages, the fire is interpreted as due to natural causes (that is, lightning strike) and to have occurred in the ranges west of Big Hill where this species was growing. Sediment accumulation rates for this part of the core places this fire at c 700 ± 140 yrs BP.

The presence of increased amounts of *Pteridium* at this depth could be just a reflection of the ongoing nature of the earlier disturbance recorded at 0.73 m depth. Following this disturbance *P. taxifolia* continues as the main primary forest taxon in conjunction with *Dacrycarpus dacrydioides* (Figure 4. 3. 7), which returns to the site; this is further evidence of damp, and disturbed conditions. High *P. taxifolia* counts, both above and below the disturbance at 0.65 m depth, indicate that this species continued its role as the dominant forest tree in the Big Hill area until well after the disturbance. During the disturbance *Dacrydium cupressinum* also declines but soon recovers to play a minor role up to the top of the zone.

However, there is a sharp decline in *P. taxifolia*, along with all forest taxa beginning at 0.55 m. depth. Based on sediment accumulation rates of 0.69 mm/yr., this decline occurred around about 570 ± 170 yrs BP. (1380 AD.). This is within Grant's date for his Waihirere Erosional Period (1280 - 1400 AD.). Grant (1991) maintains that fires accompanied the gales that destroyed the forests during the Waihirere Erosional Period. Minor amounts of < 5 μm charcoal are present in the sub-sample at this depth. This indicates that it is possible that fires contributed to the *P. taxifolia* decline in the Big Hill area at this time. But it is also possible that the source of the *P. taxifolia* and other forest pollen was not destroyed by fire at this time, but regressed more slowly due to some other factor, The rapid expansion of *Dacrycarpus dacrydioides* at this time (Figure 4. 3. 4) does tend to support the inference that damper, disturbed conditions prevailed in the region at this time. Natural senescence is also a possible explanation for the decline, with *P. taxifolia* being slowly replaced by *Dacrydium* as the natural evolution of the forest ecosystem. Natural secescence would also provide ample combustible material for the minor fire that the small amounts of 5 μm charcoal indicate occurred around this time.

However, the 568 ± 140 yrs BP. date is similar to the date of the erosional event at the Hinerua site. This latter was dated by sediment accumulation rates at *c.* 600 ± 170 yrs BP. (see 4. 2. 5 above), and thought to be a storm induced event. There is some evidence of increased wetness at the Hinerua site following the event, but pollen percentages indicate the regional beech forest was untouched by the event. So it is also possible increased storminess along the southern section of the eastern Ruahine Range about this time affected the Hinerua and Big Hill areas in different ways.

Although no sedimentological disturbance is signalled at 0.45 m depth at Big Hill, at this point there is a massive increase in *Pteridium* counts, in conjunction with the sudden introduction of equally massive amounts of *Typha* (raupo) to the site. Both Cyperaceae and *Blechnum* counts are also exceptionally high at this point. This localised palynologial disturbance coincides with extremely large amounts of large (*c* 65 μm) microscopically identified charcoal flakes. The size of the charcoal flakes in the Big Hill core indicates the fire occurred at the site (Patterson, et al., (1987). Based on the site accumulation rate of 0.69 mm/yr., calculated for this part of the core, the initial fire at 0.45 m depth, is dated at 435 ± 170 yrs BP., and is interpreted as Polynesian burning of the area to promote the growth of *Pteridium*.

Good edible *fecula* (root of the fern, *Pteridium*) was not to be found everywhere. Colenso (1880) reports that in Hawkes Bay it was more readily obtained in areas of low-lying, rich, loose alluvial soils, on the banks of rivers, and especially in pumice-rich soils. The Big Hill site is situated on the slopes above the Ngaruroro River, and the surrounding land meets all the above criteria. The alluvial slopes of this river are rich in pumice left behind as the Taupo ignimbrite swept down the river in 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990). Colenso recalled that during his early journeys in Hawkes Bay he travelled over an isolated hill which had been long farmed for its fine fern-root, and for which "the occupancy and use for the digging of the root had been fought over several times". He also writes that these cultivations were rigidly preserved and no trespassing was ever allowed (Colenso, 1880).

Continuing high *Pteridium* counts in conjunction with equally large amounts of c. 65 µm and larger charcoal flakes at the 0.35 m depth indicate the site was continually burned for about two hundred years after 435 ± 170 yrs BP. to promote the growth of this food source. The best quality root was obtained by firing the fern every three to five years. The season for the firing of the fern was in August; this firing improved the quality of the root crop, but burning at any other time of the year injured the root and resulted in an inferior very fibrous crop (Colenso, 1880).

In conjunction with the anthropogenic burning exceptionally high counts of *Typha* (*raupo*) are recorded. The roots or rhizomes of *raupo* furnished a small food supply in the form of a kind of flour; this was obtained from the inner part of the rootstock and made into cakes. Sometimes this white inner part was eaten raw, or cut into small pieces and steamed in a gourd vessel. *Raupo* pollen (known as *pungapunga*) was also collected by the early Maori, made into cakes with water, and then baked (Best, 1977b) in the days when *raupo* was plentiful and a large labour force was available to collect the flower heads (Riley, 1994). At the site of collection the seed *pappus* was stripped off and the pollen exposed to the sun in order to dry it throughly (Best, 1977b). The pollen was then obtained by gently beating it out of the dense flowering spikes (Colenso, 1880). This custom of harvesting the *raupo* pollen at source is undoubtedly responsible for the prolific spread of this swamp plant in the sag ponds along the Mohaka Fault at Big Hill at this time. The young undeveloped leaves of *raupo* were also collected from the bottom of a swamp, cooked in a steaming pit and eaten as greens, especially in times of scarcity (Best, 1977b).

The exceptionally high *Typha* counts at these two depths, indicating this swamp plant was being utilised by the early Maoris at the time, lends support to the premise that the Maori was active in the area and using fire to promote the growth of the bracken fern root, known to them as *aruhe*. Across the Ngaruroro River, immediately north of Big Hill, is Whanawhana (the fort) where archaeological evidence has been found of a fortified settlement. The bracken root was a main source of food for active warriors in times of inter-tribal war (Best, 1977b). The date calculated for this anthropogenic land clearance at Big Hill is similar to those Wilmshurst (1997) reports for two sites in northern Hawkes Bay, namely, Tutira (490 cal yrs BP.) and Putere (485 cal yrs BP.).

The similarity of these above three dates, linked to the close proximity of the fortified village to the Big Hill cultivation site, tends to indicate the start of tribal unrest in Hawkes Bay, among Polynesian settlers already established in the region, and not the initial arrival of Polynesians in the area.

A third sedimentological disturbance occurs in this zone is at 0.37 - 0.39 m depth. Based on a sediment accumulation rate of 0.69 mm/yr., the disturbance is dated at *c* 335 ± 140 yrs BP. (1612 AD.), and is linked to a coarse sandy lens in the stratigraphy at this depth.. Primary forest percentages at this point are low due to the Polynesian burning discussed above. Nevertheless, because of the calculated date and the fact that this disturbance is represented by a 20 mm sediment pulse, it is assigned (albeit very tentatively) to the Matawhero Erosional Period (1510 - 1620 AD.) (Grant, 1985).

However, as all the above dates, and sediment accumulation rates are based on the radiocarbon date of 1040 ± 140 yrs BP., there is a ± of 140 years built into all the chronology of the site above 0.90 m depth. So although it is possible to fit the two sedimentological disturbances discussed above into Grant's time frame for two of his erosional periods, there are other possible explanations. For example, Neall and Hanson (1995) report evidence of a storm event in their number 2 trench on Trotter farm, where rounded, well sorted river pebbles were washed into the trench in three layers. These gravels were tilted during a subsequent earthquake and further gravels deposited. A wood sample from within these gravels returned a radiocarbon date of 257 ± 44 yrs BP. (1707 AD.). Given the ± of 140 years inherent in all the calculated dates for the upper section of the Big Hill site, it is possible the disturbance recorded between 0.37 - 0.39 m depth is, in fact, a record of the 257 ± 44 yrs BP. storm event identified by Neall and Hanson.

The next erosional event in this zone, at 0.26 m depth, has been assigned a date of 1800 AD. (see above) and could be linked (again very tentatively) to Grant's Wakarara Erosional Period (1770 - 1800 AD.). At this point organic rich silt in the stratigraphy replaces the very fibrous peat below, indicating a major storm event or events probably occurred. A most definite forest regression occurs, as signalled by the minimal pollen percentages of all primary forest taxa, while at the same time grass percentages are exceptionally high. There is no evidence of fire being the cause of the forest regression at this point. Manuka/kanuka also enters the record at this time. The presence of manuka is evidence of the first stage of forest renewal following a general regression. So the evidence does not negate the possibility that the forest in the region was destroyed by gales between 1770 and 1800 AD., as required by Grant's hypothesis. *Blechnum* counts are down, but *Typha* (*raupo*) continues to dominate the wetland taxa, indicating the site is still under water. However, *Pteridium* counts are drastically reduced, and there is no evidence of burning in the area.

Following this event, the forest does not return to Big Hill area. Instead native grasses together with *Astelia solandri* and minor manuka/ kanuka *Coprosma*, and Asteraceae (Tubuliflorae) become established. This flora is very similar to that described by the early run holders when they first attempted to graze the area in the mid-nineteenth century (see above).

The pollen record in the top zone is one of increasing pastoral grasses and introduced tree species, and reflects European land use in the Big Hill area since the late nineteenth century.

Based on the above evidence the following sedimentological history of the Big Hill site is concluded.

- About 3700 ± 90 yrs BP. a topographical depression formed at the Big Hill site probably due to an earthquake event.

- At 3280 ± 20 yrs BP. the Waimihia Tephra was deposited at the site (1.09 - 1.31 m).

- Soon after this date the site was affected by an influx of greywacke colluvium (0.90 - 1.09 m), signalling an erosional event (probably due to an earthquake event) that so strongly influenced the site that no sediment or water accumulated there for about 2000 years.

- A hiatus is recorded at the site between *c*. 3075 and *c*. 1075 yrs BP. (0.90 m)

- At *c*. 1075 yrs BP. further sedimentation occurred, indicating a topographical depression had again formed at the site (probably due to an earthquake).

- At *c.* 830 yrs BP. (0.72 - 73 m) the site was again affected by an influx of gritty sand signalling an erosional event probably (due to an earthquake).

- Around 700 yrs BP. (0.60 - 0.65 m) coarse fibrous peat accumulated. The pollen record indicates the site was both wet and disturbed at this point.

Around 570 yrs BP. (0.55 m) the site is still wet and disturbed. This may be due to increased storminess. Although there are minor very small charcoal flakes at the site, there is no evidence of fire affecting the site. This event may represent burning of the forest in the nearby ranges. (? Waihirere Erosional Period)

By 435 yrs BP. (0.45 m) the site has been invaded by *Pteridium. Typha*, Cyperaceae and other wetland species. This is due to Polynesian activities in the area

- At *c.* 338 yrs BP. (0.37 - 0.39 m) coarse sand was again deposited at the site, indicating a further erosional event (? Matawhero Erosional Period). The pollen record indicates the site was both disturbed (due to continuing Polynesian activities in the area) and under water at this point. It is also possible this sediment pulse is a record of a storm event which occurred in the area in about 257 ± 44 yrs BP.

- At *c* 150 yrs BP. (0.26 m) very fibrous peat is replaced by organic rich silt at the site, indicating site disturbance (?Wakarara Erosional Period). The pollen record indicates the site is still under water, and there was a general, permanent forest regression in the region. Polynesian activities are greatly reduced, and in fact, the site may have been abandoned by Polynesians by this time.

- From *c* 1870 AD. to the present, the site was periodically disturbed by grazing sheep and to a lesser extent cattle, and by European land clearance.

The above was concluded by linking the palynological record extracted from 10 cm subsampling to the sedimentological record of the site. This was underpinned with a radiocarbon date at the base of the record, a further radiocarbon date above the hiatus recorded at 0.90 m depth, and historical dates of known European land clearance and occupancy, and supported by estimated sediment accumulation rates.

4.4 INTRODUCTION

The Willowford site is situated on Willowford Station in western Hawkes Bay (V20 102 918). Access is by means of Willowford Road, off the Napier/Taihape Road, about 8 km east of the Blowhard Bush area.

The scarp of the Mohaka Fault in the general area is not well defined and appears to die out. However, the fault can be discerned on a colluvial slope to the north of Willowford Station, with uplift to the east. North of Willowford Station the Willowford Stream follows the line of Willowford Road. On Willowford Station there is an S-bend in this stream along the presumed trace of the Mohaka Fault - the offset being 70 to 80 m. East of the fault trace the gradient of this stream increases as it drains into the nearby Tutaekuri River. Although water ponds in places in the streambed, coring the bed of the stream was not possible as the subsurface is comprised mainly of large (>300 mm), well rounded greywacke boulders. The same sized boulders were also exposed in the banksides, indicating the current Willowford Stream is cutting down through old alluvial river gravels.

Figure 4. 4. 1 is a map of the Willowford region in the vicinity of the Mohaka Fault. The trace of the fault is definable as a linear feature affecting the local drainage pattern. Figure 4. 4. 2 is a general view of the rolling downland to the south of Willowford with the pond cored to the left. In the foreground the trace of the fault is not apparent in the generally hummocky relief of Willowford Station. Figure 4. 4. 3 is a view to the north

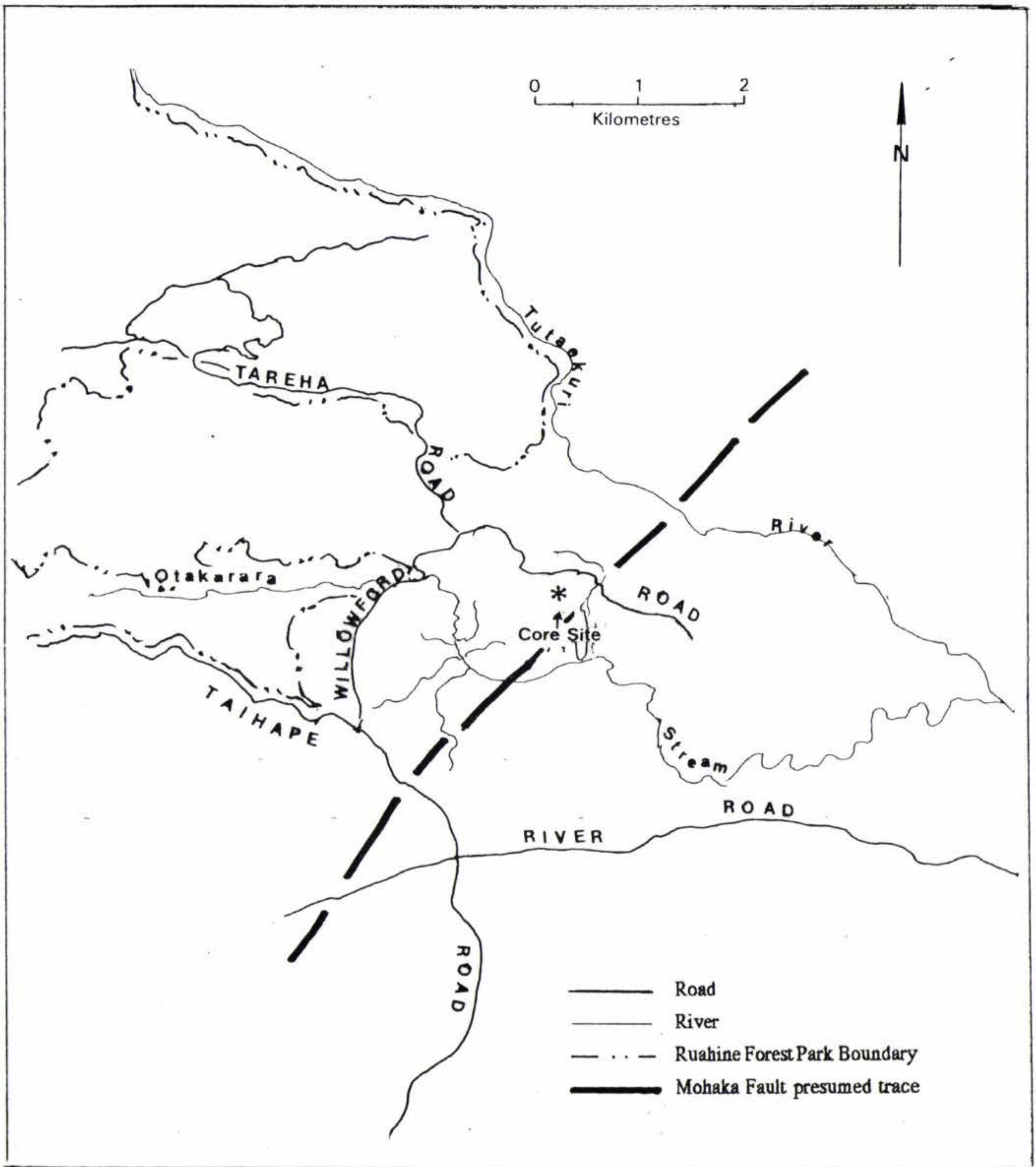


Figure 4. 4. 1 Map of the Willowford region in the vicintiy of the locally obscur~ed trace of the Mohaka Fault. The core site is indicated by an *.

Figure 4. 4. 2 General view of Willowford and the pond cored, looking south

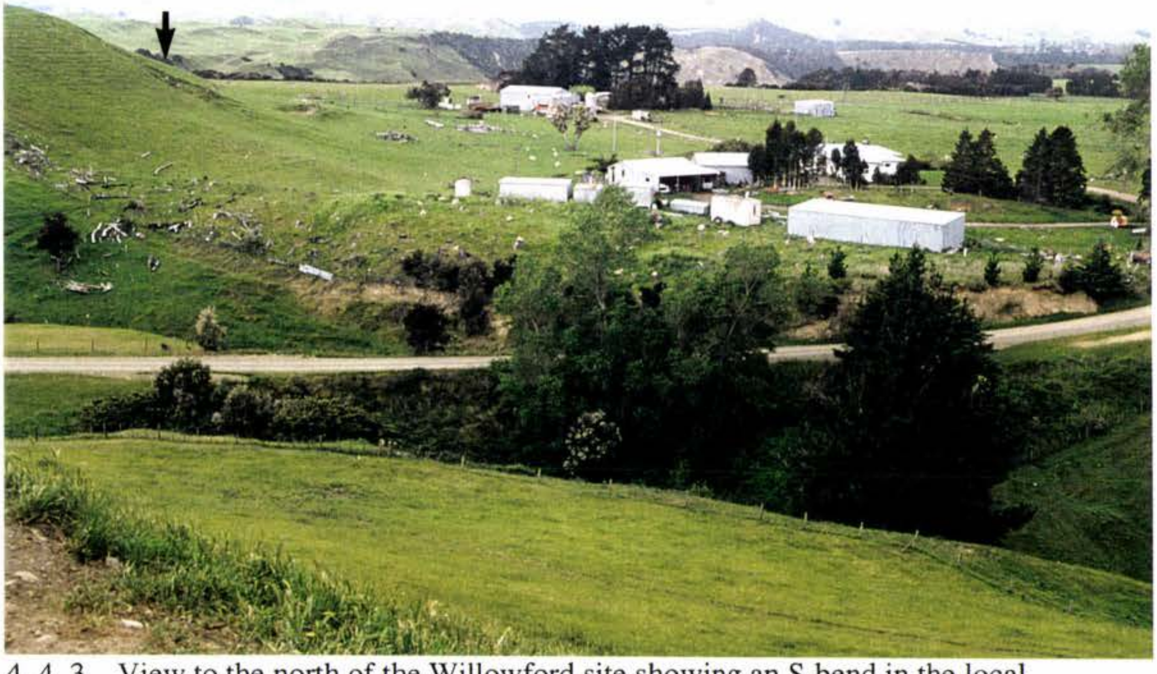


Figure 4. 4. 3 View to the north of the Willowford site showing an S-bend in the local Willowford stream in the centre along the presumed trace of the Mohaka Fault and the fault itselt, visible as a break in slope, arrowed at the top

of the Willowford site. The Willowford stream passes under the access road in the foreground in an S-bend along the presumed trace of the Mohaka Fault. The fault trace itself, visible on the colluvial slope farther north, is indicated by an arrow.

However, there is a series of small ponds along a NNE/SSW line south of both the outcrop of the Mohaka Fault to the north of Willowford Station and the S-bend in the Willowford stream on Willowford Station itself. The most accessible of these ponds is the largest and was selected as the pollen core site. This pond, a topographic low, collects runoff from four small inlet depressions along the western side of the low. The area has recently been dammed to the east to raise the level of the water: the dam now acts as a farm access track. Overflow from the pond is piped under the track and ponds naturally below where drainage is eventually into the Tutaekuri River farther east.

In the summer prior to coring (1995/6) the new landowner of Willowford Station, not used to farming under Hawkes Bay conditions, had overstocked his farm and used the pond (currently with a water depth of 4 m) to water his cattle during a drought. As a result the pond dried up. In spite of damage by trampling, it was decided to include the site in the Mohaka Fault core programme because, below the disturbed layers, the pollen record would be indicative of the vegetation cover immediately prior to any forest clearance in this area.

Rainfall in the Willowford area has been recorded at Waiwhare 3 kilometres farther east at 1275 mm yr^{-1}. (Anon., 1973). The soils in the area are Brown and Pallic Soil intergrades, with shallow A horizons (Hewitt, 1992). The soils are a reflection of the rainfall regime.

4.4.1 GEOLOGY AND GEOMORPHOLOGY

The immediate Willowford area has not been intensively mapped, especially west of the Mohaka Fault scarp at Willowford. However, Beu (1995) has mapped the area east of the fault as the southwestern limb of the Matapiro Syncline, which is truncated in the Willowford area by the Mohaka Fault. The oldest lithology cropping out in the area is a Tertiary mudstone exposed in a road cutting at the junction of the Napier-Taihape Road with Willowford Road. The mudstone has been observed in the banks of Willowford Stream along Willowford Road, and it is expected that the formation underlies a long narrow strip adjacent to and east of the Mohaka Fault Zone in the area. An overlying coquina limestone visible in the Waikonini Stream bed 300 m north of the Napier-Taihape Road bridge has been identified by Beu (1995) as Waiwhare Limestone, the lowest exposed limestone in the south-western limb of the Matapiro Syncline.

The age of the Willowford Mudstone is not well constrained by molluscs, but scattered, slightly weathered inner shelf, soft bottom facies leads Beu (1995) to conclude that this mudstone is probably a lateral equivalent of the upper part of Taradale Mudstone - the base of the Nukumaruan succession in the southeastern limb of Matapiro Syncline. Superposition dictates that the Waiwhare Limestone is a lateral equivalent of both Park Island Limestone, which overlies the Taradale Mudstone, and Darky Spur Formation in the Tangoio Block.

Around the high terraces to the northwest are Waitotaran marine sandstones and siltstones. Immediately to the north of Willowford are remnants of pre-Waitotaran abrasion surfaces on the greywacke undermass. Post--Tertiary strata are non-marine and consist of remnants of a considerably eroded pumice cover of Pleistocene age and high terraces formed by the Ngaruroro River before it cut its present course between the Burns Range and the Comet west of Willowford.

At Willowford the topography is generally undulating to hilly. However, immediately northeast of the core site there is a lower area of flat terrace along the true right bank of the Tutaekuri River, with surface gravels identical to the greywacke gravels in the banks and bed of the Willowford Stream (Figure 4. 4. 3). These gravels appear to be laid down very recently possibly during the sedimentation that accompanied the gales and erosion of the Matawhero Erosional Period (Grant, 1996) (See discussion in 4. 4. 6 below). The source of these recent gravels would have to be the remnant greywacke from the nearby scarps along the eastern slopes of The Lizard and Blowhard areas through which the Waikonini Stream currently flows. On the other hand the greywacke gravels in the banks of Willowford Stream, with its higher elevation, would have to be from an earlier sedimentary episode and be sourced in either the Don Juan Range (an uplifted greywacke block to the northwest of Willowford) and/or the Kohurau Graben through which the present Tutaekuri River flows. It is also possible that these well rounded gravels, may have been laid down by the Ngaruroro River before this river altered its course.

4.4.2 PRESENT DAY VEGETATION

The Willowford area is currently in introduced pasture, with some native grasses and ferns, especially in boggy areas. Small stands of manuka, scrub and a few native shrubs are found in places along the banks of the Willowford Stream, especially where topography is steeper due to downcutting by the stream. Manuka is also scattered in gullies on the grassed hillsides. Macrocarpa have been planted along the access road to the station homestead.

Early station diaries in the general Willowford/Kaweka area also mention several islands of podocarps which were utilised by the early settlers for building requirements, but most of these localities are now lost. Stock grazing and burning since the 1870s has resulted in a network of induced forest communities (Elder, 1965).

At the head of the Tutaekuri River in the southeast Kaweka Range mountain beech (*Nothofagus solandri* var. *cliffortioides*) formerly extended to the timberline where it consisted of gnarled over-mature trees. These have since been burned and their place taken by a silver tussock cover. Red beech (*Nothofagus fusca*) occurs sporadically, being confined to favourable and sheltered positions. In places burning of red beech has been followed by regeneration of mountain beech, and where both species coexist, hybrids are common (Elder, 1965).

In the Blowhard area a few kilometers to the west of Willowford there is a remnant of podocarp-broadleaved forest on the eastern (lee) side of a ridge between 720 and 820 m asl. The situation is well protected from both westerly winds and fires from a westerly direction. The dominant podocarp in this area is *Prumnopitys taxifolia*. Other important podocarps are *Dacrydium cupressinum*, *Dacrycarpus dacrydioides* and *Prumnopitys ferruginea*. The age of most of these podocarps, as defined by increment coring, is estimated to be in excess of 500 years, some up to 800 years (Grant, 1996).

Northeast of the Blowhard there are several remnant podocarps consisting of *Prumnopitys taxifolia* and some *Dacrydium cupressinum* in deep gullies. Burned logs of *Prumnopitys taxifolia* and *Nestegis cunninghamii* litter nearby paddocks (Grant, 1996).

On the Glenross Range south of the Blowhard, manuka and kanuka scrub and tussock are common and extend north to the Blowhard area. On the Burns Range south west of Willowford there are stands of red and mountain beech at altitudes up to 760 m, with scattered *Dacrydium* in conjunction with lowland understorey trees and shrubs such as *Carpodetus serratus*, *Melicytus ramiflorus*, *Griselinia littoralis*, *Myrsine australis*, *Fuchsia excorticata*, *Aristotelia serrata* and *Brachyglottis repanda* (Grant, 1996).

4.4.3 RECENT SITE HISTORY

Willowford originally formed part of the Mangawhare run. This property was situated some sixty-five kilometres west of Napier and initially consisted of 8810 ha taken up in 1861 by Samuel and John Begg. Further leases totalling about 19 050 ha increased the acreage to 27850 ha of rough hill country extending as far as the Kaweka Range. This increased acreage lying between the Blowhard and the Kaweka Range, forms part of the Kohurau Graben. The soils in this area were considered very poor. Nevertheless, by 1872 there were 11 505 sheep on the property which lay on both sides of what was to become the Napier-Taihape Road (Macgregor, 1970).

In 1879 Kinross, the then owner of Mangawhare, split the leasehold property in two, retaining the 12 150 ha south of the Napier-Taihape Road for himself, and renamed his land Glenross. The Mangawhare property north of the road, passed to the Hon. G.M. Waterhouse who by 1886 was grazing 22 400 sheep on the reduced acreage.

The Mangawhare property as a whole was watered by the upper reaches of the Tutaekuri River and the Otakarara Stream which runs between steep hills. The flats (high terraces) between the Tutaekuri and the Otakarara were reached by a narrow winding path up a very steep hill. Due to high winds Sandy Ridge supported only some native grasses between intermittent islands of stunted flax (Macgregor, 1970).

Over the years various acreages were sold from the property, and the property changed hands several times. Waiwhare, 3 kilometres east of Willowford Station was one of the larger blocks to be sold off early (Macgregor, 1970). Willowford Station land was part of the Waiwhare sale. There is a record of the mustering of merino wethers on the Kaweka Range and Blowhard plateau from Waiwhare in 1873 (Elder, 1959). The land north of the Tutaekuri River between the Blowhard and the Don Juan Range is now farmed as the Mangatutu Station (Elder, 1959). Currently the whole Willowford and Mangatutu area is in pasture and grazes mainly sheep, or mixed sheep and beef cattle.

PALEOECOLOGY 4. 4. 4.

The results of the pollen analysis of the Willowford site are presented in Figures 4. 4. 4 and 4. 4. 5. the stratigraphy is presented separately in Figure 4. 4. 6. A sample of organic mud taken from a depth of 1.29 m depth was dated (WK - 5214) at 480 ± 170 yrs BP.

FIGURE 4.4.4 RELATIVE POLLEN DIAGRAM WILLOWFORD SITE

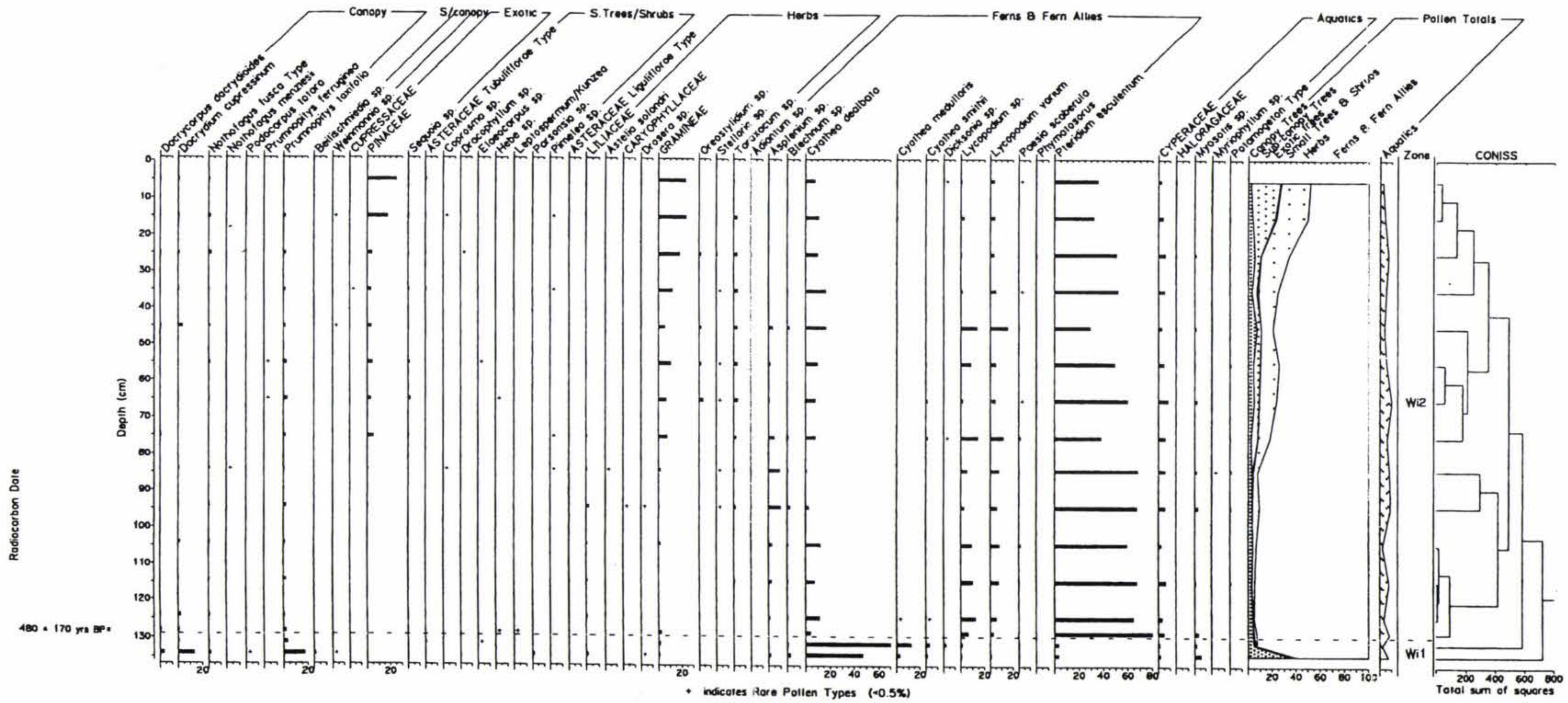
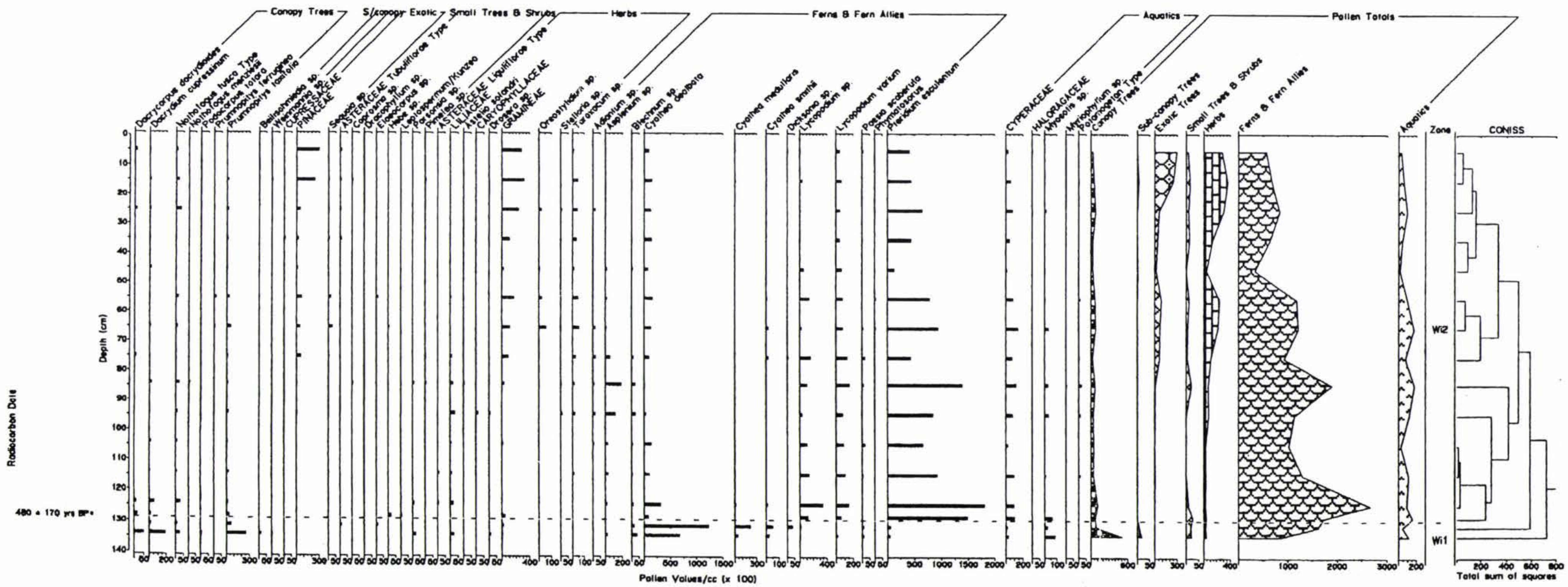


FIGURE 4. 4. 5 ABSOLUTE POLLEN DIAGRAM WILLOWFORD SITE



The pollen diagrams have been zoned using a subjective assessment in conjunction with a visual inspection of the diagrams and the CONISS dendrogram provided by the Tiliagraph programme. Two zones have been assigned, namely Wi1 and Wi2; Wi is the code assigned to the Willowford site.

Zone Wi1 1.36 - 1.29 m

The forest pollen at the base of this zone is dominated by *Prumnopitys taxifolia* in conjunction with *Dacrydium cupressinum*. Also present in minor amounts are *Dacrycarpus dacrydioides* and *Nothofagus fusca* type. Percentages of all four taxa decrease markedly at the top of the zone. The understorey tree, *Litsea* also has a minor presence at the base of the zone. Abundant charcoal present from 1.33 m depth to the top of the zone, suggests the decrease in forest taxa can be attributed to a fire that destroyed the forest in the immediate area of the site. Following the fire, all forest taxa are greatly reduced, while at the same time *Elaeocarpus* makes an appearance but leaves the record immediately above.

The tree fern *Cyathea dealbata* dominates the base of the zone and increases, in conjunction with *C. medullaris, C. smithii* and *Dicksonia* at the top of the zone. The ferns *Blechnum* and *Asplenium* are also present in the basal layer, as are minor percentages of *Pteridium esculentum*. The swamp plant *Myriophyllum* together with *Myosotis* and minor percentages of *Drosera* and Cyperaceae, have a notable presence at the base of the zone, but decrease at the top. The high frequencies of the various fern spores together with relatively high aquatic counts are indicative of a flora more associated with scrub vegetation. The reduction in aquatic and fern percentages at the top of the zone can be attributed to a temporary destruction of the groundcover both in and around the site during the fire. The diversity of the tree ferns at the top of the zone can be associated with regrowth following a fire. Minor amounts of Asteraceae (Tubuliflorae) and Poaceae also enter the record immediately after the fire. These taxa are also indicative of regrowth following disturbance.

Zone Wi2 1.29 - 0 m

The base of this zone is dominated by a massive influx of *Pteridium* into the record, while at the same time there is a marked decline in the frequency of tree ferns. *Pteridium* percentages remain high up to the present day, apart from minor reductions corresponding to the depths of 0.80 m and 0.45 m. This apparent decline in percentage of bracken spores is probably a reflection of the increase in *Lycopodium* species, a taxon which dominates these two depths. The fern ally *Lycopodium* and the tree fern *Cyathea dealbata* form a minor but important part of the flora in this zone suggesting the general area was covered by an abundant pteridophyte flora more associated with open slightly damp conditions.

Forest taxa counts are generally low throughout the zone. *Prumnopitys taxifolia* remains as the main forest taxon in conjunction with *Dacrydium cupressinum*, and *Weinmannia* appears intermittently towards the top of the zone. There is also a minor but constant *Nothofagus fusca* presence throughout most of the zone, and a slight increase in values of this taxon towards the present day.

Pollen of small tree and shrub taxa are generally rare throughout the zone. *Hebe* is present at the base of the zone. *Coprosma* makes an isolated appearance at 0.85 m depth. *Elaeocarpus* returns to the site at 0.55 m depth. Asteraceae Tubuliflorae type appears as a very minor percentage at 0.35 m depth and remains to the top of the zone. Thus the zonation at the 1.29 m depth is on the basis of the ecological groupings of the pteridophyte flora, with the forest component showing a background value.

Grasses, initially only native taxa, enter the record at 0.85 m depth. *Taraxacum*, probably the native species, is present in small percentages throughout the zone, with a slight increase signalled in conjunction with grass expansion. Apart from these two taxa, herb flora are generally rare. This is no doubt a reflection of the rich and varied pteridophyte flora in the zone.

Pinus radiata enters the record at 0.75 m depth and has a small but steady presence up to 0.15 m depth when it expands rapidly. The presence of this taxon at 0. 75 m depth may be evidence of European activity in the area and signal a change to a more rapid sediment accumulation rate than lower down the profile. However, the Willowford area was one of the first parcels of land opened up to grazing in the mid-nineteenth century, and was on the route taken by early run holders droving their flocks to the tussock lands in the high country to the west. The area is also prone to drought in summer. When the site dries out the bed of the pond shrinks and large relatively deep cracks form in the bed. This happened as recently as the summer before the site was cored (Wayne Jeffers, pers. comm. 1997). For this reason the presence of minor counts of *Pinus radiata* from 0.75 m to 0,25 m depth is attributed to contamination from higher up the profile due to either stock trampling by the early run holders' flocks as they foraged for edible plant matter and/or, the drying out of the site during the dry summer months. For the above reasons it is the rapid expansion of *Pinus radiata* percentages at 0.15 m depth that is accepted here as reflecting the increased plantations of this tree in in the Willowford area in the present century. And the presence of this taxon lower down the profile is interpreted as due to contamination from above.

4.4.5 DISCUSSION

Sediments at the Willowford site are basically organic rich, structureless, sandy silts from the top of the profile down to 1.29 m depth . At this point the sediment coarsens to a silty sand, with white ash and lapilli scattered throughout. There are minor, black, scattered 2 mm peds, with a well developed crumb structure, at the base of the profile. A stratigraphic description of this site is set out in Figure 4. 4. 6.

Based on the radiocarbon date of 480 ± 170 yrs BP. at 1.29 m depth being calibrated as AD 1470 and the assumption that deposition has been at a constant rate at the site, it is estimated that sediment accumulated at a rate of 4.09 mm/yr.

On the basis of the above radiocarbon date it is evident the sediment record at the Willowford site extends back at least 550 years. At some time prior to this time an unrecorded event, possibly an earthquake, resulted in the formation of a topographical depression and/or the blockage of drainage from the site. The stratigraphy indicates there have been two episodes of sediment accumulation in the last 550 years. The first episode (unit C4), involving deposition of a poorly developed silty sand, was terminated by a fire which temporarily destroyed the flora at the site c. 528 years ago (480 yrs BP.). Since that time there have been two distinct changes to the stratigraphy, one at 1.12 m depth and the other at 0.35 m depth. At 1.12 m depth there is a change from a dark grey sandy silt to a black organic rich silt. This is interpreted as a natural change as mineral inwash was excluded from the pond margins. This indicates more stable conditions around the pond. At 0.35 m the sediment coarsens to a sandy silt. This is attributed to slightly disturbed conditions occasioned by the use of the area for sheep grazing.

WILLOWFORD SITE

	m		
	0	C1	Dark grey (N 3/0) organic rich sandy silt; structureless; minor charcoal; distinct wavy boundary.
	0.35	C2	Black (10 YR 2/1) organic rich silt; structureless; concentration of white 1 mm ash at 0.40 m; ash scattered below; concentration of white 1 mm ash at 0.59 - 0.61 m; below 0.61 m silt coarsens down profile; small *c* 5 mm wood fragments scattered throughout; organic content decreases downprofile; minor charcoal 77- 81 cm; 4mm gravel lens at base; distinct boundary.
	1.12	C3	Dark grey (N 3/0) sandy silt; structureless; some organic content; organic content increasing towards base; some angular clasts (3 mm); minor charcoal scattered throughout; gradual boundary over 2 0 mm.
14C date 480 ± 170 yrs BP	1.29	C4	Olive black (5 GY 3/1) organic rich silty sand; white ash and lapilli c. (4mm) scattered throughout; charcoal present down to 1.33 m some peds (2 mm) with a well developed crumb structure, scattered throughout at the base
	1.36		Base of site

Figure 4. 4. 6 Stratigraphic column. Site cored with the Livingstone piston corer.

The pollen record of the Willowford site at 1.34 m depth indicates that immediately prior to 530 years ago the Willowford area was forested. The forest was dominated by *Prumnopitys taxifolia* in association with *Dacrydium cupressinum* with minor *P. ferruginea* and *Dacrycarpus dacrydioides* , plus some *Podocarpus totara* and *Nothofagus*. The understorey component near the site consisted of the tree ferns *Cyathea dealbata* , plus minor *C. medullaris* and *C. smithii* . Minor *Asplenium* , *Blechnum*, Liliaceae and bracken made up the ground cover, together with the aquatic plant *Myosostis*, and the reed Cyperaceae which suggests the site was also slightly wet.

This flora does accord well with the description of a (Waihirere) forest remnant at Blowhard Bush, a few kilometres to the west of Willowford (Grant, 1996). Blowhard Bush is a scenic reserve lying on the eastern side of a ridge between 720 and 820 m above sea level. *P. taxifolia* and *Dacrydium* are dominant in the forest remnant, with minor *Dacrycarpus dacrydioides* and *P. ferruginea*. Increment coring indicates one *P. taxifolia* is estimated to be 700-800 years old; another 600-650 years old; a third 550-600 years old; two *Dacrydium* are 550-600 and 500 years old respectively. One *P. ferruginea* is 400-450 years old. *Nestegis*, *Griselinia littoralis*, *Elaeocarpus* and *Ripogonum scandens* are common understorey species, and young black beech borders the stand (Grant, 1996).

The date for the Waihirere Period of sedimentation is determined by Grant using the Kaharoa Tephra which erupted from the Tarawera Complex in 1270 AD. and lies at the base of the Waihirere gravels. Living trees of Waihirere age have been found, Grant maintains, in about 30 stands of forest in the North Island. Increment coring indicates these forests had established between about 1290 and 1490 AD - making them 500 to 700 years old (Grant, 1996).

The pollen record at Willowford establishes that after the c. 480 ± 170 yrs BP. fire, forest did not return to the area. In its stead a pteridophyte flora became well established. Immediately following the fire *Cyathea dealbata* (silver fern), already an important pre-fire forest component, expanded significantly. Based on steady accumulation rates of 4.09 mm/yr, within four to five years this tree fern was replaced by bracken (*Pteridium esculentum*) which became the dominant flora in the area until the twentieth century. This estimated accumulation rate is an exceptionally fast one. As the soils in the general area are pallic soils formed on loess, the accumulation rate may well be a reflection of the silty nature of the surrounding substrate. Stripping of the forest cover also makes these soils very prone to wind and rain erosion.

Near the confluence of the Donald River with the Tutaekuri River, northwest of Willowford, Grant describes a major erosion period involving the deposition of 1 m of coarse gravel over an old soil, which is at the surface of earlier alluvium about 5 m thick. Ring counts on two *Dacrycarpus dacrydioides* (kahikatea) on the surface gave ages of 200-210 years - or dates of 1785 to 1795 AD. (Grant, 1996). Grant (1996) maintains Wakarara age sediments drowned the butts of all large trees. Podocarp species usually survived this alluviation, but *Nothofagus* often succumbed and remained only as decayed stumps . Grant estimates that 35-40% of the forests of the central and northern Ruahine Range were destroyed during the Wakarara Erosional Period (Figure 4. 2).

With the above in mind, pollen counts of important taxa of local interpretive importance have been presented in diagram form (Figure 4. 4. 7). As in the case of the previous sites, the information in this figure is provided as an amplification of the data presented in the absolute pollen diagram (Figure 4. 4. 6). The aim of this exercise is to see

Interpretive Stratigraphic Data based on sediment accumulation rates & pollen information	sampled (m)	Regional Forest: Beech	Rimu	Matai	Exotic Forest: Pinus radiata	Sequoia	Regional Non-forest: Grass	Bracken	Silver fern	Hen & chicken (& Blechnum)	Disturbed Site: Lycopodium	Cyperaceae
	0.05	2	2	1	68		64	97	21	1	12	6
Intensive pastoral (sheep) farming	0.15	4	2	4	47	1	63	86	20		18	11
	0.25	7	3	5	11	1	51	141	28	4	11	17
Sheep grazing disturb native grasses	0.35	1	2	4	8	2	32	136	44	1	16	14
	0.45	3	10	4	9	1	15	80	45	13	79	7
Fire disturbance - c. 1770 AD ?	0.55	3	1	6	(12)	(3)	29	137	28	4	37	14
Bracken peaks again	0.65	2	2	20	(8)	(5)	20	182	24	7	18	27
Fire disturbance c.1700 AD, grass in	0.75			4			20	105	22	23	70	17
Bracken peaks; Hen & chicken at site		3	3	2			4	201	2	32	37	17
Hen & chicken fern at site	0.94	2	1	5			1	179	6	33	22	16
Bracken & Lycopodium increase	1.04	3	5	4			5	183	7		53	7
Erosional Event - Gravel	1.14	1	1	5				179	18		45	18
Tree ferns replaced by bracken	1.24		6	2				202	10		54	10
14C date 480 ± 170 yrs BP -->	1.28		2	4			5	171	8		19	2
Fire destroys forest - tree ferns in	1.31	1	2	7			3		149	3		2
Region in pre-Waihirere forest	1.34	6	45	58			2		6	15	5	6
Ferns & fern allies at site												
Base of site	1.36											

* 1cc sampled at each depth

* 220 dryland taxa counted at each depth, or 4 slides fully scanned where not enough dryland taxa accumulated

Figure 4.4.7 Interpretive stratigraphy of the Willowford site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995) whether or not there is any evidence in the record of changes that could be attributed to climate-induced forcing (Grant's hypothesis). As the trace of the Mohaka Fault is not apparent in the Willowford area the aspect of earthquake-induced erosional events (Neall & Hanson's hypothesis) will not be addressed.

In Figure 4.4.7 the sudden disappearance of forest taxa from the record at a depth of *c* 1.32 m (1458 AD., based on accumulation rates) following a fire is very obvious. The temporary nature of the *C. dealbata* cover which survived the forest destruction in the area is also notable. This tree fern was soon superseded by *Pteridium* in conjunction with *Lycopodium*, about 1470 AD. (480 ± 170 yrs BP.). The fern *Blechnum*, present at the site before the fire, also leaves the record immediately after. This tends to indicate the site stabilised fairly quickly following the fire.

Although the predominance of *P. taxifolia* in this pre-fire podocarp forest suggests the forest make up was the same as that flourishing on the nearby Blowhard at the time, the date of 1458 AD. for the fire tends to place the destruction of the forest at Willowford later than that of Grant's Waihirere Erosional Period, when he estimates 94 % of forests in New Zealand were destroyed by gales and burning (Figure 4.2).

The forest did not return to the Willowford area, following the fire. The slight disturbance at 1.12 m depth, signalled by a gravel lens is too minor to attribute to Grant's Matawhero Erosional Period. There is a slight dip in bracken percentages in conjunction with the gravel influx. *Lycopodium* counts remain high. The reed Cyperaceae increases slightly following the deposition of the gravel. This rise could be attributable to increased dampness at the site due to increased runoff following partial clearance of the *Pteridium* (bracken).

The flora was again disturbed *c.* 1600 AD. (0.94 m depth). Evidence for this disturbance is the introduction of *Asplenium bulbiferum* (hen and chicken fern) at the site and the sudden reduction of *Lycopodium* percentages. A further disturbance took place around 1700 AD. (0.75 m depth). This date is based on the sediment accumulation rate, and the evidence for the disturbance is the sudden reduction in both *Pteridium* and *Lycopodium* percentages, while at the same time *C. dealbata* counts increase and native grasses enjoy an expansion. The increase in these two taxa was probably due to the exploitation of an environmental niche created by the reduced ground cover. However, there is no evidence of at either of these depths any sedimentological disturbance that could be related to any of Grant's erosional periods.

Following the disturbance in *c.* 1700 AD. *Pteridium* re-establishes within ten years. *C. dealbata* and native grasses, now established at the site retain a low but steady presence, and *Lycopodium* recovers some of its previous importance. By *c.* 1730 AD. (0.65 m depth) matai is again present in appreciable amounts for the first time since forest clearance occurred in *c.* 1458 AD. *Pteridium* again peaks, as does Cyperaceae in a more minor way. At the time covered by 0.55 m depth the area had again been subject to fire. At this point both *P. taxifolia* and *Pteridium* decline, while at the same time *Lycopodium* and grasses increase in importance, and *C dealbata* remains steady.

At the 0.45 m depth (*c.* 1810 AD. on the basis of sediment accumulation rates) a very notable dip in bracken percentages, and a more modest temporary decline in Cyperaceae occur. At the same time *Lycopodium* undergoes a temporary, massive increase in percentages and silver fern doubles its percentage count. *Dacrydium* also makes a temporary appearance.

The depth of 0.35 m has been assigned to *c.* 1855 AD. mainly on the basis of the accumulation rate, the increase in native grasses, and the notable decline of *Asplenium* (hen and chicken) and *Lycopodium*. It was from the 1850s on that the early European lease-holders grazed the Willowford area. Trampling by flocks of sheep would account for the decline of the ferns and their replacement by grasses. *Dacrydium* also declines at this time. This can be ascribed to the use of this timber by the early settlers in the building of their homesteads and equipment sheds.

At the 0.25 m depth on the basis of the accumulation rate, the increasing grass counts, the still high *Pteridium* percentages, and continuing presence of other ferns at the site. Another reason is the increasing importance of *Pinus radiata* at 0.15 m depth (1930 AD.) and above. It is believed that the presence of *Pinus radiata* and *Sequoia* in the pollen count as low as a depth of 0.65 m is due to contamination. The area suffers from a moisture deficit in most summers. When the ground dries out in droughty conditions, the silty soils in the region crack and shrink, allowing matter from the surface to penetrate to the lower depths. Heavy trampling by browsing sheep since the 1850s will also have facilitated this mixing process.

Although it might be possible to tentatively assign some of Grant's erosional periods to some of the palynological and sedimentological disturbances evident at this site, the all pervasiveness of *Pteridium* in the area since forest clearance, while not negating Grant's hypothesis, gives rise to a much more feasible alternative explanation for the non-return of the forest.

The pollen record at Willowford indicates *Pteridium* invaded the site within ten years of the c. 1450 AD. fire, and became the dominant species until pastoral sheep farming was established in the area early in the twentieth century. It has been estimated that bracken will take over a site if the area is fired once every five to ten years (M. Roche pers. comm. 1997). From 1.33 m depth up to the present day, charcoal is present in the profile at most depths, indicating the area has been subject to periodic fires over the last 500 years.

While it is possible the original fire that destroyed the forest was a natural event, such as lightning strike, this does not explain the continual firing of the area. A possible explanation for the constant presence of charcoal in the stratigraphy could be attributed to Maori cultivation in the area.

While Maori presence along the middle and lower reaches of the Tutaekuri River is reasonably well known and documented (Buchanan, 1973; Wilson, 1939; Parsons, 1997), little is known about Maori activities in the upper reaches of the Tutaekuri River. The general Maori name for all the land west of Matapiro through which the upper Tutaekuri flows was Ruahine (Buchanan, 1973). Willowford is part of a block of land containing some 7200 ha on the south side of the Tutaekuri River above Tunanui. This estate came before the Maori Land Court in 1870. It was claimed by Paora Kaiwhata, principal chief of Ngati Mahu and Ngati Hinepare, who said he lived at Moteo, belonged to the tribe of Ngai Taita and knew the piece of land by the name of Te Kohurau. He claimed the land by virtue of the fact that the land had belonged to Ngai Taita an ancestor or the Ngati Ruapirau which had amalgamated with the Ngati Mahu through marriage. On the grounds that other applicants failed to prove their case Ngati Mahu were awarded title (Parsons, 1998).

Physical evidence of Maori presence in the Willowford area is minimal. However, Dick Ensor who worked on the original Waiwhare Station, which also included the Willowford area, did find a Maori pendant while ploughing. As well, signs of temporary Maori encampments have been found on the sandy terraces on the hills between the Otakarara Stream and the Tutaekuri River (P. Parsons pers. comm. 1998). The Puketitiri forest to the north of the Kohurau lands, reputed to be especially rich is pigeons, titis and eels, was also extensively used by the descendants of Tawhao as a food source (Parsons, 1998).

Although no evidence of permanent Maori occupation has been found in the Willowford area, use of the Tutaekuri River as a means of accessing the interior is well documented (Buchanan, 1973; Wilson, 1976). The claim that was put before the Maori Land Count in 1870 indicates the area, which was basically in fern and *Pteridium*, was considered worth having. The Maori knew that the way to keep bracken rejuvenating was to repeatedly fire the land, so that the bracken would return naturally. What was required was an accessible tract of land away from any permanent villages or pa which could be burnt periodically without any threat to the people or their possessions, and a means of transporting large quantities of bracken root back to the villages.

The evidence of the temporary encampments in the vicinity of Willowford, indicates there was Maori activity in the area of a transient nature. Figures 4. 4. 1 and 4. 4. 2 indicate, the Willowford area is reasonably flat with ready access to the Tutaekuri River. Pollen analysis indicates bracken was the all pervading ground cover for the last 500 years. Charcoal in the Willowford sediments for the last 500 years indicates the continual firing of the area was by human hand. It is possible the fire seen by Captain Cook while he stood off Napier in 1769, was a burn off that raged out of control.

Thus there is no real evidence in either the pollen or sediment record at Willoford site that could be attributed to any of Grant's erosional periods. It is more likely the continual presence of *Pteridium* (bracken) in conjunction with repeated firing of the area, is evidence the Willowford area was used by the Maori for the cultivation of the bracken root from which they obtained starch, a vital staple ingredient in their diet.

Based on the above evidence the following history of the site is concluded

- At a date unknown, but prior to 1450 AD. a topographical depression formed at the site, possibly due to an earthquake and/or erosional event.

- By c. 1450 AD. (1.35 m) the Willowford area was forested and the site slightly disturbed and damp. Just after 1450 AD. the forest was burnt. *Cyathea dealbata*, a species possessing some pioneering characteristics, invaded the site. T

- By *c.*1470 AD. (1.30 m) *Pteridium* has invaded the area, and by 1500 AD. dominates the site in conjunction with *Lycopodium*. Minor charcoal up to 1.12 m indicates fire was constant at the site.

- In *c.* 1550 AD. (1.12 m) the site was affected by a influx of gravel indicating a very minor erosional event but the site stabilises immediately above.

- In *c.* 1615 AD. (0.94 m) the site is again disturbed, *Pteridium* is still dominant but the pteridophyte flora diversifies to include the hen and chicken fern, *Asplenium*.

- In *c.* 1700 AD. (0.75 m) the area is disturbed by fire, probably due to human activity, *Pteridium* and *C. dealbata* decline and *Lycopodium* and native grasses grow at the site, but *Pteridium* reestablishes within ten years.

- By *c.* 1730 AD. (0.65 m) Forest is reestablishing in the region, and *Pteridium* again dominates the site. Cyperaceae is also important.

- In *c.* 1770 AD. (0.55 m) the area is affected by fire and both the regenerating forest and the *Pteridium* cover are reduced, but *C. dealbata* is not affected by the fire, and *Pteridium* recovers soon after, indicating the fire may have been due to human activity.

- In *c.* 1800 AD. (*c.* 0.45 m) the site is again disturbed and the *Pteridium* cover is again reduced, while at the same time *C. dealbata* and *Lycopodium* cover increases. A regional forest signals a return to the area.

- In the 1850s (0.35 m) the site is again disturbed, this time by browsing sheep. *Asplenium* and *Lycopodium* are greatly reduced while *Pteridium* exploits the ecological niche so created and expands. The regional forest declines again as the timber is used by the early European settlers.

- In the 1890s (0.25 m) the grass cover increases at the site and regional forest cover remains minimal.

- In the twentieth century (0.20 m and above) the grass cover in the area has increased at the expense of the *Pteridium* and monolete fern cover. *Pinus radiata* forest is gradually expanding, but native forest still has a small but constant presence in the region.

The above evidence suggests the Willowford area has been affected by periodic human induced burning followed by bracken and other fern regeneration since the original regional forest was destroyed by a fire due to natural or anthropogenic causes, about 530 years ago.

HAWKSTONE SITE

4. 5. INTRODUCTION

The Hawkstone site is on Hawkstone Station situated about 50 kilometres northwest of Napier and 10 kilometres south of Puketitiri (V20/140 995). Access to the site is by means of a well developed farm track off Hawkston Road.

The trace of the Mohaka Fault in the Hawkstone area is sharp and up-thrown to the east. At the core site water has ponded along a 200 m depression, west of the fault. The site is a mire as defined by Wardle (1991) and is rapidly being infilled by *Typha* as well as native and exotic grasses. Water draining off the nearby hills enters the mire via a topographical depression towards the southern end of the site and backs up northwards along the fault scarp for c. 150 m.

Overflow from the mire drains naturally from the south of the site and has been artificially channelled under the Hawkstone farm access road (Figure 4. 5. 3) to exit into its natural channel eroded into the soft sandy sediment east of the Mohaka Fault. The apparent horizontal offset between the axis of the valley feeding water into the mire and the natural channel draining the site was paced out at *c* 80 m. Figure 4. 5. 1 is a map of the Hawkstone region adjacent to the Mohaka Fault zone. The fault trace can be seen as a NNE-SSW linear feature from the offset nature of the local streams. Figure 4. 5. 2 is a view of the *Typha*-rich mire being cored with the Hiller peat borer. Figure 4. 5. 3 is a view of the NNE-trending Mohaka Fault scarp at Hawkstone showing the scarp in relation to the adjacent mire.

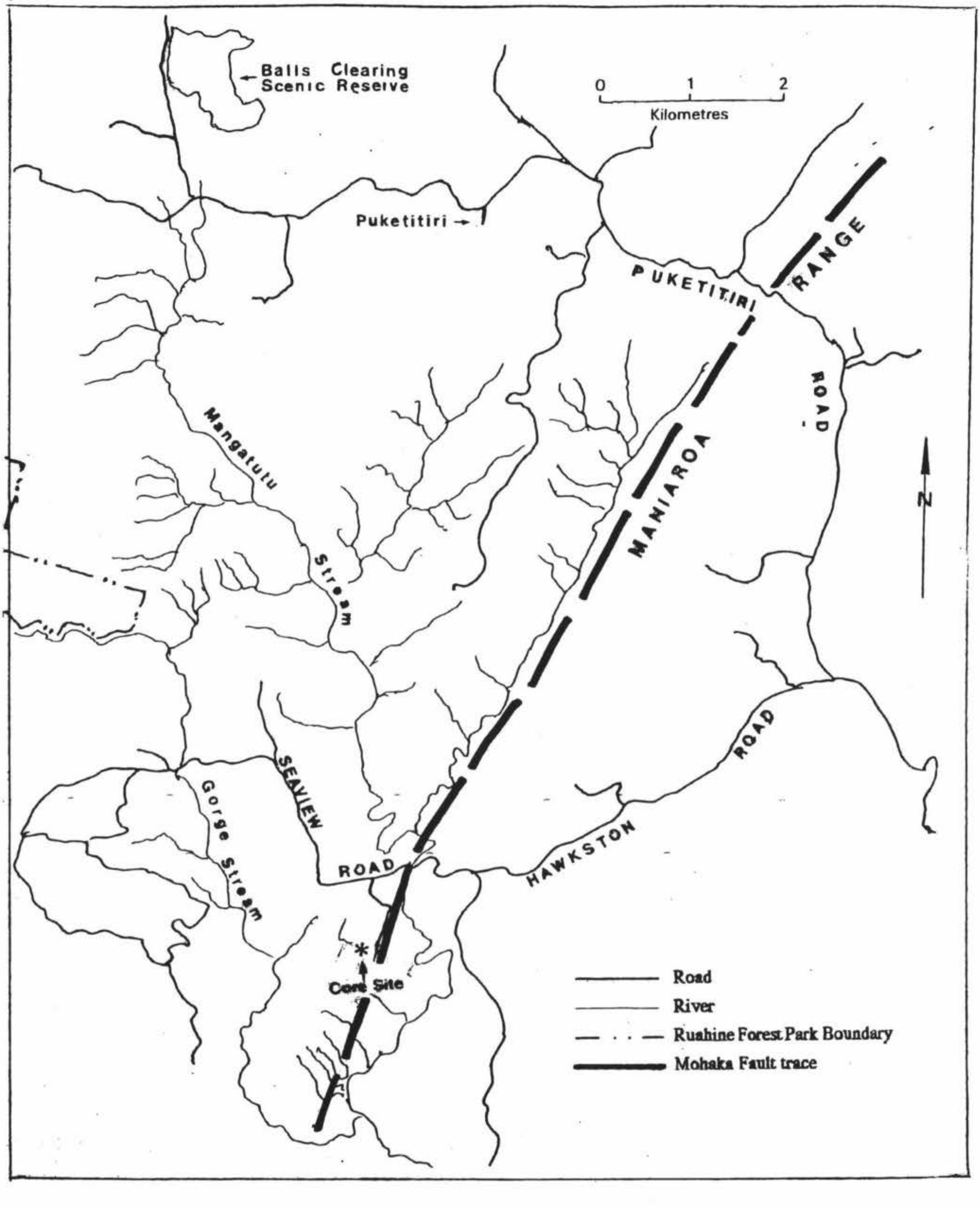


Figure 4. 5. 1 Map of the Hawkstone region in the vicinity of the Mohaka Fault trace. The site cored is indicated by an *

Figure 4. 5. 2 Coring the *Typha* -rich mire at Hawkstone

Figure 4. 5. 3 The NNE-trending tree clad Mohaka Fault trace at Hawkstone, with the mire that was cored enhanced in black to the left.

Figure 4. 5. 4 The mire at Hawkstone set within pasture clad rolling hills along the Mohaka Fault scarp, as seen from a hill northwest of the mire

South of the core site, part of the fault scarp has been levelled to provide flat access to a newly constructed milkingshed complex. Figure 4. 5. 4 looking southeast from the topographical high northwest of the site shows the mire in relation to this levelled area. To the right of the building, the intact fault scarp can be seen continuing in a southwest direction. The tree covered fault scarp to the east of the mire is just discernible on the left. The mire was cored and augered to a depth of 3. 41 m. At this point fine sandy sediment similar to the material found in the fault scarp was encountered.

Rainfall in the Hawkstone area has been recorded on Hawkstone Station at 1632 mm/yr (Anon., 1973). Hawkstone is situated 366 m above sea level and the high country west of the site rises to 460 m. In most places ash and pumice from the Taupo Volcanic Zone have mantled the landscape, and the soils are Brown Soils (Hewitt, 1992). In a few areas shallow black rendzina soils have formed on localised exposed limestone; and in other areas where no pumice cover has remained, the soils are Allophanic Soils (Hewitt, 1992), These latter are a reflection of the moderate rainfall regime in the Puketitiri area.

4.5.1 GEOLOGY AND GEOMORPHOLOGY

The lithology in the immediate Hawkstone area, and to the east of the Mohaka Fault comprises a brown, poorly consolidated, weathered, fine sandstone with a mud component. By extrapolation of Kingma's (1957b) mapping of the Kohurau Depression, the strata are of Waitotoran age. The sandstone is also exposed in the fault scarp, both at the core site and farther north along the access road. The sandstone sequence at Hawkstone dips to the south east at 10° and has been heavily dissected by the local stream that drains the core site.

Geomorphic features in the general area include horizontally offset topography in the form of right laterally offset streams and ridges, the formation of shutter ridges, distinctive linear troughs parallel to the Mohaka Fault Zone, and the remnants of late Tertiary marine erosion surfaces. There is evidence of abundant superficial mass movement (large landslides, perhaps triggered by large earthquakes), aggradation and downcutting of rivers.

4.5.2 PRESENT DAY VEGETATION

The present day vegetation in the general Hawkstone area is mainly composed of introduced pasture grasses. In steep gullies and along natural drainage channels there are patches of manuka and a few other native shrubs. Along the Mohaka Fault scarp there is a 200 metre-long stand of introduced trees including mature macrocarpa, willows, sequoia and gum trees, as well as kanuka and tall grasses.

To the west of Hawkstone are the northern foothills of the Blowhard. At present the area has a uniform cover of manuka scrub with scattered islands of podocarp forest. Northwest of Hawkstone, there is an area of *Danthonia rigida* tussock on a reasonably large natural clearing on the flat summit of the Black Birch Range. In a 1925 survey the lower part of this clearing, now dominated by manuka scrub, was found to be covered in *Celmisia* spp. (Mountain daisies). The daisies, in turn, had replaced tussock and forest following firing of the area in the late nineteenth century. The eastern slopes of Black Birch Range are covered in mountain beech (*Nothofagus solandri* var. *cliffortioides*) and the western side of the range in red beech (*Nothofagus fusca*) (Elder, 1959).

Until the 1870s there were some 5 000 ha of thick mixed podocarp forest in the Puketitiri area north of Hawkstone. With clearing for farming and felling for timber production, which began at the turn of the century, this forest had almost disappeared by the 1930s. Local public interest in saving the remaining remnant of this forest resulted in the preservation of 36 ha of native forest north of Patoka. With an average density of 780 cubic m per hectare, the density of the timber in this block is as great as any in New Zealand. In 1945 this area was designated as Balls Clearing Scenic Reserve, named after Jack Ball who began farming in the district in 1890 and who built a hut to live in on the natural grassed clearing east of the reserve. The reserve now comprises 135 ha divided into four blocks - the main residual 36 ha forest block, two native regeneration areas to the north and east of the forest block, containing mainly *Dacrydium* seedlings and saplings, and a southern block of exotic and native plantings (Balls Clearing Scenic Reserve publicity pamphlet).

The podocarps in Balls Clearing consist mainly of a canopy of *Dacrydium* with some *P. taxifolia* and minor *P. ferruginea*; emergent *Dacrycarpus dacrydioides* is also very evident. Except along the openings afforded by walking tracks, the understorey is made up entirely of *Pseudopanax arboreum* (both mature and rejuvenating) and the tree fern *Cyathea dealbata* (silver fern). The ground cover is *Blechnum*, plus minor *Microlaena avenacea* (bush rice grass). In one part of the forest stand young *Nothofagus fusca* have established along an opening in the forest canopy afforded by the course of a meandering stream. Beneath the beech trees is a carpet of thriving *Carpodetus serratus* seedlings. *Carpodetus* was not seen elsewhere in the reserve.

In the open, along the fringes of the forest, lowland shrubs are thriving. Those identified were *Pseudopanax arboreum*, *Pseudowintera colorata* *Neopanax anomalum*, *Aristotelis serrata*, *Fuchsia excorticata*, *Melicytus lanceolatus*, and *Coprosma grandifolia*. Walking tracks within the forest are lined with introduced grasses, some *Microlaeno avenacea* (bush rice grass), abundant young *Myrsine* seedlings, and a small leaved *Coprosma*. To the northeast of the reserve is a mire which collects drainage off a nearby fan. Vegetation in the mire is very dense, consisting of manuka scrub, cabbage trees and introduced and native grasses.

4.5.3 RECENT SITE HISTORY

The first settlers arrived in the Puketitiri district in the 1850s. At that time vast areas east of the Black Birch Range were covered in a thick podocarp forest, this being a remnant of a much greater forest that had existed in pre-European times, and had subsequently suffered from repeated fires. The forest found by the first settlers stretched north to Hukanui, as far east as Dunmore, and west to the foothills of the Kaweka Range, and as far south as the Gorge Stream (Wright, 1985).

During the Maori wars of the 1860s part of the Armed Constabulary was stationed on what was later to become Hawkstone Station. In the late 1860s this land was taken up for sheep farming by Michael Edward Groome in conjunction with Murray Roberts Ltd. In the 1870s Groome sold 232 ha to James Hallett who already owned 2733 ha at nearby Puketitiri. Hallett eventually took over the whole of Hawkstone. Each year 7000 merino wethers were mustered and taken via the Iron Whare in the Kaweka Range to the Kiwi Saddle area where there was a good native grass cover and very little scrub.

Apart from being mustered for shearing, the sheep were left to fend for themselves for the year. In 1904 the property changed hands again. Hawkstone now totalled 2834 ha freehold and the sheep grazed were 7500 Romney Marsh and Lincoln cross-breds. By this time 200 head of cattle were also on the property (Macgregor, 1970).

The turn of the century saw the start of commercial milling in the Puketitiri district. The Puketitiri bush was one of the thickest in Hawkes Bay (Wright, 1985). By 1905 there were two mills in the area. The Hawkes Bay Timber Co. was cutting forest on settlers' freehold land. The annual output from this mill was 212.37 m^3 of *Dacrydium* and *P. taxifolia* for use both locally and in the housing trade in Napier and Palmerston North, as well as *Dacrycarpus dacrydioides* for export. At the same time John Holt's mill at Hukanui, to the west of Puketitiri was milling 1389.86 m^3 of timber annually. Again output was a mix of *Dacrydium* and *P. taxifolia* destined for the Napier housing trade, plus minor *Dacrydarpus dacrydioides*. By 1907 the bush at Hukanui was almost cut out and annual returns for Holt's mill were down to 1015 m^3. At the same time the Hawkes Bay Timber Co. had increased its annual footage to 1936.64 m^3 (Gazetted Reports to Parliament of Sawmilling in Hawkes Bay for 1905 and 1907).

The Hukanui forest was left in a cut over condition until the entire forest had been cut out. The land was then developed for farming by the mill then sold on. In 1928 a further mill was established in the Huchinson Reserve area on Hukanui Road, primarily milling *Dacrycarpus dacrydioides*, plus some *P. taxifolia*. Virtually no *Podocarpus totara* was milled at this site (Wright, 1985).

Meanwhile at the start of World War I the back part of the Puketitiri portion of Hawkstone (that basically cleared of forest) was given to the Hawkes Bay War Relief

Association. The remainder of the land was sold in 1918 to the Bell brothers, who began developing the property, first building the farm homestead, then subdividing the land into paddocks, laying down good access roads, and constructing three farm cottages and a six-stand woolshed with night pens for 900 sheep. Over the next thirty odd years Hawkstone was divided into several farms, which at times were run in conjunction with the main Hawkstone holding. By 1949 when the station was purchased by John Alexander it had been reduced to 1250 ha with a carrying capacity of only 1500 sheep. Topdressing and further land development increased the carrying capacity to 7500 sheep and the land had been subdivided into twenty-eight paddocks. By 1970 Hawkstone, now reduced to 905 ha, had been sold again and was carrying 540 sheep and 600 head of cattle (Macgregor, 1970). The property has since changed hands again and the current owners have developed the station as a dairy farm. Development has included the construction of two dairy sheds, one of which is situated immediately southeast of the mire cored for pollen analysis (Figure 4. 5. 4) (G.C. Syme pers. comm. 1997).

4.5.4 PALAEOECOLOGY

The results of the pollen analysis of the Hawkstone site are presented in Figures 4. 5. 5 and 4. 5. 6. The stratigraphy is presented separately in Figure 4. 5. 7 (p.195). A sample of organic silt from a depth of 3. 22 m was dated (Wk - 5028) at 6250 ± 390 yrs BP.

The pollen diagrams have been zoned using a subjective assessment in conjunction with a visual inspection of the diagrams and the CONISS dendrogram provided by the Tiliagraph programme. Four zones have been assigned, namely, Ha1, Ha2, Ha3 and Ha4. Ha is the code assigned to the Hawkstone site.

FIGURE 4. 5. 5 RELATIVE POLLEN DIAGRAM HAWKSTONE SITE

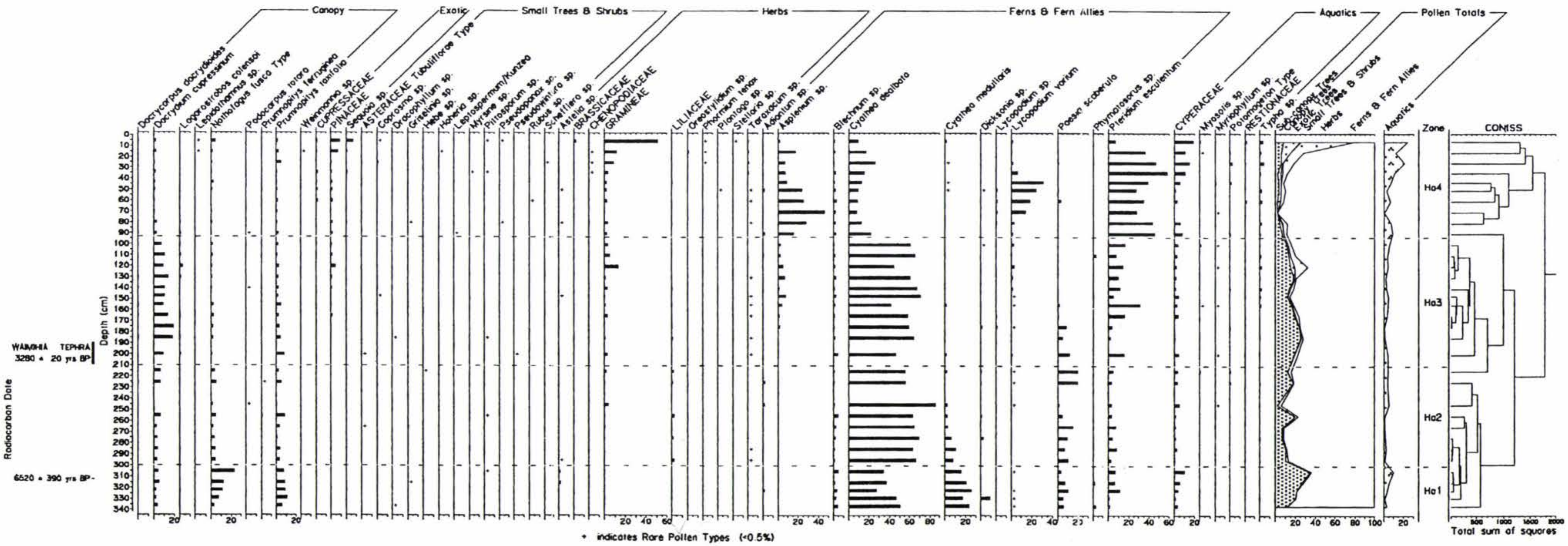
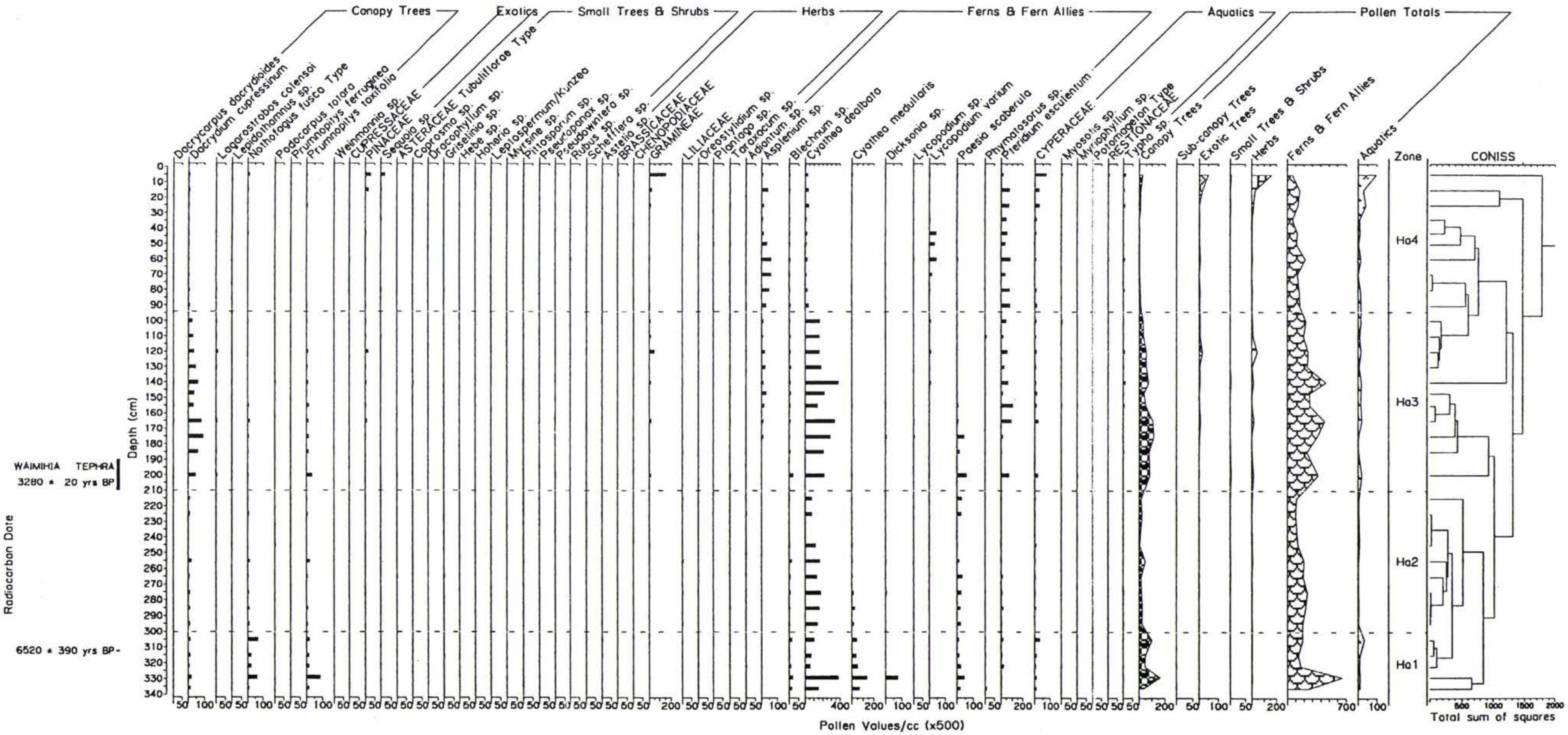


FIGURE 4. 5. 6 ABSOLUTE POLLEN DIAGRAM HAWKSTONE SITE



Zone Ha1 3.41 - 3.00 m

The terrestrial pollen in this zone is dominated by both *Nothofagus fusca* and a mixed podocarp assemblage made up of *Prumnopitys taxifolia* (matai) in conjunction with *Dacrydium cupressinum* (rimu). *P. taxifolia* dominates the base of the zone, but declines towards the top, while at the same time *Nothofagus* expands steadily to become the dominant forest taxon at the top of the zone.

Ferns dominate the understorey of the zone. Their presence increases in step with the increase in forest taxa to mid-zone where peat formation commenced. Ferns decline slightly above mid zone. The main tree fern is *Cyathea dealbata*, in conjunction with *C. medullaris* and minor *Dicksonia*. Ferns also form a conspicuous component of the ground cover around the site. *Paesia scaberula* (ring fern) in conjunction with *Blechnum* also has a minor but steady input throughout the zone. *Pteridium esculentum* (bracken) becomes important at mid-zone and maintains a steady presence to the top of the zone. Minor *Typha* (raupo) is also present in the zone.

Charcoal between 3.06 and 3.10 m depth indicates the site was affected by fire near the top of the zone. However, pollen percentages of primary forest taxa at 3.05 m depth indicate this fire had no immediate detrimental affect on the regional forest.

The overall high frequencies of the various fern spores throughout the zone indicate there was an abundant pteridophyte flora in the region of the site at the time. This tends to suggest that this site was an open, moderately disturbed, fern-covered area, with podocarp forest on the nearby hills. Moderate but increasing amounts of the reed Cyperaceae indicate there was an expanding swamp vegetation at the site.

Zone Ha2 3.00 - 2.10 m

The major change that defines this zone is that all pollen and spore counts are low at the base. This decline in the frequency of primary forest taxa suggests a recession of the forest following a major disturbance.

Nothofagus, *P. taxifolia* and *Dacrydium* all have a minor presence throughout the zone, and all three taxa increase by 2.55 m depth just below mid-zone. At mid zone charcoal in the stratigraphic column (2.50 m depth) indicates the site was again affected by a fire. Following the deposition of the mid-zone charcoal low pollen counts of primary forest taxa indicate that the forest in the region was very slow to reestablish. Nevertheless, at the top of the Ha2 zone forest taxa percentages indicate that a mixed podocarp forest was returning to the area and that *Dacrydium cupressinum* was replacing *Prumnopitys taxifolia* as the dominant podocarp in the region. *Nothofagus*, although slowly recovering, never attained its former importance.

As in the previous zone, *C. dealbata* continues to dominate the ground cover component of the flora, decreasing slightly above the charcoal layer. *C. medullaris* also has a minor presence up to the charcoal at 2.50 m depth, then declines. *Paesia scaberula* and *Pteridium* are present from the base of the zone; both decline immediately above the charcoal layer, then return towards the top of the zone. *Blechnum* also returns after the disturbance due to the deposition of the charcoal. Minor Cyperaceae and Liliaceae are present at the base of the zone. These species both maintain a small presence to the top of the zone.

Zone Ha3 2.10 - 0.93 m

The major division between this zone and the previous zone is where the percentage of pollen from primary forest taxa and tree fern spores increases rapidly. *Dacrydium* now dominates the forest taxa in association with minor *Prumnopitys taxifolia* , and *Nothofagus* maintains the slow recovery initiated in the previous zone. The tree fern *Cyathea dealbata* totally dominates the secondary forest taxa at the base of the zone. *Blechnum*, *Paesia scaberula* and grass counts remain as they were at the top of the previous zone, whilst *Pteridium* and Cyperaceae percentages fall sharply. *Typha* and *Potomageton* enter the record, followed immediately by *Myosotis*, then *Myriophyllum*. All four are intermittently present to the top of the zone indicating damper conditions than in the zone below.

The bottom of the zone is further defined by the deposition of a 0.2 m layer of volcanic ash and charcoal in a sandy silt matrix. At this point *Pteridium* and *Blechnum* percentages increase, native grasses, present as minor counts since the deposition of the mid-zone charcoal, increase slightly. However, there is no evidence the volcanic ash or a fire had any effect on the recovering podocarp forest in the Hawkstone region.

The presence of minor charcoal at 1.57 m depth indicates the area was again disturbed by fire. At the 1.55 m depth the recovering *P. taxifolia* and *Nothofagus* species receive a relatively major set back, while at the same time *Dacrydium* and tree ferns suffer a minor temporary set back but recover immediately. *Blechnum* percentages increase slightly, a further fern, *Asplenium*, enters the record, *Typha* returns to the record and together with *Lycopodium* maintains a steady notable presence to the top of the zone. *Pteridium* is temporarily present in high values in response to the disturbance. The evidence suggests the disruption to the flora was caused by the fire.

At the time indicated by the 1.20 m depth the presence of charcoal indicates a further fire disturbed the region. Again *Dacrydium* and tree ferns suffer a minor set back. Both recover slightly before the top of the zone but do not fully attain their previous importance. Both grasses and *Pteridium* which have very variable percentages within the zone, increase significantly following the fire, and percentages remain relatively high to the top of the zone. Cyperaceae maintains a steady minor presence throughout the entire zone.

Zone Ha4 0.93-0 m

The major change that defines this zone is a sudden increase in *Pteridium* percentages accompanied by equally sudden rises in *Blechnum* and Cyperaceae counts, while at the same time regional forest percentages and silver fern counts are greatly reduced. White pumiceous ash and charcoal in the stratigraphic column at the base of the zone indicates the disturbance to the flora in the Hawkstone region may be due to a volcanic eruption followed by a fire. Both the regional forest and the tree ferns never recover following this disturbance.

From the base of the zone up to 0.70 m depth charcoal in the stratigraphic column indicates the site was continually affected by fire. Both *Pteridium* and *Blechnum* percentages increase as a result. A minor concentration of charcoal at 0.70 m depth may indicate a more major fire in the area. In response to this disturbance *Pteridium* counts temporarily decrease while *Blechnum* counts further increase, as do *Lycopodium* percentages. Although the regional forest barely registers a presence, Cupressaceae (cedar) enters the record in a minor way. This taxon could include introduced *Cedrus*. Grasses and Cyperaceae are not recorded in the mire vegetation at this level.

At 0.43 m depth a further concentration of charcoal occurs indicating fire again affected the site. In response to this disturbance, *Pteridium* further increases in importance to dominate the site until the land was converted to pasture by European settlers in the twentieth century. *Blechnum* percentages remain stable. *Lycopodium* counts peak at the level of the fire, then decline quickly. Cyperacese increases dramatically in importance and counts remain high up to the present day. *Cyathea dealbata* regains some of its former importance, only to decline with land clearance for farming.

At the top of the zone, which corresponds to post-1880s, introduced pasture taxa dominate the pollen record in conjunction with minor *Pteridium* and tree ferns. The pollen record indicates that a *Nothofagus* forest is again establishing in the region. Introduced *Pinus radiata* forest is well established in the area as well. Grasses, reeds, bulrushes, plus some sedges (Restionaceae) dominate the vegetation in the mire.

4.5.5. DISCUSSION

Sediments at the Hawkstone site are basically organic rich sandy silts. Volcanic ash and fine lapilli are present in one discrete layer between 1.90 and 2.10 m depth, and at times scattered throughout the stratigraphic column. Charcoal is present in conjunction with the volcanic ash deposits, as discrete layers and at times is scattered throughout the column. Charcoal counts were not done for any of the depths subsampled. There were two basic reasons for this. First, the sediments were of an extremely eutrophic nature, and thus the pollen subsamples did not cleanup well when processed for pollen analysis. It was felt the excessive organic content remaining after processing would both mask, and make difficult to identify, all charcoal present at any one depth. The second reason was that, as with previous sites in this study, the core was subsampled at 10 cm intervals unless core breaks in the recovered sections dictated otherwise. Due to wet site conditions sediment recovery was generally poor. After pollen subsampling was completed, a more complete stratigraphic description was carried out on the core which involved probing and handling the remaining material. It was found that several sections of the core contained extensive charcoal, some of which had been subsampled, some not. As the material had been handled, contamination became a factor. This coupled with poor recovery rate due to alternating wet/dry and eutrophic conditions, meant further subsampling was not an option. Thus as many of the more charcoal rich levels had not been subsampled, it was felt that any charcoal count done of those that were, would give a false picture of the true overall fire history of the site and it was decided not to do any charcoal counts.

The base of the site is a fine sand similar to the fine sandstone exposed in the Mohaka Fault scarp in the Hawkstone area. A sample of the organic rich sandy silt above the fine sandstone, at 3.22 m depth, returned a radiocarbon date (Wk - 5028) of 6250 ± 390 yrs BP. This marks the beginning of peat accumulation at the site.

The radiocarbon date indicates that there is a *c*. 6750 year pollen record at the Hawkstone site. The stratigraphy of the core does not indicate any major depositional breaks during this time. For this reason it is assumed sediment accumulation has been relatively constant at the site. However, as discussed below, based on tephrochronology at the site the accumulation rate has varied over time.

The Taupo eruption of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990) is assigned to 0.93 m depth, based on a slight change in sediment texture, together with scattered, coarse, white, soft pumiceous ash in the stratigraphic column above this depth. Again based on stratigraphic position, description and size of the deposit, the 0.2 m white lapilli layer in a sandy silt matrix found between 1.90 and 2.10 m depth is assigned to the Waimihia Lapilli deposited around 3280 ± 20 yrs BP. (Froggatt & Lowe, 1990).

Using the radiocarbon date for the site and known tephrochronology of volcanic ash deposits in western Hawkes Bay the following sediment accumulation rates have been estimated.

- Between 3.22 and 2.10 m depth an accumulation rate of 0.39 mm/yr. is calculated. This rate is based on the radiocarbon date of 6250 ± 390 yrs BP. at 3.22 m depth and the date of the Waimihia Tephra which first appears at 2.10 m depth.
- The 0.2 m of sediment between 2.10 and 1.90 m depth has been excluded from the sediment accumulation calculations on the grounds that it was a hard compacted layer of Waimihia lapilli in a sandy silt matrix that could only be sampled by auger. This compactness contrasts with the soft sediments both above and below this layer, which were easily penetrated by the Hiller borer. The compact nature of the sediment, together with the sandy silt matrix and a minor organic content indicate this 0.2 m was deposited in a relatively short time span as reworked Waimihia lapilli and sediment dragged off the higher ground surrounding of the site. As such, the pollen from the sample at 2.00 m depth could also be reworked grains. Many of the grains at this depth are broken and corroded. This also suggests they may be reworked grains.
- Between 1.90 and 0.93 m depth an accumulation rate of 0.68 mm/yr. is calculated. This is based on the dates for the Waimihia Tephra and the Taupo Tephra (1850 ± 10 yrs BP. (Froggatt & Lowe, 1990)).
- Between 0.93 m depth and the top of the column an accumulation rate of 0.49 mm/yr. is calculated. This rate is based on the first appearance of the Taupo Tephra at 0.93 m depth and 1997 AD. as the date for the top of the column.

A stratigraphic description of the site is presented in Figure 4. 5. 7. The above tephrochronology has been added to the interpretive stratigraphic data presented in Figure 4. 5. 8.

Based on the accumulation rate below the Waimihia Tephra of 0.39 mm/yr. the site began accumulating sediment and pollen about 6750 years ago. The pollen record at Hawkstone (Figure 4. 5. 5) indicates that about 6750 years ago the primary forest in the region was a mixed podocarp forest consisting of mainly *Prumnopitys taxifolia* in conjunction with *Dacrydium* . The radiocarbon date indicates that peat also began forming at the site about 6250 years ago. At this time *Nothofagus* was becoming an increasingly important component of the primary forest. The regional forest remained stable until after a fire, identified by the deposition of charcoal at the site between 3.06 and 3.10 m depth. The sediment accumulation rate of 0.39 mm/yr. calculated for this part of the core, indicates this fire occurred about 5932 yrs BP. The pollen record indicates all primary forest taxa declined following this fire. Recovery was slow, with *Dacrydium* recovering faster than *P. taxifolia*. A second fire, indicated by the deposition of a further charcoal concentration at 2.50 m depth, (4341 yrs BP.) resulted in another temporary decline in the regional forest. After this decline a more vigorous *Dacrydium* dominant podocarp forest returned to the region. At the same time *Nothofagus* was more slow to recover from the set back. These dates have been added to Figure 4. 5. 8, which represents an interpretation of the stratigraphy of the site, together with the raw pollen counts of species indicative of specific ecological environments.

HAWKSTONE SITE

	m		
	0	C1	Reddish brown (2.5YR 3/1) organic rich sandy silt; structureless; gradual boundary.
	0.35	C2	Black (7.5 YR 2.5/1) organic rich silt; some very coarse, white, pumiceous ash throughout; charcoal throughout, with a minor concentration at 0.43 m, and below 0.70 m to lower boundary; gradual lower boundary over 50 mm.
	0.93	C3	Reddish black (7.5 R 2.5/1) organic rich sandy silt; some coarse organic content < 1.5 mm; charcoal at 0.93 - 0.95 m; gradual boundary.
	1.08	C4	Black (2.5 Y 2.5/1) sandy silt; some fine roots; some very fine white pumiceous ash scattered throughout; minor charcoal at 1.20 m and 1.57 m; very fine lapilli (3 mm) and pumiceous ash increasing down profile below 1.65 m; distinct lower boundary.
	1.90	2C	Black (2.5 Y 2.5/1) lapilli (3 mm) layer in a sandy silt matrix; volcanic ash and charcoal rich; some organic content; distinct lower boundary.
	2.10	3C 1	Brownish black (7.5 YR 3/1) organic rich sandy silt; sand content and organic content decreasing down profile; some charcoal content, decreasing down profile; charcoal layer at 2.50 m; charcoal content minor below 2.50 m; gradual lower boundary over 20 mm.
	2.78	3C2	Brownish black (2.5 Y 3/1) medium sandy silt, organic rich above 3.22 m; charcoal layer at 3.10 m. wood (6mm) at 3.10 m; at 3.15 m sand content increasing and silt content decreasing; organic content minor below 3.22 m; gradual indistinct lower boundary as sediment grades into fine sandstone below.
14C date 6250 ± 390 - yrs BP.	3.22		
	3.40	R	Light yellowish brown (2.5 Y 6/3) fine sand, similar to the fine sandstone in the Mohaka Fault scarp in the Hawkstone area.
	3.41		Base of site

Figure 4. 5. 7 Stratigraphic column. Top metre cored with a D corer; below 1 metre cored with a Hiller corer; lapilli layer (1.90 -2.10 m) sampled by auger; below 2.10 m cored with a Hiller corer.

Interpretive Stratigraphic Data based on sediment accumulation rates & pollen information	Depth sampled (m)	Regional Forest: Beech	Rimu	Matai	Cedar	Exotics: Pine Sequoia	Regional Groundcover: Grass	Bracken	Silver fern	Site Vegetation: Cyperaceae	Lycopodium	Asplenium Blechnum	Raupo
Pastoral farming/reafforestation	0.05	12	6	4	2	45	148	19	26	71		7	12
	0.15	6	8	8	2	33	45	147	69	47		77	6
	0.25	3	3	16			29	165	92	65	3	26	18
Charcoal rich since Taupo Tephra	0.35	1	4	1	3		9	154	39	30	4	24	2
? Fire in area	0.43	5	2	1	1		4	80	26	12	64	20	2
	0.50	2	3	2	2		4	61	20	3	54	60	4
	0.60		2	3	3		6	82	20	7	45	66	6
Fires in area since Taupo Tephra	0.70	1	2	2				63	17		33	107	1
	0.80	3	7	2			10	128	35	19	9	87	6
Taupo Tephra 1850 yrs BP --->	0.90	1	8	7			8	152	73	28		65	2
	1.00	4	20	4			9	44	167	10	7	8	1
	1.10	3	27	2			13	19	171	7	1	10	3
Fire in area - c 2248 yrs BP	1.20	2	24	7			34	38	117	6	8	16	5
?Mapara Tephra	1.30	2	40	5			2	26	169	5		24	1
	1.40	1	26	5			7	28	173	3	4	5	4
At 1.57 m Fire in area - c. 2794	1.47		28	4			1	12	191	11	1	27	2
yrs BP. ?Mangatawai Tephra	1.55	7	26	13			3	92	122	8	2	15	4
Reworked lapilli up to this level	1.65	6	37	6			8	43	161	10	1	5	
	1.75	5	56	9				9	174	1	4	5	
Site affected by ash & fire -	1.85	14	43	31			9	13	510	5		12	2
Waimihia Eruption 3280 yrs BP	2.00	2	28	12			9	47	142	13		13	
(1.90 - 2.10 m)	2.15	10	17	6			5	13	154	8	1	2	
	2.25	15	20	15			1	8	174	9		1	1
Fire in area - c. 4341 yrs BP	2.45	3		1			9	7	213	13		2	
?Hinemaiaia Tephra	2.55	12	16	21			1	7	165	3		12	
	2.65	5	7	9			2	20	191	4		7	
	2.75	8	7	2				9	168	3		4	1
	2.85	12	10	11				23	194	8		3	
Fire in area - c. 5932 yrs BP	2.95	11	8	8				6	175	2		2	1
?Motutere Tephra	3.05	86	15	26			1	24	127	41	3	16	
	3.15	36	15	25				17	110	17		4	
14C date 6250 ± 390 yrs BP -->	3.22	36	6	27				35	88	11		10	
(Start of peat formation)	3.29	22	6	30			1	2	135	3		6	1
	3.36	11	13	21				5	201	13		17	
Base of site	3.41												

* 1 cc sampled at each depth
* 200 dryland taxa counted at each depth or four slides scanned where dryland taxa did not accumulate

Figure 4.5.8 Interpretive stratigraphy of the Hawkstone site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995)

It is possible the two fires discussed above are related to the deposition of volcanic ash at the site. Taking into account the large eror of ± 390 years inherent in the dates calculated for these fires, the fire recorded at 3.06 - 3.10 m depth (5932 ± 390 yrs BP.) may be related to the deposition of the Motutere Eruption (5430 yrs BP. (Froggatt & Lowe, 1990)), and the fire at 2.50 m depth (4341 ± 390 yrs BP.) may be related to the Hinemaiaia Eruption (4500 yrs BP. (Froggatt & Lowe, 1990)). However, it is postulated here that these two tephras, although sourced in the nearby Taupo Volcanic Centre to the north-west, would have fallen cold in the Hawkstone area, if at all, and as a consequence, no fire would have ensued. For this reason, plus the fact that there is no evidence of volcanic ash in the stratigraphy at the appropriate depths, these two fires are attributed to lightning strike of non-volcanic origin.

Deposition of the Waimihia Lapilli, which was accompanied by fire in the Hawkstone area, appears, surprisingly, to have had no detrimental affect on the regional forest. Initially all primary forest taxa, especially *Dacrydium cupressinum*, thrived, perhaps benefitting from increased soil fertility following the deposition of the ash, but it is more likely preexisting conditions were the major determinant. However, the 0.2 m deposit is much greater than known thickness of the airfall material in the Hawkstone area. Given the coarseness of this sediment it is likely the pollen recorded in the subsample at 2.00 m depth (from within the deposit) has filtered down from above, or been eroded in from the sides of the mire as the deposit formed.

Two fires in the Hawkstone region between the deposition of the Waimihia Lapilli and the Taupo Tephra are recorded at the site. Both resulted in a temporary decline in primary forest cover. One fire is indicated by a concentration of charcoal at 1.57 m depth and the other by a concentration of charcoal at 1.20 m depth. Based on the sediment accumulation rate of 0.68 mm/yr. calculated for this part of the core, the fire at 1.57 m depth is dated at *c.* 2800 yrs BP. and the fire at 1.20 m depth is dated at *c*. 2250 yrs BP. These dates have been added to Figure 4. 5. 8.

It is possible these two fires may have been associated with volcanic ash showers from the Taupo Volcanic Zone. The fire at 1.57 m depth may be related to the Mangatawai Tephra dated 2500 ± 200 yrs BP. (Fergusson & Rafter, 1959), which is an andesitic tephra sourced from the Tongariro Volcanic Centre, principally from Mt Ngauruhoe. Another possibility is the Whakaipo Tephra dated 2700 yrs BP. (Froggatt & Lowe, 1990) sourced from the Taupo Volcanic Centre. The fire at 1.20 m depth may be related to the Mapara Tephra dated 2160 ± 25 yrs BP. (Froggatt & Lowe, 1990) sourced from the Taupo Volcanic Centre. However, as all these ash showers would have fallen cold in the Hawkstone area, if at all, plus the fact that there is no evidence of volcanic ash in the stratigraphy at the appropriate depths to support such a hypothesis, it is considered these fires were due to lightning strike of a non-volcanic nature.

Deposition of Taupo ash and lapilli about 1850 yrs BP. (0.93 m depth) resulted in almost total elimination of the beech forest from the pollen record. At the same time the podocarp forest also received a major setback. Charcoal and coarse, white pumiceous ash are present continually in the stratigraphy from 0.93 to 0.35 m depth. A concentration of charcoal from 0.93 to 0.70 m depth indicates the site was more intensely subjected to fire during the time covered by this 0.23 m of sediment deposition following deposition of the Taupo Tephra. The accumulation rate of 0.49 mm/yr estimated for this section of the core dates the 0.70 m depth at 1380 yrs BP. Thus the charcoal evidence indicates the site was continually subject to fire for 470 years from the time of the Taupo Tephra up to 1380 yrs BP., and to more sporadic fires from 1380 to 666 yrs BP. (0.35 m depth). The pumiceous ash is interpreted as reworked Taupo Tephra.

Wilmshurst and McGlone (1996) report outbreaks of fire occurred in the central North Island for at least 100 years after the Taupo eruption. The post-Taupo eruption fire history at Hawkstone is in agreement with these findings, with the highly combustible fronds and leaf litter of *Pteridium* fernland providing fuel for small frequent fires localised at the site to persist for centuries after the Taupo eruption.

Recovery of a regional podocarp forest only commenced at the time encapsulated in the 0.25 m depth. At this point *P. taxifolia* starts to establish and by the 0.15 m depth *Dacrydium* is establishing with *P. taxifolia* slightly constrained. Based on the accumulation rate, this places the 0.25 m depth at about 463 ± 10 yrs BP. (1487 AD.) and the 0.15 m depth at about 259 ± 10 yrs BP. (1691 AD.). There is no charcoal at the site at these depths. Possible explanations for forest recovery at these depths will be discussed further below.

Secondary forest taxa which favour open sites in low forest or shrubland are poorly represented at all depths in the Hawkstone pollen record. This may be due to the overwhelming presence of, first, tree ferns, then tree ferns in conjunction with *Pteridium* and grasses near the site. As the presence of charcoal fragments throughout much of the stratigraphic column indicates, fire was frequent throughout the 6750 year history of the site. For this reason a fire-induced seral vegetation in the form of the *Pteridium* and grasses in conjunction with minor *Taraxacum*, together with the tree ferns and a monolete fern ground cover appears to have been prevalent. The over-representation of a seral flora in the pollen spectra suggests the area around the site was always clear of primary forest, with the site acting primarily as a trap for the seral vegetation around the edges of the mire.

It is likely the source for the *Nothofagus fusca* recorded at the site was the nearby Black Birch Range, to the northwest of Hawkstone, where a stand of this species is well established today. The source of the podocarp species was undoubtedly the surrounding hill country of the Puketitiri region to the immediate north and west of the Hawkstone site. As noted above, the timber footage in this stand of forest at the beginning of the twentieth century was among the greatest recorded in New Zealand. That being so, the low pollen percentages of primary forest taxa recorded at the top of the core supports the proposal that the site was not acting primarily as a trap for regional forest pollen.

A more likely scenario is that the site has always acted as a trap for pollen from scattered islands of forest amongst a fire induced *Pteridium* and *Leptospermum* scrubland in the broken country to the west of the site. The poor dispersal habit of *Leptospermum* would account for this species not being well represented in the record here. Colenso (1880) records seeing *Pteridium* fernland with subalpine scrub and open ground on the more exposed ridges in the Blowhard area during his travels. According to Elder (1959) the Blowhard soils indicate that tussock grass or scrub has been the dominant cover there over a long period.

As mentioned above early station diaries mention several islands of podocarps west of the Hawkstone area, which were utilised or perhaps burnt at an early date. The locations of these islands, which where mainly reported as matai, are now lost. At the present day the most common species are Halls totara and *Dacrydium*, with occasionally *P. taxifolia* and *Dacrycarpus dacrydioides* . *Nestegis* occurs in association with some of the stands. *Nothofagus solandri* var. *cliffortioides* is generally dominant in the remaining smaller islands of forest, well below its usual altitudinal range, but some *Nothofagus fusca* is frequently present (Elder, 1959).

Elder's description of the present day flora in the region west of Hawkstone as a successional forest establishing in isolated stands following fire-induced scrub is consistent with the history of the Hawkstone site. The evidence of an historical fire over a considerable proportion of the Blowhard area in 1946 also supports this scenario. Following this fire the dominance of *Pteridium* even where it had been suppressed previously by *Leptospermum* was total. Ten years later this fern ally still tended to dominate the Blowhard, although *Leptospermum* could be seen emerging through it (Elder, 1959).

Although a low sediment accumulation rate has also resulted in an extremely small real time resolution at the site, some tentative correlation may be possible at the top of the record between the evidence for forest destruction and regeneration in the Hawkstone area, and Grant's hypothesis of climate-forced forest destruction (Grant, 1995).

The date of 1487 AD. calculated for the 0.25 m depth although very tenuous, given the extremely low resolution inherent in the small accumulation rate this date is based on, does corresponds with Grant's cool Sporer Minimum when forests were reestablishing following the gales and fires of the Waihirere Erosional Period. In Figure 4. 5. 8 pollen percentages for *P. taxifolia*, the recognised main podocarp species in the Blowhard region at the time of European settlement, certainly indicate this taxon was reestablishing in the region at the time indicated by this depth. *Cyathea dealbata* cover is also increasing in the area, as are grass percentages. At the same time *Pteridium* counts reach their highest level in the 6500 year history of the site. This evidence does not refute Grant's hypothesis of a more tranquil interval of decreased rainstorm activity and resultant decreased slope erosion between 1400 and 1500 AD. But neither does it support his hypothesis.

However, while there is no evidence at the Hawkstone site that questions or disproves Grant's argument concerning his erosional periods, it is felt that the resolution at the site, within the time frame of Grant's hypothesis, is too minimal to reach any valid conclusions either way.

The presence of minor amounts of *Pinus radiata* as low as 1.70 m depth and more so at at 1.20 m depth, presents a problem. Given the very overgrown nature of the mire, and field conditions that were far from ideal, both for coring and retrieval of the core sample (see Figure 4. 5. 6), together with the, at times, water saturated nature of the segments being retrieved, it is believed contamination was a distinct possibility.

Pinus radiata is notorious for its ubiquitous habit. Thus the presence of minor amounts of this pollen grain as low down in the core as 20 cm above the 20 cm deposit of Waimihia Tephra (1.90 - 210 m depth) has been attributed to contamination during core retrival and transfer of the segments to core boxes for transport, at the site.

With regard to whether or not there is evidence in the record at the Hawkstone site of any earthquake-induced erosional events (Neall & Hanson's hypothesis), these writers report that a charcoal fragment from within colluvium in a trench dug on Hawkstone

Station retuned a date (NZA 4557) of 8770 ± 120 yrs BP. The Neall and Hanson trench was excavated across the Mohaka Fault trace about 200 metres from the mire that was sampled for this study. At the base of their trench is the Karapiti Tephra dated at c. 10100 yrs BP. (Wilson, 1994). Immediately above this tephra is a paleosol containing the Mangamate Tephra (c. 10000 yrs BP., Donoghue et al., 1991) in the base. There is a sandy clay unit to the east of the paleosol. Overlying both the paleosol and the sandy clay unit is a colluvial layer with the 8770 ± 120 yrs BP. date. Overlying the paleosol to the west is a a peaty loam containing the Waimihia Tephra dated at 3280 ± 20 yrs BP. (Froggatt & Lowe, 1990). Towards the top of the peaty loam is the Taupo Tephra dated at 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990).

Neall & Hanson (1995) believe an earthquake or earthquakes prior to 10 100 yrs BP. (the date for the Karapiti Tephra (Wilson, 1994) changed the throw of the Mohaka Fault from west to east (the Fault is currently upthrown to the east throughout the entire study area) and caused ponding of drainage and sediment accumulation to the west of the fault. A second earthquake occurred around 8770 ± 120 yrs BP. , and as a result colluvium containing the dated charcoal fragment fell into the trench. Due to continuing ponded drainage, peat then began accumulating. At about 0.60 m from the base of the peat the Waimihia Tephra was then deposited. Peat accumulation resumed and includes the Taupo Tephra of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990). Peat accumulation then subsequently ceased. A third earthquake disturbed both the Waimihia and Taupo Tephras in the trench.

The sediment at the base of the mire cored for this study is a light yellowish brown fine sand similar to the unconsolidated sandstone found below the topsoil in the nearby Mohaka Fault scarp. That makes the date of (WK - 5028) 6250 ± 390 yrs BP. towards the base of the peat, the time when peat began accumulating at the site. Therefore it is accepted that the earthquake event recorded in the Hawkstone trench of Neall & Hanson, which resulted in ponded drainage and peat formation in the trench, was also responsible for the ponded drainage at the mire site which led to the onset of the formation of peat.

The 0.20 m of the Waimihia Lapilli in the mire was relatively compact layer. However, the Taupo Tephra as a discrete layer was not encountered. It is only recorded as very coarse white soft pumiceous ash scattered throughout the column from 0.93 m up to 0.35 m. depth At the change in lithology at 0.35 m depth there is no evidence of any charcoal, so it is concluded there was no fire in the immediate area at the time. That being so, it is possible, given the structureless nature of the sediment, that it is a deposit of colluvium introduced into the site as a result of an undated, post-1850 yrs BP. earthquake recorded in the Neall & Hanson trench. The accumulation rate of 0.49 mm/yr would place this earthquake event at around 1284 AD. (666 ± 10 yrs BP.).

This date is perhaps too far removed from the 805 ± 58 yrs BP. that Neall & Hanson (1995) obtained from a wood sample between a sandy silt loam and a gravel unit in their McCool Farm trench, which is interpreted as representing an earthquake event. However, the date is closer to the *c.* 770 ± 60 yrs BP. date for an erosional event that Hubbard and Neall (1980) obtained in the West Tamaki Catchment of the central Ruhine Range. As this date is also believed to represent an earthquake event, it is not to be discounted that the earthquake that Neall & Hanson have identified as occurring along the Hawkstone segment of the Mohaka Fault, after the Taupo Eruption that disturbed both the Taupo and the Waimihia Tephras at Hawkstone, was part of, or close in time to, movements farther south along the Mohaka Fault, that have been discussed previously.

Based on the above interpretations the following sedimentological and fire history of the Hawkstone site is proposed (the dates at 3.20 m 3.05 m and 2.50 m depths all have the ± 390 years error

- Close to 8770 yrs BP. an earthquake event blocked the drainage at the site.
- About 6750 yrs BP. a topographical depression had formed at the site, and sediment began accumulating.

- By about 6250 yrs BP. (3.20 m) The site was wet due to ponded drainage, and peat began forming.

- At about 5925 yrs BP. (3.05 m) fire, due to lightning strike, occurred at the site.

- At about 4350 yrs BP. (2.50 m) a natural fire again occurred at the site.

- At 3280 ± 20 yrs BP. (1.90 - 2.10 m) a 0.20 m layer of volcanic ash and lapilli, identified as the Waimihia Lapilli was deposited, and the site was affected by ash and fire of volcanic origin, but probably due to lightning strike.

- At about 2800 yrs BP. (1.57 m) the site was again disturbed by fire.

- At about 2250 yrs BP. (1.20 m) the site was again disturbed by fire.

- At 1850 ± 10 yrs BP. (0.93 m) the site was affected by the Taupo Tephra and the site was disturbed by fire of volcanic origin.

- From 1850 to 1400 yrs BP. (0.93 -0.70 m) the site was continually disturbed by minor fires that prevented the forest returning to the area.

- At about 830 yrs BP. (0.43 m) the site was again disturbed by a major fire.

- At about 650 yrs BP. (0.35 m) the site was disturbed by an erosional event (possibly due to an earthquake dated 666 ± 10 yrs BP) and sandy silt began accumulating.

- At about 450 yrs BP. - (0.25 m) a *Prumnopitys taxifolia* dominated forest began returning to the area.

- At about 250yrs BP. - (0.15 m) A mixed pococarp forest was establishing in the area. Balls Clearing Scenic Reserve at Puketitiri (see Frontispiece) is a remnant of this forest.

By linking the palynological record extracted from 10 cm subsampling of the Hawkstone site to the sedimentological record of the site, underpinning the data with a radiocarbon date at the base, and evidence of known tephras in the Hawkstone area, it is concluded that fire has been the main factor influencing both regional forest expansion and regression, and on site changes in flora, throughout the 6750 year history of the Hawkstone site. These fires have been caused by both lightning strike due to volcanic activity sourced in the Taupo Volcanic Zone, and storm induced lightning strike The site formed following an earthquake event. There is no evidence of the site being further affected by an earthquake until after the Taupo Tephra was deposited at the site. The possible date for the second earthquake is about 666 ± 10 yrs BP. There is no charcoal recorded at the site later than this date. This tends to indicate there is no record of early Polynesian burning at the site.

TE POHUE SITE

4.6. INTRODUCTION

The Te Pohue site is the lake at Te Pohue, 60 km northwest of Napier (V20/280 107). Access is by means of State Highway 5 (Napier-Taupo Road). The lake appears to have formed by damming of the old Mangaone River headwaters by a landslide derived from the nearby Te Waka Range, directly west of Te Pohue village (R. Black pers. comm.) . At the southwestern end of the lake State Highway 5 is built across the toe of this slide.

The lake has formed in a topographical depression. Drainage seeps naturally to the east through coarse, sandy Tertiary strata. There is a distinct strand surface around the lake about 0.5 m above the current lake level. Mr Hughes, who owns and farms the land around the lake, lowered the lake level by diverting water underneath State Highway 5 where it drains into the nearby Kings Stream to the west. This has resulted in the formation of a boggy area at the southwestern end of the lake, where Mr Hughes' cattle gain access to the lake water.

Northeast of the lake just above the level of the strand surface, there is a small artificial pond which follows the natural contours of the topography, apart from where it abuts onto the strand. At this point an artificial dam has been constructed. The water in this pond is stagnant and rich in algae, *Typha* (raupo) and water weeds.

Rainfall in the Te Pohue district increases northward from 1390 mm/yr at Glengarry in the south (Anon., 1973), to 1600 mm/ yr at Rukamoana, and 2000 mm/yr along the Te Waka Range and at the Titiokura summit (Parsons, 1997). The soils in the area are Pumice Soils (Hewitt, 1992), formed on a 10 to 15 cm layer of ash and pumice from the Taupo eruption 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990).

Figure 4. 6. 1 is a sketch of the Te Pohue region. It shows the lake in relation to the Te Waka Range in the west with Kings Stream along the foot of the range, the village at Te Pohue, State Highway 50, Pohui and Ohurakura Bush, the Maungaharuru Range, Northlands, and the artificial pond to the east of the lake, mentioned in the text.

Two cores were extracted from the centre of the lake using a Livingstone Piston Corer. One core, taken from the deepest part (water depth 5 m) was used for pollen analysis. The second core obtained about 5 m from the first (water depth 4.5 m) was used as a control on the stratigraphy of the site. Both cores were about 3 m long. Coring stopped in each case because pumice from the Taupo Ignimbrite (1850 ± 10 yrs BP. (Froggatt & Lowe, 1990) blocked the piston corer. In both cores several reworked layers of the ignimbrite are visible in the lowermost metre of the sediment.

4. 6. 1 GEOLOGY & GEOMORPHOLOGY

In the greater Te Pohue district the main sediments are outcrops of conglomerates, limestones and fossiliferous mudstone over basal greywacke. These sediments form lagoonal and shallow marine sediments of Tongaporutuan-Kapitean age (2-4 m. yrs BP.) (Beu, 1995). Exposed at Te Waka Trig, directly northwest of the lake, is a 50 m thick

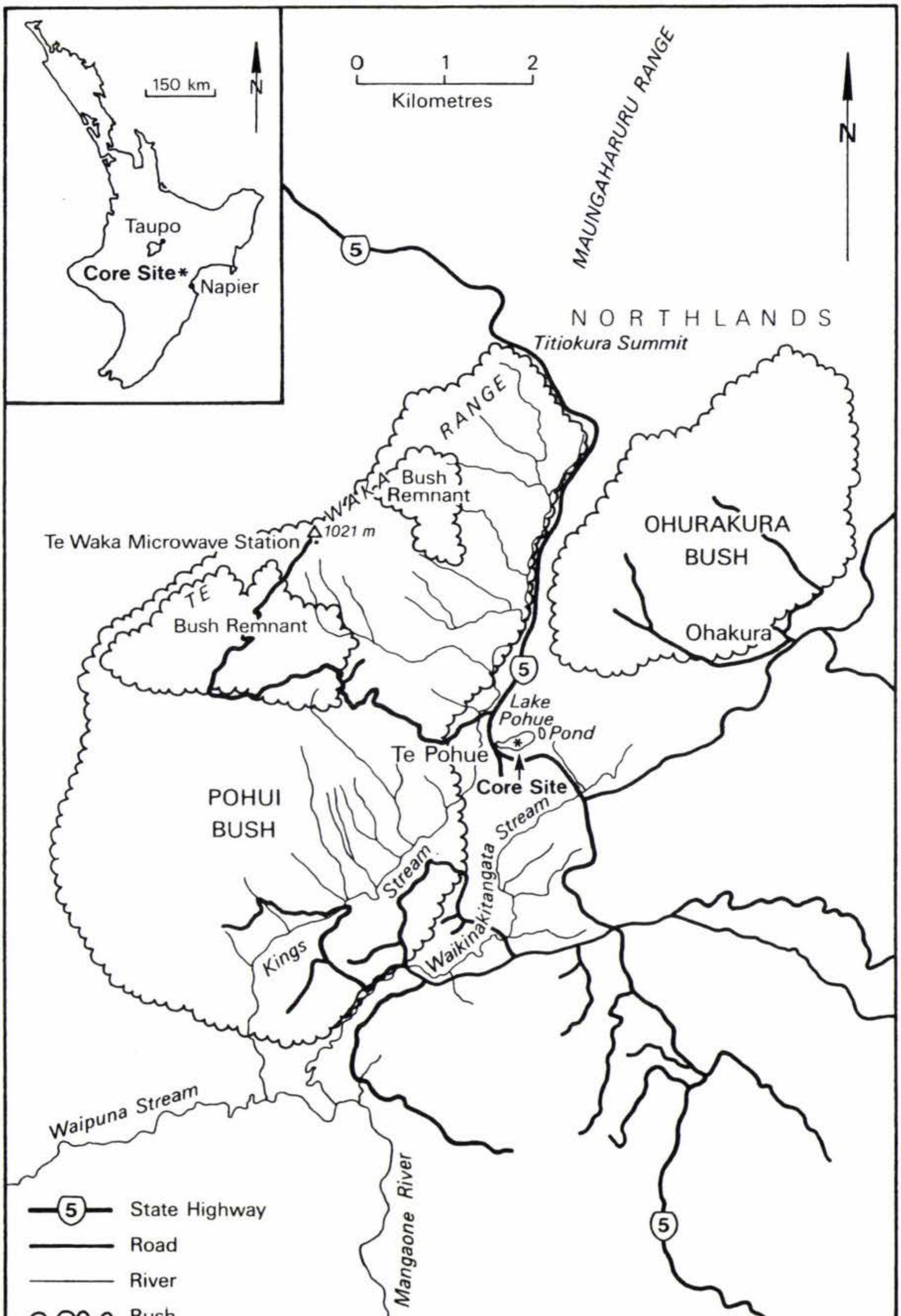


Figure 4. 6.1. Map of the Te Pohue region showing the lake site cored and its proximity to the original Pohui and Ohurakura bush stand, and their present-day remnants

thin-bedded flaggy limestone. This limestone is overlain by a c. 30 m brown weathered, sandy mudstone which passes up into 50 m of more massive, fine-grained yellow calcarenite which forms the high bluffs to the south of Te Pohue village. Together these three units form the Te Waka Limestone, of Kapitean age (Beu, 1995).

The northwestern perimeter of the lake is a steep, smoothly contoured hill consisting of unconsolidated yellow-brown, slightly shelly, muddy, fine, sandstone. To the southwest of the lake, State Highway 50 cuts through a topographical high consisting of a poorly bedded, fine grained, brownish-yellow calcarenite. The sediments exposed on both sides of the lake appear to correlate with the lowermost unit of the Te Waka Limestone. The present day landscape in the Te Pohue district is generally hummocky and broken in nature. Air photographs and visual inspection of the area to the north and west indicates strike/slip movement along the Te Waka Fault, a splinter of the Mohaka Fault, is responsible for rupturing the original continuous shallow marine sediments in the region.

Neotectonics, coupled with landsliding on tilted slippery mudstone bedding planes, explain the geomorphology of the region. As a result of faulting and erosion, uplifted greywacke crops out west of the Mohaka River to the northwest. At Te Pohue, large limestone and sandstone blocks from the crest of Te Waka Range have slid on the underlying mudstone to dam the Mangaone River flowing southward below the Range. Another landslide, one of the many that have temporarily blocked the Mohaka River within the last 40 000 years, slid off the Maungaharuru Range, north of Te Pohue, diverting the river into its present course. Based on the tephra cover on both the above landslides, these events are considered to have occurred between 5000 and 6500 years ago. (Black *in* Parsons, 1997). A further massive slide has scoured out a huge amphitheatre on the eastern side of Titiokura Saddle, flowing towards the Ohurakura Road area to the east.

There is ample evidence that landsliding is an ongoing geological process in the district. One example of this is a distinct hummocky surface in the Northlands area (Figure 4. 6. 1), where conglomerate has slid on mudstone. Pumice from the Taupo Tephra of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990) is evident near the surface of the slide, but no Waimihia Lapilli (3280 ± 20 yrs BP.) (Froggatt & Lowe, 1990), is present within the cover beds. This indicates the event occurred between these two eruptions (Black *in* Parsons, 1997). There is also a large debris fall off the limestone of Te Waka Ridge above the lake which also has no Waimihia Lapilli present within its coverbeds. The debris fall does however, have a distinct 3 cm layer of Taupo Pumice spread uniformly over the fall deposit about 20 cm below the surface (Figures 4. 6. 3 and 4. 6. 4). It is possible, therefore, the Northlands slide identified by Black, and the rockfall above the lake at Te Pohue, are coeval.

Figure 4. 6. 2 is a general view of the lake at Te Pohue looking northeast with the moored raft directly above the core site in the middle distance. The scrub cover evident on the surrounding hills was absent in 1915 when a photograph of the lake (Parsons, 1997) showed the area was in introduced pasture. Limestone boulders off the nearby Te Waka limestone ridge are common on the lake bottom and imbedded within the lake sediments near the western edge of the lake. One of these boulders features in the foreground of Figure 4. 6. 2. Figure 4. 6. 3 is of the overflow point at the western end of the lake. In the middle background is the scar of a massive landslide of pre-Waimihia Tephra age, which came off the Te Waka Ridge behind. This was the slide believed responsible for blocking the ancient course of the Mangaone River. In the background

Figure 4. 6. 2 Lake at Te Pohue. The moored raft in the centre right of the figure marks the core site

Figure 4. 6. 3 Overflow area at the western end of the lake at Te Pohue. In the middle background is the scar of a massive pre-Waimihia Tephra landslide that came off the Te Waka Ridge above. On the left, arrowed, is a debris fall that came off the limestone ridge above, between the deposition of the Waimihia and Taupo Tephras

on the left of the Figure is part of the large post-Waimihia debris fall that came off the limestone on the ridge above. This debris fall has the uniform 3 cm cover of Taupo Pumice beneath 20 cm of topsoil referred to above. Figure 4. 6. 4, taken from the top of the pre-Waimihia Lapilli landslide that dammed the Mangaone River, is a panoramic view of the Te Pohue area to the southeast. In the centre of the Figure is the hummocky terrain of the landslide, with the lake just visible in the middle distance *c.* one kilometre away. The extensive broken nature of the terrain suggests the landslide extended considerably beyond the immediate Te Pohue area. To the left is the scar that delineates the northern perimeter of the pre-Waimihia Lapilli landslide. On the right of the Figure is the post-Waimahia debris fall (arrowed) referred to above.

4.6.2 PRESENT DAY VEGETATION

The present day vegetation in the Te Pohue district is mainly introduced pasture, with increasing amounts of commercial plantings of exotic forest blocks. Beginning with the commercial planting of *Pinus radiata* on Rukumoana Station in the early 1920s, much of the steeper lands of the greater Te Pohue region have since been planted in this species (Parsons, 1997).

The Pohui Bush and the Ohurakura Bush (Figure 4. 6. 1.) are two remnant areas of native bush in the Te Pohue district. The Pohui Bush once covered an area of 28 km^2 and stretched along the eastern slopes of Te Waka Range. The Ohurakura Bush originally covered the area north of the lake up to the Titiokura summit and along the lower slopes of the Maungaharuru Range in the Northlands area.

Figure 4. 6. 4 View from above the scar of the pre-Waimihia tephra landslide. On the right, arrowed, is a second view of the post-Waimihia/pre-Taupo Tephra debris fall

The Pohui Bush today is a remnant 3.5 km^2 of *Nothofagus fusca* (red beech) forest, with scattered podocarps, mainly *Dacrydium cupressinum* (rimu) and *Prumnopitys taxifolia* (matai). The northern part of this Bush is situated 1.5 km southwest of Titiokura Summit at an altitude of 880 m. A survey done by Dr. Pat Grant in 1955 indicated that nearer the summit there were large *Nothofagus fusca* with flangy butts, short boles and large spreading heads. Increment coring indicated these trees were 350 to 450 years old and most were dead or dying. *Dacrydium* had been felled at these higher levels and much *Dacrydium* pole regeneration had developed under *Weinmannia* (kamahi) and *Nothofagus*. In 1955 *Podocarpus hallii* (mountain totara) saplings were also scattered under the *Nothofagus*, but the dominant ground cover was *Polystichum vestitum* - the prickly shield fern. Currently *Pseudowintera* (horopito) is abundant and *Griselinia* (broadleaf) is dying out in this part of the bush. At lower levels *P. taxifolia* was widespread in 1955, with less frequent occurences of *Nestegis* (maire), *Dacrydium cupressinum, Dacrycarpus dacrydioides* and *Podocarpus hallii*. Logging was carried out in this area in 1936 (Grant *in* Parsons, 1997).

On the road to the microwave station on the top of the Te Waka Range there is a dense, 3 km^2 *Nothofagus fusca* forest which extends from 740 to 960 m. Here, there are two cohorts of *Nothofagus*, one probably 350 to 450 years old and the other about 50 to 150 years old (Grant *in* Parsons 1997). No younger *Nothofagus* is evident. According to J.J. King, who was born on the property and farmed the immediate area since 1949, the bush in this area was milled from about 1942 to 1952. *Nothofagus* had not regenerated due to the introduction of goats (J.J. King pers. comm. 1995).

On top of the Te Waka Range southwest of the Te Waka Trig, at the turn of the century, *Phormium tenax* (flax), *Discaria toumatou* (matagouri), and *Aciphylla colensoi* (wild

Spaniard) grew among native grasses. A small mountain daisy and isolated stands of kanuka were also common. By 1955 the tops were covered only in native grasses for a distance of 3 km south from the microwave station (J.J. King pers. comm. 1996).

Today some *Dacrydium cupressinum* and *P. taxifolia* is evident in this part of the residual bush up to about 820 m. Below 820 m the hardwoods *Weinmannia racemosa* (kamahi), *Knightia excelsa* (rewarewa) and *Nestegis cunninghamii* (maire) are evident. In the understorey *Hoheria populnea* (houhere), *Pennantia corymbosa* (kaikomako), *Fuchsia excorticata* (kotukutuku), *Carpodetus serratus* (putaputaweta), *Griselinia littoralis* (broadleaf), *Melicytus ramiflorus* (mahoe), *Melicope simplex* (poataniwha), *Urtica ferox* (ongaonga), *Coprosma propinqua* (mikimiki) and *Polystichum vestitum* (prickly shield fern) together with *Histiopteris incisa* (water fern), are all present in varying amounts. However, *Pseudowintera* (horopito) is the dominant understorey species in this part of the bush. Above 820 m Hall's totara ascends to the tree line.. Hall's totara is also hybridising with other podocarp species in the area (A. Cunningham pers. comm. 1996). There is an increase in the frequency of 9 to 12 m tall *Griselinia* (broadleaf), usually with broken heads. This species is present to the upper limits of the remnant Pohui Bush on the eastern slopes of the Te Waka Range.

The Ohurakura Bush remnant lies between 400 m and 500 m altitude with an average annual rainfall of about 2000 mm. Grant's 1955 survey indicated that this bush was dominated by *Dacrydium cupressinum* and *Prumnopitys taxifolia*. *Podocarpus hallii* was sparsely scattered throughout and *Dacrycarpus dacydioides* had colonised the damper gully bottoms. *Prumnopitys ferruginea* occured occasionally; and some large *Podocarpus hallii* (mountain totara) grew on the better drained sites higher up towards the Titiokura summit. Both *Dacrydium* and *P. taxifolia* were dated by growth rings at mostly 300 years, with some older *P. taxifolia* at 450 and 480 years. Due to windthrow the canopy was very broken and the gaps were filled with *Elaeocarpus dentatus* (hinau), *Beilschmiedia tawa* (tawa), *Knightia excelsa* (rewarewa), *Hedycarya arborea* (pigeonwood), *Alectryon excelsum* (titoki), *Fuchsia excorticata* (kotukutuku), *Aristotelia serrata* (wineberry), *Macropiper excelsum* (kawakawa), *Melicytus* (mahoe), *Brachyglottus repanda* (rangiora), *Pseudowintera* (horopito), *Schefflera digitata* (pate), *Geniostoma rupestre* (hangehange) *Carpodetus serratus* (putaputaweta), *Nestegis cunninghamii* (maire), *Pennantia corymbosa* (kaikomako), *Rhipogonum scandens* (supplejack) and the white rata liane *Metrosideros diffusa*. There were at least 19 species of fern present, reflecting a moister environment in comparison with the nearby Pohui Bush (Grant *in* Parsons, 1997).

Sawmilling statistics for the Te Pohue area indicate that rimu produced the greatest quantity of timber, followed by matai, then totara and kahikatea least of all. The original Pohui Bush and Ohurakura Bush were not as thick as the Bush at Puketitiri (see 4. 5. 2. above) having only some 66900 m^3 of timber per ha as against 93660 m^3 per ha at Puketitiri. This did not mean that many of the trees were small; on the contrary, a good number were only just able to go through the breaking down saws of Holt's Mill, the main mill in the district, without first being split in half. Some logs were even too large to be handled, and were left where they were felled (Wright, 1985).

The flora in the remnant Ohurakura Bush as described by Grant (*in* Parsons, 1997) is very similar to the rejuvenating vegetation found around the lake at Te Pohue today. In addition to the extremely diverse secondary forest taxa described in the remnant Bush, there are introduced pasture grasses, macrocarpa and eucalypt trees around the lake. There are also two areas of *Typha* (bulrushes) along the edge of the lake (see Figures 4. 6. 2 and 4. 6. 3).

4.6.3 RECENT SITE HISTORY

The Te Pohue district including the Pohui Bush was part of the Ahuriri Block purchased from Maori in 1851. In 1862, the Government, seeking to capitalise on the stands of native timber within the Ahuriri Purchase put up a series of 9 to 16 ha sections of bush at Te Pohue for auction. These sections bordered both sides of Kings Stream at the foot of Te Waka Range, from its source to where it joins the modern Mangaone River. Local runholders were prominent in the first allocation of these bush sections. Initially, most of the runholders milled the timber for homesteads, farm buildings and fencing. Timber was later rafted down the Mangaone River when in flood, then on down the Tutaekuri River to Meeanee. In this way much of the timber felled between 1870 and 1900 was made available to the Napier building industry, or used on the timberless Heretaunga Plains for fencing material. But losses were often great, especially due to flash floods. One example was the great flood of 1867, when all the timber in the Mangaone ended up on the flood plains of the Tutaekuri River at Meeanee, or was lost out to sea. At least four mills are known to have existed along Kings Stream. As the supply of millable timber was expended in the immediate area, tramlines were used to gather in logs from the outlying bush.

Directly north of Te Pohue was Maori land which, following the Maori Wars, became part of the Mohaha Waikare Confiscation of 1867. Two Block were involved. The Kaiwaka Block of 12 465 ha, which extended down the eastern slopes of the Maungaharuru Range as far as the Esk River; and the Wairara Block of 13 770 ha which extended along the west side of the Maungaharuru Range from the summit to the Mohaka River north of the Range. This block was retained by the Government in an 1870 land settlement with local Maori.

The Kaiwaka Block, incorporating the 1053 ha Ohurakura Bush, was awarded posthumously to a prominent loyalist chief, Tareha, in the Native Land Court. His heirs then subdivided the block and leased the land to European settlers. The Ohurakura Bush, was subsequently sold to Harold Robert Holt in 1922. Holt felled the timber for the Hawkes Bay building industry. The cleared ground was then developed for farming and sold on.

However, what established Te Pohue as a well known site was not timber milling but the fact that, of the three options proposed for a road through to Taupo, the route through Te Pohue over the Titiokura Saddle and on to Te Harato was the one chosen. What forced the issue was the need to get the Armed Constabulary into the area quickly during the Maori Wars to counter incursions from the Taupo area of marauding Hauhaus. Te Pohue was located on the Maori walking track into the interior. This track passed directly by the lake before ascending the hill to the Titiokura pass. Maori war parties used this track to gain access to the Heretaunga Plains area (Parsons, 1997).

The siting of the original settlement at Pohue was for a purely practical reason - it was one day's journey from Ahuriri. When the coach service to Taupo run by Cobb & Co opened in 1872 it was logical to place the changing station for the horses on the flats at the foot of the Titiokura Hill, and use fresh horses for the climb to the Titiokura summit. It was not until the first hotel at Te Pohue burned down in 1897 that the lake became the focus of settlement when Joseph King rebuilt his hotel on its shores.

The second hotel survived until the 1931 Napier Earthquake, when a second major tremor, about ten days after the first one that destroyed Napier "...smashed right and left. Wrecked the mill and every house ... Smashed down our two tanks, pushed the wash-house wall in a bit and windows clean out." (A letter from Kath McRobbie to her mother quoted by Parsons (1997)). The earthquake also caused the ground to crack. One such fissure across the top of Te Pohue Pa exposed an old *urupa* (a burial ground) revealing a deposit of human bones. Minor quakes over the following weeks sealed the burial site again (Parsons, 1997).

Today the Te Pohue district is a mixed farming community. However, many areas are now being planted in *Pinus radiata* and Douglas fir on the higher points. One example of this reversion to forestry is the original Ohurakura Bush area clear felled by Robert Holt & Sons. This block is being converted back to forest and, apart from a small native reserve, now has a total of 1114 ha in *Pinus radiata*. This block is just visible in the top left hand corner of Figure 4.6.4.

4.6.4 PALAEOECOLOGY

The results of the pollen analysis of the Te Pohue site are presented in Figures 4.6.5 and 4.6.6 . The stratigraphy is presented separately in Figure 4.6.7 (p. 231). A sample of silt taken at 1.98 m depth, from above a series of pumiceous silty layers that continued to the base of the site, was dated (Wk - 5029) at 2220 ± 170 yrs BP.

The pollen diagrams have been zoned using a subjective assessment in conjunction with a visual inspection of the diagrams and the CONISS dendrogram provided by the Tiliagraph programme. Three zones have been assigned, namely TP1, TP2 and TP3; TP is the code assigned to the Te Pohue site.

FIGURE 4. 6. 5 RELATIVE POLLEN DIAGRAM TE POHUE SITE

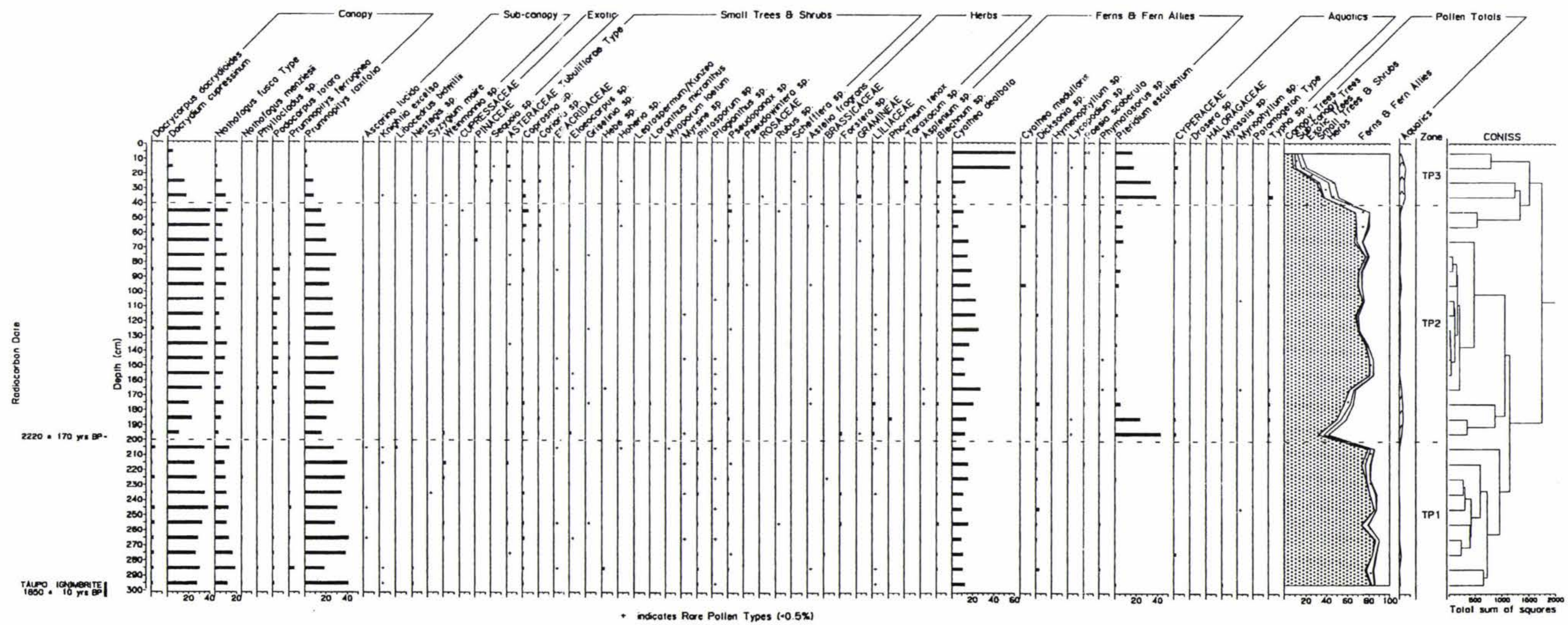
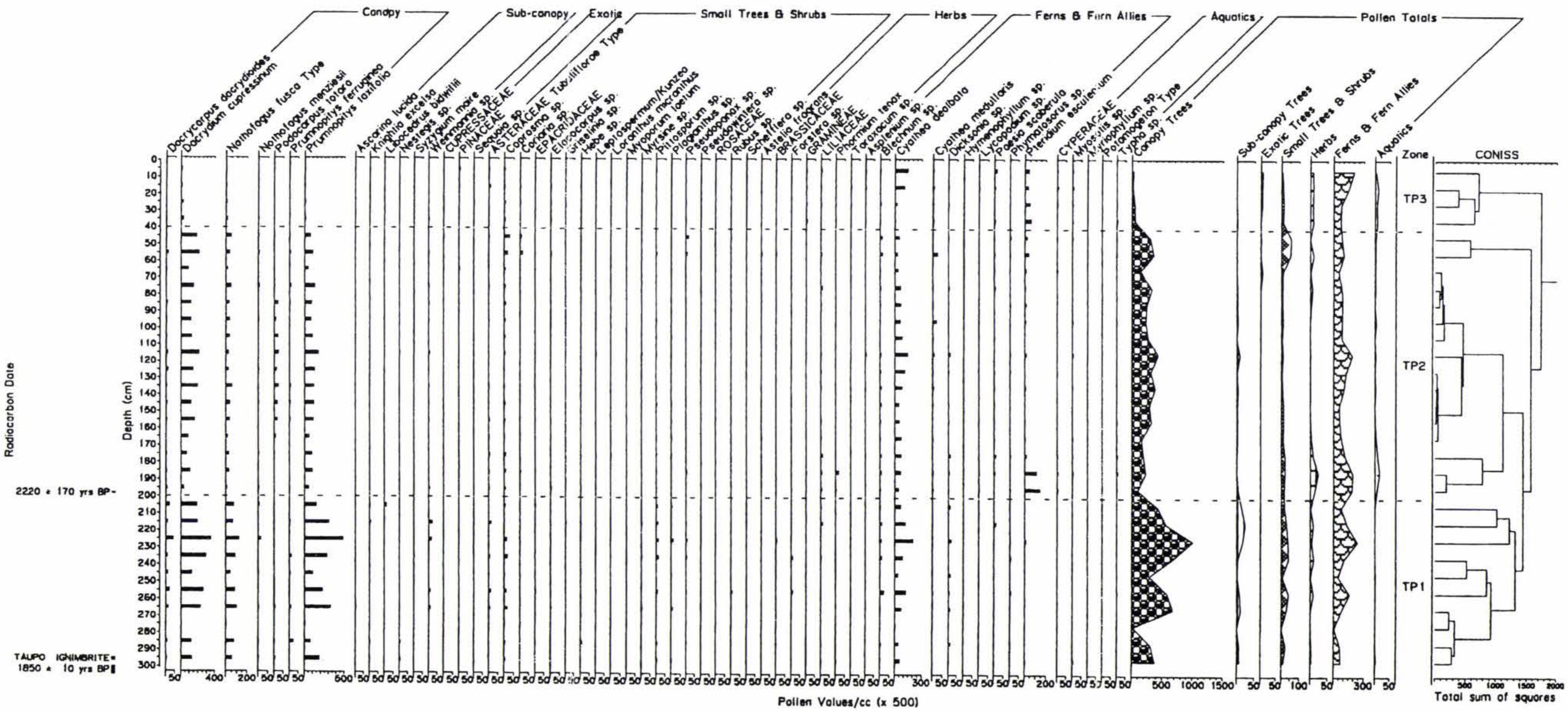


FIGURE 4. 6. 6 ABSOLUTE POLLEN DIAGRAM TE POHUE SITE



Zone TP1 3.00 - 2.01 m

There are three criteria for defining the lowermost metre of sediment as a zone. First, is the dominant presence of forest taxa throughout the zone; second, is the continual presence of pumice in the stratigraphic column up to 2. 01 m; and the third, is the introduction of *Pteridium*, Cyperaceae and *Typha* into the site accompanied by an almost total elimination of forest species above 2. 01 m depth, which also coincides with a layer of abundant fine charcoal.

Nothofagus spp. and the podocarps, *Prumnopitys taxifolia* and *Dacrydium cupressinum*, are the main forest species in the zone. All three species are present in roughly equal amounts in conjunction with minor *Dacrycarpus dacrydioides*. *Prumnopitys ferruginea* and *Podocarpus totara* (mountain totara) are also present in low amounts. This zone is also characterised by a relatively high percentage of pollen derived from small trees and shrubs. The most important of these secondary forest taxa are *Coprosma*, *Pittosporum*, *Pseudopanax*, *Pseudowintera*, *Myrsine* and *Hebe*. Also present is the sub-canopy tree *Weinmannia*, and the fern *Blechnum*. Although counts are low, these last two taxa may indicate a minor disturbance in the vicinity of the site.

The radiocarbon date of 2220 ± 170 yrs BP. was obtained from a charcoal rich orgainic layer immediately above the last record of pumice in the stratigraphy of the site and just below the invasion of the site by *Pteridium* (bracken) at c. 1.95 m depth. This radiocarbon date just above the top of the basal pollen zone at 2.01 m depth is about 370 years older than the Taupo Ignimbrite of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990) which underlies the peaty silt sediments below 3.00 m depth, and forms the base of this lake site.

Steep relief around the present-day lake indicates the lake has formed in a depression between two northeast/southwest trending topographical highs. Due to this steep relief it is here interpreted that the lake bed acted as a trap for pumice, ash, ground litter and sediments off the surrounding slopes immediately following the deposition of the Taupo Ignimbrite. It is postulated that a radiocarbon date *c*. 370 years older that the ignimbrite being recorded at the top of the zone may be due to two contributing actors. First, the carbon at the level dated is composed of ash from the fires that burned the forest in the Te Pohue area at the time of the Taupo Eruption. As such, the carbon dated would have entered the lake as inwash and be a composite of the total ages of the trees and debris that made up the inwash. Second, old carbon dissolved from carbonates in the limestone dominated bedrock in the catchment became incorporated in organic material in the lake. This is known as the "hard water effect" (Deevey et al., 1954). Eden et al. (1993), reporting on a tephra sequence in Lake Tutira, situated about 25 km east of the lake at Te Pohue, note a disparity between radiocarbon dates obtained from organic-rich clays in cores and known ages of adjacent tephra deposits of 500 - 800 years, with the radiocarbon dates being the older. Page and Trustrum (1997), reporting on the lake sediment record in Lake Tutira, also attribute this age disparity to the "hard water effect".

As *Pteridium* is known to establish immediately following the destruction of previous vegetation by ashfall and fire (Wilmshurst & McGlone, 1996) this is taken to indicate there is very little time elapsed between the deposition of the Taupo Ignimbrite and the establishment of *Pteridium* (bracken) around the lake at Te Pohue. As the primary ignimbrite flow is found at the base of the site at 3 m depth and the last of the pumice from this eruption to enter the site from the surrounding slopes is recorded at 2.01 m depth, it is also postulated this entire metre of sediment was deposited at the site within a very short period of time. The total absence of *Pteridium* from the pollen record in this *c* 1 m lowermost sequence supports this premise.

It follows, therefore, that the pollen record for the whole of the basal zone gives a composite picture of the primary and secondary forest growing around the lake prior to, during and immediately after the Taupo eruption, up to when *Pteridium* became established at the site within a matter of years. That is, from prior to and just after *c*. 1850 ± 10 yrs BP. The pollen record for the entire metre is from inwashed pollen from litter on the surrounding slopes. This record shows that a mixed podocarp and beech forest was well established in the region. Both secondary forest taxa and tree ferns, predominantly *Cyathea dealbata*, were important components of this forest.

What is not recorded in this zone is an abundance of wetland taxa. Very minor counts of Cyperaceae, together with only traces of the wetland species *Myosotis* (N.Z. forget-me-not) and *Typha* throughout the entire record in this zone, suggest the site, although wet, may not have been underwater. *Potamogeton*, a wetland taxon always indicative of ponding water is not recorded during the period covered by the zone. Thus there is no evidence in the pollen record at the time of the Taupo eruption to suggest the site was a lake. However, the sediments in this basal zone have come off the surrounding slopes where drier conditions prevailed. Thus the pollen record is more likely to reflect this terrestrial habitat than any wetland habitat that may have existed around the fringe of a lake at the time. It is considered that any extensive evidence of wetland vegetation would only be found buried below the compacted primary ignimbrite deposit at the base of the site.

Zone TP2 2.01 - 0.40 m

The major change that defines this zone is the rapid expansion of *Pteridium* and wetland taxa from the base of the zone to 1.45 m depth. Cyperaceae and *Typha* enter the record, possibly in response to more fertile conditions brought about by the deposition of ash from the Taupo eruption. Liliaceae also forms a notable component of the herb taxa at the base and *Myosotis* joints the above aquatic species immediately above the base, as does *Phorium tenax* (N.Z. flax). *Blechnum* is present, but only as a very minor contributor. This increase in wetland species at the base of the zone could be an indication that water began accumulating at the site. The reduction in wetland percentages by 1.45 m depth could be a reflection of the deepening and widening of the lake, thus making the pollen source of these species, too distant to be reflected in the pollen record at the site. An alternative hypothesis is that the returning forest reduced the sunlight around the edges of the lake, making conditions marginal for *Typha* and other wetland species.

Tree ferns were not adversely affected by the volcanic disturbance recorded at the top of the previous zone. Following the almost total elimination of *Pteridium* these ferns gradually take over the ground cover component of a returning podocarp forest by the time recorded at 1. 65 m depth. At the same time there is a marked decline in the frequency of all wetland taxa. Counts of these aquatic species remain low until they all undergo a small expansion towards the top of the zone.

Pollen percentages of primary forest taxa indicate the forest returned to the Te Pohue area very soon after the Taupo eruption. Pollen species indicate that the forest was of the same composition as that before the eruption. One exception is that *Podocarpus totara* became marginally more important than in the previous forest. As this change coincided with a very slight reduction in *Prumnopitys ferruginea* and *Dacrycarpus dacrydioides* percentages, the variation could be attributed to both more fertile conditions and slightly drier conditions prevailing after the eruption. Another possibility is that *Podocarpus totara* may be more resistant to fire damage.

The pollen record also shows that the small tree and shrub component of the post-Taupo eruption forest contained basically the same species as before the eruption. Pollen percentages of these taxa indicate they were just as important a part of the understorey as before the eruption. This situation remained relatively static until near the top of the zone when all these species underwent a minor expansion. This expansion was mirrored by a minor increase in *Pteridium* and some wetland taxa, excluding *Typha*, while, at the same time, tree ferns declined slightly.

Towards the top of the zone at 0.65 m depth there was also a slight decline in podocarp percentages. At this point *Prumnopitys taxifolia* regressed slightly and *Podocarpus totara*, after recording a minor but constant presence throughout the zone, almost left the record. *Coriaria* enters the site at this point. This small tree is indicative of disturbed conditions. This disturbance is also reflected in minor changes in the stratigraphic record just above this level. At this point there is a change in texture from moderately firm dry silt in the core at the 0.65 m depth to a 20 mm layer of very soft dry silt up to the 0.63 m depth. This disturbance could indicate a storm induced erosional event or a coseismic event.

At the top of the zone no regression is recorded in the *Nothofagus* component of the primary forest in the Te Pohue area. *Nothofagus* may, in fact, have been increasing in importance. The pollen record shows that at this time both the *Pteridium* and small trees and shrubs were exploiting a more open site following a minor disturbance to the podocarp forest in the area. Minor *Blechnum* in the record at this point indicates the disturbance was probably local. Beech forest, growing on the higher ground away from the lake was not affected by the disturbance.

Zone TP3 0.40 - 0 m

As with the previous zone the major change that defines this zone is the rapid expansion of both *Pteridium* and wetland taxa at the base of the zone. Both *Typha* and

Myosotis return to the record, with the addition of a further wetland taxon, *Potamogeton*. Podocarp percentages decline rapidly from the base of the zone to almost disappear from the record at the top of the zone. *Nothofagus* follows the same pattern of decline but at a slower rate. Small trees and shrubs, especially *Coprosma*, *Pseudopanax* and *Coriaria*, which were increasing slightly at the top of the previous zone, also undergo a further decline, and do not appear at the top of this zone, which corresponds with current time. The exotic forest taxa, *Pinus radiata* and *Sequoia* appear in the record at mid-zone and increase in importance towards the top. Grasses and *Taraxacum* both enter the record at the base of the zone and have a minor presence throughout.

The forest disturbance in this zone is due to forest clearance by European settlers. By the mid-1860s European runholders had begun clearing *Dacrydium cupressinum* and *Prumnopitys taxifolia* in the Pohui forest. Immediately following forest clearance, tree ferns accompanied by minor percentages of *Paesia scaberula* (ring fern) and *Blechnum* become very prominent in the pollen record. At this point *Pteridium* declines in importance while grasses increase slightly. *Typha* and other wetland taxa also decline at the top of the zone. The reduction in both *Pteridium* and wetland taxa could be a reflection of drier conditions as the cleared land around the lake was drained and developed for pastoral farming.

4.6.5. DISCUSSION

Sediments at the Te Pohue site are lake silts - soft at the top of the column and consolidating lower down the profile. From 1. 95 m to 2 m depth is a charcoal and organic rich silty layer, with a 20 mm concentration of fine, white, round, pumice lapilli immediately below. There is no ash or lapilli in the stratigraphy above the 2 m depth. A sample of the organic silt at 1.97-1.98 m depths returned a radiocarbon date (Wk - 5029) of 2220 ± 170 yrs BP. Below 2.01 m depth there are abundant fine, white, elongate, pumice lapilli through, and numerous sandy lenses. At 3 m depth pumice from the Taupo Ignimbrite was encountered. This pumice dates the base of the site at 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990). A stratigraphic description of this site is presented in Figure 4. 6. 7.

Based on the date of the Taupo Ignimbrite, the pollen record at Te Pohue extends back 1850 years. During this time the Te Pohue area was in podocarp forest until European forest clearance in the mid-nineteenth century. The main podocarp species were *Dacrydium cupressinum* and *Prumnopitys taxifolia*. *Phyllocladus* and *Prumnopitys ferruginea* also registered a very minor presence in the forest throughout its recorded history. Immediately prior to the Taupo eruption *Dacrycarpus dacrydioides* was a minor contributor of note. There was also a minor *Nothofagus* component in the area. It is very likely the beech was confined to the higher ground along the Te Waka Range where it is found today, with the podocarp forest restricted to the slopes of the Range and the lower areas around the lake, where it was still well established in the mid-nineteenth century.

The understorey component of the Pohui Bush was rich and varied before the Taupo eruption. This variety is no doubt a reflection of both a slightly open canopy and abundant bird life in the area. The birds would have fed on the berries and nectar of these shrub species and thus assisted in their pollination. A more open canopy would have allowed sunlight to penetrate to the forest floor encouraging small tree and shrub growth.

TE POHUE SITE

	m		
	0 - 0.23	C1	Dark olive (7.5 Y 4/3) silt; soft; no structural features; charcoal at 0.15 - 0.16 m; gradual boundary over 30 mm, well defined break.
	0.23 - 0.60	C2	Dark brownish black (7.5 YR 2/2 silt; no structural features; 0.23 - 0.30 m wet, 0.30 - 0.40 m very moist, 0.40 - 0.60 m drier; gradational boundary.
	0.60 - 0.63	C3	Olive brown (2.5 Y 4/3) silt; very soft; dry; gradational boundary.
	0.63 - 0.90	C4	Dark brown (7.5 YR 3/3) silt; moderately firm; boundary is a sharp natural break.
	0.90 - 1.61	C5	Dark brown (7.5 YR 3/3) silt; slightly firmer than above; at 1.40 m and below profile is more consolidated; gradual colour change at base; gradual boundary.
	1.61 - 1.86	C6	Olive brown (2.5 Y 4/3) silt; profile still consolidating; gradual boundary.
C14 date 2220 ± 170 - yrs BP.	1.86 - 2.08 (1.95)	2C1	Dark grey (N 3/2) silt; at 1.95 m gradationally browner silt, and abundant fine charcoal; at 2.01 - 2.03 m concentration of fine, white, round, pumice lapilli (3 mm) in silt; gradational boundary.
	2.08 - 2.36	2C2	Dark brownish black (7.5 YR 3/1) silt; sand lens at 2.15 m; gradational boundary.
	2.36 - 2.42	3C1	Dark grey (N 3/2) silt; fine, white, elongate, pumice lapilli throughout; gradational boundary.
	2.42 - 2.52	3C2	Olive (5Y 5/4) silt; white, elongate, pumice lapilli in a fine sandy lens at 2.46 - 2.47 m; distinct boundary.
	2.52 - 2.535	3C3	Dark brown (7.5 YR 3/3) silt; distinct boundary.
	2.535 - 2.60	3C4	Brownish grey (10 YR 4/1) silt; abundant fine, white, elongate pumice lapilli throughout; gradational boundary.
	2.60 - 2.85	3C5	Brownish grey (10 YR3/4) silt; abundant fine, white, elongate lapilli throughout; charcoal at 2.81 m; gradational boundary.
	2.85 - 3.00	3C6	Dark brown (7.5 YR 3/3) silty pumiceous sand; fine texture; compact; abundant fine white lapilli increasing towards base; gradational lightening of colour to greyish brown (7.5 YR 4/2) towards base.
	3.00	4C	At 3.00 m sediment (Taupo Ignimbrite) too compacted to core.

Figure 4.6.7 Stratigraphic column. Site cored with the Livingstone piston corer.

Following the Taupo eruption the small tree and shrub component of the forest did not recover its former importance in the Lake Te Pohue area, even though a soil enriched with volcanic ash would also have created more fertile conditions.

A possible reason for the non-return of the understorey component of the bush is that an even-aged forest of closely spaced even-aged trees, was quick to exploit the more fertile conditions following the deposition of the ignimbrite flow and soon took over the area. Thus the prompt closure of the canopy by a forest assemblage would exclude sunlight from reaching the forest floor, so creating an environment in which understorey species do not thrive.

However, slight changes to the minor components of the primary forest also occurred after the Taupo eruption. Following the eruption the contribution of *Dacrycarpus dacrydioides* became minimal. This tree's place in the forest was taken by *Podocarpus hallii* (mountain totara). This species also declined during a further very slight disturbance that occurred towards the time corresponding to the *c.* 0.80 m depth. It is possible this latter decline can be attributed to the death of a single cohort of even-aged reasonably mature trees due to an isolated cyclonic storm event, without any maturing younger cohorts to take the place of the mature stand.

Comparison of the 1850 year-pollen record at Te Pohue with rejuvenating or growing native species in the region today indicates there has been no major change in flora in the region within this timeframe. The mixed podocarp forest with a strong understorey component evident in the pollen record prior to the Taupo eruption, and in the subsequent *c.* 1800 years prior to forest clearance last century, contains basically the same species that are found in the remnant Pohui Bush and Ohurakaura Bush today. Red beech, always a minor component of the forest for the last 1850 years, is also present today in the bush remnant on the track up to the Te Waka microwave station.

The above is in agreement with what Wilmshurst and McGlone (1996) have found in their study of forest disturbance in the central North Island following the deposition of the Taupo Ignimbrite. These writers report that post-eruption forests were similar in composition to those existing before the Taupo eruption. They further find that although the degree and nature of vegetation disturbance after the eruption varied according to the thickness of the ashfall, local topography and vigour of the forest, regeneration was completed within 120 to 225 years, and was in no way related to tephra thickness or distance from source.

Again, as with the previous sites discussed, to see if there is any evidence in the record of changes that can be attributed to climate-induced forcing (Grant's hypothesis) and or/ earthquake-induced erosional events (Neall & Hanson's hypothesis), a further pollen diagram has been prepared containing interpretive stratigraphic data based on sediment accumulation rates, and raw pollen data of local interpretive importance (Figure 4. 6. 8).

In calculating an accumulation rate for the Te Pohue site, the known date for the Taupo Ignimbrite of 1850 ± 10 yrs BP. is assigned to the 3. 00 m depth; the known date of c. 1860

Interpretive Stratigraphic Data based on sediment accumulation rates & pollen information	Depth sampled (m)	Regional Forest: Beech	Rimu	Matai	Miro	Exotics: Pinus R Sequoia	Regional Ground cover: Grass	Bracken	Silver fern Tree ferns	Ring fern Blechnum	Site Vegetation: Cyperaceae	Bulrushes (Raupo)
	0.05	2	12	6			3	45	178	2	3	
Fire in area (1946)	0.15	6	13	7	1	8	5	54	181	3	10	
	0.25	19	51	25	1	8	5	105	46		4	4
19th C. European forest clearance	0.35	28	53	25		10	13	116	14	3		12
	0.45	37	136	52	2			16	36		1	1
	0.55	21	139	67	3	→ 9		24	34	9		1
Disturbance due to Maori presence	0.65	24	139	72		(Coriaria)		25	56	3	4	
	0.75	34	116	100	6			5	51	3		
	0.86	26	104	77	2			15	63	3		1
Disturbance nr. lake c.700 yrs BP	0.95	32	114	78				10	74	3	1	2
	1.05	28	115	91				2	80			
	1.15	13	123	99				8	88	7		
	1.25	18	111	102				1	92	4	2	
	1.35	34	119	72	3			5	54	5		
After Taupo Eruption - same regional	1.45	28	103	97	3			1	39	6	1	
forest reestablishes as before the eruption	1.55	22	121	84	2			3	38	3		1
Bulrushes and Cyperaceae on site	1.65	19	121	73	1			5	105	5		4
	1.75	28	74	100	1			18	77	9	3	5
	1.85	18	79	72	1			81	49	5	4	5
C14 Date 2220 ± 170 yrs BP	1.95	11	36	53				144	43	3	5	2
	2.05	41	109	86	1				39	2		
Ash and lapilli lenses in stratigraphic	2.15	28	85	137	1				53	4		
column from 2.01 m depth to base -	2.25	30	89	121				3	51	2		
from Taupo Eruption, 1850 ± 10 yrs BP	2.35	31	110	106	4				33	4		
	2.45	33	107	85	5			1	27			
	2.55	34	111	95					54	9		1
	2.65	36	84	121	3				26	1		
	2.75	45	75	108	1			1	31	3		
	2.85	61	100	60	17				34	4		
	2.95	38	96	141				4	43			
Taupo Ignimbrite blocked corer ------>	3.00											

* 1 cc sampled at each depth

* 200 dryland taxa counted at each depth or four slides scanned where dryland taxa did not accumulate

Figure 4.6.8 Interpretive stratigraphy of the Te Pohue site, based on sediment accumulation rates and some raw pollen counts of species indicative of specific environments. These environments are discussed in the text both in relation to Grant's hypothesis regarding climate forced periodic erosional events in the Hawkes Bay region since the 13th century, and to possible erosional events due to movement along the Mohaka Fault as postulated by Neall and Hanson (1995)

AD. for European forest clearance around the lake is assigned to the 0.40 m depth; the sediments between 3.00 m and 2.00 m are eliminated from the equation on the basis that they represents erosional inwash events that occurred immediately after the Taupo eruption. This results in an accumulation rate of 0.91 mm/yr for the site.

Based on this accumulation rate, raw pollen counts indicate several things happened immediately after the volcanic eruption. *Pteridium* became the established groundcover in the lake area, in conjunction with minor amounts of Cyperaceae (reeds), bulrushes and ring fern. Tree ferns suffered no noticeable damage. In the regional forest, *Prumnopitys taxifolia* was not severely affected by the eruption and recovered relatively quickly to be the dominant podocarp by 1355 yrs BP. (1.75 m depth). Dacrydium *cupressinum* regressed markedly. Charcoal in the stratigraphic column at 1.95-2.00m depth indicates there was fire in the area in the wake of the ignimbrite flow. *Dacrydium cupressinum* then recovered very slowly over the next 380 years. By about 1465 yrs PB. (1.65 m depth) this tree emerged as the dominant podocarp species in the forest.

From c. 1465 yrs BP. until European forest clearance raw pollen counts indicate *Dacrydium cupressinum* remained the dominant podocarp in the region. *Prumnopitys taxifolia* counts, on the other hand, peaked several times during this time, with a distinctive gross periodicity of about 500 years. This 500 year timeframe reflects the average natural life of this species from sapling to senescence (Wardle, 1991), although Grant (1996) has reported evidence of 700 year-old *P. taxifolia* growing in the Blowhard region today. The *P. taxifolia* peaks in the Te Pohue record are found at 1575 yrs BP. (1.75 m depth), 915 yrs BP. (1.15 m depth) and 475 yrs BP. (0.75 m depth). On this basis the cohort of *P. taxifolia* felled in the 1860s would have been about 400 years old.

Fires occurred during the Taupo eruption and continued for several decades after (Wilmshurst & McGlone, 1996). At Te Pohue *Pteridium* dominated the flora after these fires. This dominance lasted while the regional forest was reestablishing in the region. As the forest became reestablished, *Pteridium* was replaced by tree ferns as the dominant ground cover. Local climate may have been the controlling factor in this replacement as *Pteridium* tends to be suppressed more readily by forest in wetter conditions (Levy, 1923).

With the full recovery of the regional forest, tree ferns returned to their former minor role. When *Prumnopitys taxifolia* peaked for a second time about 910 yrs BP. (1.15 m depth) there was a further corresponding peak in tree ferns. During the next 500 years these ferns maintained a relatively steady high profile, until a further peak in *P. taxifolia*, at 0.75 m depth, coincided with a gradual decline in importance of the tree fern. As the ferns declined *Pteridium* increased slightly in importance from about 700 yrs BP. (0.95 m depth). This minor increase lasted for about 200 years. At no stage is there any evidence of a disturbance in the regional forest. That being so, the presence of this bracken species indicates the disturbance was localised in the vicinity of the site. There is no evidence at the site of fire being the cause of this disturbance. Neither is there any evidence of an increase in wetland taxa that would indicate particularly wet conditions.

However, the date of 700 yrs BP. for disturbance in the Te Pohue area corresponds with disturbances identified at several of the previous sites discussed in this study. These disturbances have been attributed to an earthquake event on the main segment of the Mohaka Fault. The Te Waka Fault, a splinter fault off the Mohaka Fault is situated along the NNE/SSW trending Te Waka Ridge immediately west of the lake. Neall & Hanson (1995) do not report any evidence of fault movement on the splinter fault about this time. However, they do report that, in a trench excavated in the northwest-dipping Te Waka Limestone across the flank of the fault on Wedd's Property on nearby Puketitiri Road, there is evidence that both the Waimihia and Taupo Tephras were disrupted at some time. Neall & Hanson attribute this to possible strike slip movement along the fault. There are a number of small scarps both on this property and the neighbouring Duno Property which all have the same height and all displace both the Waimihia Lapilli and Taupo Tephra. This displacement tends to indicate there has been at least one-post Taupo Tephra movement along the splinter fault.

Given the present-day hummocky nature of the original pre-Waimihia Lapilli landslide at the base of the limestone ridge (Figure 4. 6. 4), it is here suggested that movement of this loosely compacted debris is ongoing. Probing of the lake sediments at the western end of the lake has produced evidence of large limestone blocks found within the lake sediments at various depths. One such exposed block is visible in the foreground of Figure 4. 6. 2. It is possible that reworking of this material was responsible for a disturbance around the lake *c.* 700 yrs BP (signalled by a sharp break in the sediments at 0.90 m depth). A strike-slip movement on the Te Waka Fault around this time could have remobilised the poorly consolidated sediment on the slopes between the fault trace and the lake, or brought down fresh debris and caused the local disturbance to the vegetation recorded in the pollen diagrams. This movement may correlate with the post-Taupo Tephra disturbance identified by Neall & Hanson (1995) in the Wedd trench.

There is a further disturbance recorded in the pollen record at 0.65 m depth. Based on constant sediment accumulation rates of 0.91 mm/yr this depth corresponds with a date of 365 yrs BP., or 1585 AD. At this point *Pteridium* counts again increase. *Pteridium* counts indicate this local disturbance continued until there was an even greater disturbance to the environment when the forest was felled in the mid-nineteenth century. The presence of *Coriaria* and *Elaeocarpus,* a shrub and tree which are among the first to colonise a disturbed site, at 0.65 m depth, is further evidence of the very disturbed nature of the area. The pollen record shows there was minor disturbance to the regional forest as well This indicates a further disturbance of a local nature. Above this depth there is a change in the lake sediments from sandy silt below 0.63 m depth to fibrous silt above.

It is generally accepted that Maori were well established in New Zealand and were freely moving about the North Island by the mid-sixteenth century, even earlier. Given their nomadic lifestyle, which usually involved moving with the seasons in search of food, disturbance to the habitat along their favoured trails through the bush must have occurred.

While it is not recorded exactly when Maori first visited Te Pohue, it is known they periodically set up camp round the lake. There is also evidence of several *kainga* (unfortified villages) in the district. Te Pohue was also on the route for both migrating tribes from the Taupo/Rotorua area to Ahuriri, and *vice-versa*, as well as for war parties from the interior intent on attacking the various pa on the Heretaunga Plains. (Parsons, 1997).

Because of an abundant bird life in both the Pohui forest at Te Pohue and the nearby forest at Puketitiri these areas were visited every winter by Maori in search of food. The fat, well-fed birds that had been feasting on the berries from the various forest trees all through the autumn were snared to become part of the staple diet in the winter when fishing was not an option. One of the favoured means of trapping the birds was to light a fire in front of a net placed across the flight path of the birds as they flew inland, then kill the birds with a stick as they fell to the ground. A certain amount of disturbance to the understorey must have ensued. The remains of many bird-snaring camps can still be seen at Te Pohue today (Parsons, 1997). Minor fires often burned the understorey. Tracks through the bush would have caused further disturbance to the forest , as would thrashing with sticks during bird snaring. The larger camp sites of the migrating tribes and war parties would also have disturbed the undergrowth.

The disturbance to the forest understorey at Te Pohue recorded in the pollen diagrams and reflected in the stratigraphy of the lake sediments from 0.63 m depth up until the time the forest was cleared by European settlers, corresponds to the time the Maori were very active in the area around the lake. For this reason it is postulated that, even though there is no charcoal in the stratigraphy at this level to support the inference of forest damage by burning, the disturbance to the environment recorded at 0.65 m depth (c. 365 yrs BP.) and above, is nevertheless, a reflection of Maori activities in the Te Pohue area.

There is no evidence in any of the pollen diagrams for this site of any disturbance to the regional forest in the past 700 years that can be attributed satisfactorily to Grant's (1996) theory of forest change due to climate forcing. The only disturbance recorded at Te Pohue during this 700 year period is the one which commenced at 0.65 m depth referred to above. Although, it must be noted, the 1580 AD. date assigned to this level does place this disturbance within Grant's Matawhero Erosional Period.

However, due to the minor effect this disturbance had on the regional forest, plus the fact that disturbance to the understorey component of the forest continued until European forest clearance almost three centuries later, has led to the conclusion that there is no evidence at the Te Pohue site to support Grant's theory of periodic gales and/or fires destroying the forests in the central North Island several times during the last 800 years.

One problem with the Te Pohue pollen record concerns the lack of grass in the record at the level corresponding to the present time. The slopes around the lake were in grass at least as late as 1915 when a photograph taken at the time shows the land had been clear felled and was in pasture (Parsons, 1997). The strand area around the lake is in grass today. For these reasons the low counts of this taxon throughout the post-forest clearance zone are difficult to explain. One possible explanation is that the Livingstone piston corer used to core the lake site, althogh known to work best in well decomposed, sloppy peats and lake sediments (Moore & Webb, 1978), has one drawback. This corer is is known to easily miss the topmost layer of sediment, and/or introduce contamination at the top of each core segment due to inwash and/or mixing of the sediment with the lake water.

Another problem is the large percentage of *Cyathea dealbata* at the top of this zone. This tree fern is not very noticeable in the regenerating secondary forest around the lake today, nevertheless it tends to dominate the pollen record. *Typha*, on the other hand, is very evident in two areas around the perimeter of the lake but does not appear at the top of pollen record. Regenerating species around the lake today include *Pittosporum*, *Coprosma* and *Pseudopanax* yet these do not appear in the pollen record either. These understorey species are bird, wind and insect pollinated. Thus their non- appearance in the pollen record cannot be attributed to a decline in the native bird population in the Te Pohue region following the destruction of their habitat, even though the removal of the forest in the late nineteenth century, is known to have resulted in a dramatic decline in bird life in general as their source of food disappeared with the forest.

However, older identities at Te Pohue believe the bird life is now returning to the area in increasing numbers (J.J. King pers. comm.; Parsons, 1997). This return is no doubt a reflection of stability in the two remnant native bush stands in the area.

Recent growth ring counts have been done on *Dacrydium cupressinum* and *Prumnpitys taxifolia* growing in the remnant native bush stands at Te Pohue. Annual growth rings for *Dacrydium* are as great as 10 mm, while *P. taxifolia* growth rings are only 1 - 2 mm per year (P. King pers. comm.) This indicates that *Dacrydium* is the podocarp species much more suitable to present day climatic conditions in the region.

The stratigraphy at Lake Te Pohue indicates that lake silts have been accumulating at the site since the Taupo eruption. Apart from a minor disturbance to the sediments at 0.90 m depth, which had no obvious effect of the vegetation cover, the lake sediments have remained reasonably undisturbed. For this reason the sedimentological history attempted for the previous five sites, has not been included here, as it would serve no purpose.

CHAPTER FIVE : OVERVIEW, DISCUSSION AND INTERPRETATION

5.1 INTRODUCTION

Along the east coast of the North Island of New Zealand, the Pacific plate obliquely converges with the Australian plate at latitude 39°50'S along the Hikurangi margin (Cashman et al., 1992). Convergence is estimated at a rate of 55 mm/yr (Walcott, 1978). In the Hawkes Bay area the dip of the subducting plate ranges from as shallow as 6° in the offshore segment, to 20° beneath the Ruahine Range to the west (Bannister, 1988).

Geomorphology was the determinant factor in the selection of the area for palynological investigation. The field area is located in a transitional zone between the eastern margin of the frontal ridge of the accretionary margin and the western margin of its forearc basin (Berryman, 1988). Erosional processes have shaped the geomorphology of the area. These processes have been modified by the interplay of lithology, structure, climate, time and human impact. Lithology influences geomorphic development by virtue of rock strength or resistance to erosion. Structure affects geomorphology directly by folding and dislocation of the land surface. Climate and time may accentuate or mask the effect lithology and geological structure have on the environment. Human impact may mask or accentuate the influences of all, or any one, of the above factors. The proportional influence of all five factors determines the nature and intensity of the disturbance to the environment. This disturbance is reflected in the palynological record of the region.

5.2 GEOLOGY, GEOMORPHOLOGY AND TECTONIC SETTING

In the study area the eastern portion of the frontal ridge is made up principally of the Ruahine Range in the south, the Wakarara Range in the centre and the Kaweka Range in the north. The Ruahine Range has an altitude of 1000 - 1700 m above sea level and a NNE-SSW trend. The range, of Triassic and Jurassic age, is composed of largely unfossiliferous, fine to medium muddy sandstone, and alternating muddy sandstones and argillite with local occurrences of red chert (Kingma, 1959). These strata have been slightly metamorphosed (Kingma, 1962) and are commonly referred to as Mesozoic greywacke. The Range was not emergent until the early Pleistocene (Beu et al., 1980). The strata are now highly deformed and overturned to the northwest (Spörli & Bell, 1976). The persistence of the Range (the axial tectonic belt) is attributed to rock strength and tectonic uplift (Kamp, 1992).

The Wakarara Range is a greywacke piercement, emergent in the latest Waitotaran. Plio-Pleistocene beds are found on the eastern side of the range, where upper Pliocene beds rest unconformably on the greywacke basement rocks. Extensive terracing is evident on both sides of the range. In the east Nukumaruan marine strata unconformably underlie Castlecliffian and Haweran terraces. The range is flanked in the west and south by faults and in the east by steep-dipping upper Pliocene strata (Kingma, 1958).

The Kaweka Range is also an indurated greywacke piercement. These Torlesse rocks are unconformably overlain by a Miocene-Pliocene cover sequence that includes sandstone and limestone (Te Waka Limestone). The limestone forms a prominent buttress to the west and north of the range (Browne, 1986).

Immediately east and down dip of the Ruahine Range lies the western portion of the accretionary ridge. This is a belt of lowlands extending northeastward from Wairarapa to Hawkes Bay. Sediments in this basin are fossiliferous marine mudstones, sandstones, and thin coquina limestones of late Pliocene and early Pleistocene age (Kamp, 1992). The inboard portion of the accretionary margin is exposed today because of the late Neogene subduction of relatively thick buoyant crust of the Hikurangi-Chatham plateau - a segment of the Pacific Plate - which is both thicker and less dense than typical oceanic crust. The result is that Neogene and Quaternary strata are emergent over a large area of the forearc (Kelsey, et al., 1995).

Oblique convergence at the plate boundary has resulted in strain partitioning across the accretionary ridge. At present the dominant strain regime along the eastern boundary of the frontal ridge is strike-slip faulting. In this region, the Mohaka and Ruahine Faults - two major extensions of the Wellington Fault - accommodate the dextral component of the oblique convergence along the plate margin (Eardman & Kelsey, 1992; Kelsey, et al., 1995).

The NE-SW trending Ruahine Fault is generally located within greywacke basement rocks on the hilly eastern flanks of the Ruahine, Black Birch and Kaweka Ranges. In places slivers of Neogene sediments are infaulted against it (Grindley, 1960). North of the field area the fault crosses alluval surfaces.

In the southern part of the study area the Mohaka Fault forms the boundary between Mesozoic basement and Neogene strata in the Kashmir/Hinerua/Big Hill regions. North of Big Hill the fault forms the contact between the Neogene rocks within the Ohara Depression and the emergent greywacke strata of the Wakarara Range to the east.

Immediately north of the Wakarara Range the fault trace is within Neogene sediments, but is poorly defined as far as the Tutaekuri River. North of the river the trace is again within Neogene strata in the Hawkstone area. Farther north the fault trace takes a more northerly direction and is seen as a break in slope along the western foot of the Maniaroa Range.

In places the Kaweka Range is bounded in the east by the Maniaroa Fault. The major stress direction on this fault is northeast-southwest. This is sub-parallel to the major strike-slip faults in the area, and normal to the compressional direction in the immediately adjacent forearc basin (Pettinga, 1982). Intrablock faulting is common in the frontal ridge domain. In this area emergent greywacke blocks downstep to the west across each of the intrablock faults (Kamp, 1992).

Within the study area both the Mohaka and Ruahine Faults have distinct surface traces, and are seen as major lineations across the landscape. Both faults are currently manifest as a break in slope with the throw up to the east. Other fault induced landforms in the study area include shutter ridges, ponded drainage and sag ponds, pressure ridges and tectonic bulges. The gross tectonic structure of the Kaweka area consists of northeast-trending horsts and grabens (Browne, 1986). Horst and graben topography is also apparent in the Wakarara Range and Ohara Depression area, as a consequence of lateral displacement on the Mohaka and Ruahine Faults (Lensen, 1958). Right lateral movement along the Mohaka Fault is also indicated in many places by right-laterally offset spurs. Other geomorphic features along the faults include offset streams, ridges and river terraces.

5.3 PALAEOVEGETATION

A diagrammatic overview of the vegetational history of western Hawkes Bay as revealed by this study, is included as an aid to the following discussion (Figure 5. 1). This history relates to a region extending 94 km along the western perimeter of the province from Kashmir in the south to Te Pohue in the north.

Although the length of the palaeovegetational history at the six sites varies, from c. 500 years at Willowford to c. 6500 years at Hawkstone, western Hawkes Bay was predominantly forested during the Holocene until anthropogenic disturbance occurred.

In general there is a progressive change in tall forest composition long the 94 km transect (Figure 5. 1). In the Kashmir region in the south, the vegetation cover for at least the last 800 years, until European land clearance at the end of the nineteenth century, has been *Nothofagus* forest with a moderate mixed podocarp component. There has also been a large tree fern presence throughout the history of the site. At 800 yrs BP. *Prumnopitys ferruginea* was the dominant podocarp. The forest was disturbed about 600 yrs BP. and was slow to recover. However, *Nothofagus* was still the main species in the recovering forest, but *Dacrydium cupressinum* gradually replaced *P. ferruginea* as the dominant podocarp. Following a further erosional disturbance at the site c. 200 yrs BP. a diverse shrub component became established in the vicinity. The shrubs were mainly invasive taxa such as Asteraceae Tubuliflorae type, *Pittosporum*. *Pseudopanax*. and *Rhopalostylis sapida*. a medium sized tree, also became established. At the same time the tree component of the forest became more diverse with the introduction of *Halocarpis* (pink pine) and *Nestegis*. Both these taxa are favoured by disturance.

<-- 94 kms -->

<- South **SITE** North ->

		Kashmir <14>	Hinemaa <34>	Big Hill <18>	Willowford <10>	Hawkstone <18>	Te Pohue
	Present	PP+◇	PPP+	PPP+	##PP	PPP+	ff#◇
		++◇◇	+++◇	Δ+##	###Δ	##ff	◇◇+#
	500	++◇◇	+++◇	ΔΔ+#	ΔΔΔ+	◇+#f	◇◇+f
		+++◇	+++◇	ΔΔΔΔ		◇##f	◇Δ+f
	1000		+++◇	ΔΔΔ+		◇##f	◇◇◇f
Y			+++◇	h		◇#ff	◇◇Δf
	1500		+++◇	i		◇##f	◇◇Δf
E			+++◇	a		◇##f	Δ###
	2000		+++◇	t		◇+ff	◇◇Δ+
A			+++◇	u		◇+ff	
	2500		+++◇	s		◇+ff	
R			+++◇			◇#ff	
	3000			ΔΔΔ+		◇+ff	
S				ΔΔΔ+		◇+#f	
	3500			ΔΔΔ+		Δ◇+f	
				ΔΔΔ+		Δ+ff	
	4000					Δ+ff	
						Δ+ff	
	4500					Δ+ff	
B						Δ+ff	
	5000					Δ+ff	
						Δ+ff	
	5500					Δ+ff	
P.						Δ+ff	
	6000					+Δff	
						+Δ#f	
	6500					+Δff	

LEGEND

+ *Nothofagus* forest

Δ *F. taxifolia*/mixed podocarp forest

◇ *Dacrydium*/mixed podocarp forest

f Fernland

\# *Pteridium* scrubland

P Exotic pasture

Figure 5.1 Vegetation history of western Hawkes Bay from five sites along the Mohaka Fault trace and one from the lake at Te Pohue. The predominant forest type or types is indicated at each level unless forest cover is so reduced that scrub, fernland or pasture cover is more important. Use of symbols: 3 = abundant; 2 = many; 1 = common, where a similar number of symbols appear, the most common vegetation is always placed first. Also indicated in brackets is the distance between each site in kilometres along the 94 kilometre transect investigated.

Fourteen kilometres farther north in the Hinerua region the forest for at least the last 2800 years, up until European land clearance, was predominately *Nothofagus* with a minor *Dacrydium cupressinum*-dominated mixed podocarp component. This minor component included *Prumnopitys taxifolia*, *P. ferruginea*, and *Halocarpus biformis*. There was also a moderately large tree fern presence in the vicinity of the site up until a site disturbance about 1100 yrs BP.; a less dense tree fern cover continued after the disturbance. Small trees and shrubs such as *Coprosma*, Asteraceae Tubuliflorae type and *Lophomyrtus* were also present intermittently throughout the history of the site. *Rhopalostylis sapida* was a notable component of the forest until European land clearance.

Thirty-four kilometres farther north in the Big Hill region the vegetational history is recorded in two stages; one covering the period c. 3700 to 3000 yrs BP.; the other covering the period from c. 1100 yrs BP. to the present. The two stages are separated by a depositional unconformity. In this region there is a distinct change from the *Nothofagus*/ *Dacrydium* -dominated podocarp forest at the previous site, to a *Prumnopitys taxifolia*- dominated mixed podocarp forest with a minor *Nothofagus* component. What is very evident in the history of this site is that the forest record in both stages is almost identical. A change in vegetation at this site is only signalled following a series of fires. The first, c. 600 yrs BP., temporarily introduced a small amount of *Pteridium* into the record, but affected only the *Nothofagus* component of the forest. This fire is interpreted as due to volcanic activity or storm-induced lightning strike. The second fire, about 435 yrs BP., which severely reduced the general forest cover and was accompanied by a large influx of *Pteridium*, is attributed to Polynesian burning. As the result of European occupancy in the mid-nineteenth century, the vegetation was native grasses and scrub. *Pteridium* had left the record and a *Nothofagus* forest was slowly reestablishing in the region and sedges (Restionaceae) dominated the site vegetation.

The small tree and shrub component of the earlier forest was very rich and varied, with *Nestegis*. *Coprosma*, *Plagianthus* and *Pittosporum* being the dominant genera. In the later forest the small tree component was as varied as earlier, but not as important. Intially *Pittosporum* and to a lesser degree *Nestegis* were still the dominant understorey genera, with *Myoporum* establishing following the fire c. 600 yrs BP. This shrub then died out following Polynesian burning c. 435 yrs BP., when *Pteridium*, *Typha* and ferns invaded the site. One notable difference between the understorey components of these two forests is the presence of *Ascarina* in the earlier forest up to a disturbance c. 3300 yrs BP. Following the disturbance this genera was replaced by *Dacrycarpus dacrydioides*.

In the Willowford region, eighteen kilometres north of Big Hill, a *Prumnopitys taxifolia*- dominated mixed podocarp forest with a minor *Nothofagus* component was established by 500 yrs BP. Although minor *Elaeocarpus* and *Beilschmiedia* were present in this forest, the main understorey component was made up of several varieties of tree fern. The area was burned c. 480 yrs BP. and the forest destroyed. Following this burning *Pteridium* invaded the area and, along with two species of *Lycopodium* as well as some residual tree ferns and native grasses, remained the principal vegetation cover until European occupation in the mid-nineteenth century. From c. 480 yrs BP. until European occupation the Willowford area was continually fired. This is attributed to Polynesian burning in the furtherance of cultivating the fern root, *Pteridium*.

Ten kilometres north of Willowford, across the Tutaekuri River in the Hawkstone region, the vegetational history extends back some 6500 years. The record indicates there was a *Nothofagus*/ *P. taxifolia*-dominated mixed podocarp forest in the region around 6500 yrs BP. *Dacrydium cupressinum* was the only other podocarp of note in this forest.

By 3300 yrs BP. *Dacrydium* was establishing as the dominant podocarp in the Hawkstone region, with *P. taxifolia* reduced to a minor role. A decline in the importance of *Nothofagus* is also apparent as early as c. 6000 yrs BP. This decline continued as *Dacrydium* increased in importance after 3300 yrs BP. This coincided with the deposition of 200 mm of reworked Waimihia lapilli at the site. The entire forest was destroyed by fires following the Taupo eruption in c. 1850 yrs BP. Charcoal in the profile indicates these fires lasted for several centuries. As a result of these fires forest did not return to the Hawkstone region following the Taupo eruption.

However, it is possible that rather than a record of forest cover in the Hawkstone region, the c. 6500 yrs BP. vegetational history at this site may be more representative of the vegetation growing in the immediate vicinity of the site, rather than on the site. The record indicates this area was covered by a fern- and scrubland. Initially several species of tree fern dominated the flora in conjunction with minor *Paesia scaberula* and *Pteridium*. Coincidental with the decline in *Nothofagus* c. 6000 yrs BP. , *Cyathea dealbata* became the dominant tree fern, while at the same time *Paesia scaberula* played a more important role and *Pteridium* became less important. Following the Waimihia eruption *C. dealbata* increased in importance up to the Taupo eruption; *Paesia scaberula* initially increased then became less important to barely register a presence at the time of the Taupo eruption; *Pteridium* initially expanded, then contracted, then expanded again to maintain a high, if somewhat erratic, presence up the to Taupo eruption. Following this eruption both *Pteridium* and *Asplenium* dominated the vegetation and tree ferns were reduced to a very minor role. After the post-Taupo fires ceased c. 1400 yrs BP., *Lycopodium* also became established in the area. Given the epiphytic nature of this plant it may have seeded in the burnt logs from the post-Taupo fires. Following a fire at c. 830 yrs BP. both *Asplenium* and *Lycopodium* died back and *Pteridium* totally dominated the vegetation around the site. This vegetation cover was maintained until European occupation in the mid- nineteenth century.

As discussed above (4. 5. 5), the prevailing wind in the Hawkstone region is westerly. It is very possible a hill directly to the northwest of the site and a high cliff farther west which extends beyond the southern limit of the site, protects the area from the full strength of the westerly winds. As pollen of tall tree origin is predominantly wind transported, the protection afforded by this high, upwind terrain could account for the low record of regional forest species in the vegetation record at Hawkstone. Thus the record at Hawkstone appears to be heavily dominated by inwash from the slopes around the site and reflects episodic disturbances of a local nature.

Eighteen kilometres northeast of Hawkstone, the vegetational history of the Te Pohue region dates back to the Taupo eruption of 1850 ± 10 yrs BP. At the time of the eruption a *Prumnopitys taxifolia* / *Dacrydium cupressinum* mixed podocarp forest, in conjunction with a minor *Nothofagus* component was well established in the region. Forest cover at Te Pohue was heavily reduced during the fires that accompanied the Taupo eruption. Immediately after the eruption *Pteridium* invaded the area. Within 200 to 250 years the forest in the region had fully recovered, with *P. taxifolia* recovering more quickly than *Dacrydium*. By c. 1550 yrs BP. *Dacrydium* became established as the major podocarp species in this mixed podocarp forest. Throughout the history of the site *P. taxifolia* appears to have suffered cyclic dieback every 500 to 600 years up to European forest clearance in the mid-nineteenth century. This forest tree is known to live up to 1400 years (Wardle, 1991), although Grant (1996) reports on finding trees up to 800 years in the Hawkes Bay region. It is possible this cyclic dieback is due to the effect of isolated cyclonic storms on a mature stand of these trees.

Tree ferns were the main understorey component of this forest both at the time of the Taupo eruption and afterwards. A very diverse small trees and shrubs component also played a minor role in both the pre-Taupo and post-Taupo forest. The pollen record indicates that predominantly the same species that were present before the eruption, returned afterwards. The main understorey taxa were *Pittosporum and Pseudopanax* both common to all sites within the study area, with the addition of *Pseudowintera*, *Myrsine* and *Hebe*. These last three could be indicative of slightly wetter, cooler conditions in this northern region.

In summary, the overall palaeoecology of western Hawkes Bay, can be divided into three zones.

(1) Prior to c. 6000 yrs BP. there was a *Nothofagus* forest with a minor *Prumnopitys taxifolia* component in the middle sector.

(2) From 6000 to 3300 yrs BP. *Prumnopitys taxifolia* replaced *Nothofagus* as the dominant forest species in the middle sector.

(3) For the past c. 3300 years there has been a *Nothofagus* forest with a minor mixed podocarp component in the southern sector, the continuation of a *Prumnopitys taxifolia* - dominated podocarp forest with a minor *Nothofagus* component in the central sector, and a *Dacrydium cupressinum*-dominated mixed podocarp forest with a minor *Nothofagus* component in the northern sector. About 3300 yrs BP. a change in the dominant tall tree in the northern part of the central sector (i.e. the Hawkstone area) from *Prumnopitys taxifolia* to *Dacrydium cupressinum* locates this region within the northern sector from 3300 yrs BP. to the present.

5.4 DISCUSSION

In this section, the results of this study are presented as an integral palaeohistory of western Hawkes Bay. Consideration of the palaeoecological findings from the sites are addressed under four headings: - climatic implications; fire influences, due to both natural and anthropogenic causes; the interaction between erosion and vegetation disturbances; and earthquake disturbance.

5.4.1 CLIMATE IMPLICATIONS

5.4.1.1 New Zealand Climate over the last 7000 years

The concept of a climatic optimum c. 3000 - 6500 years ago implying climate conditions as being slightly warmer thatn those of the present is firmly entrenched in the literature (Harris, 1963). However, during this period *Nothofagus* spread in many upland area, especially in the northeast of the South Island; *Dacrydium* and *Nothofagus menziesii* began to spread in coastal districts of the South Island; lowland forest replaced shrubland- grassland in central Otago; *Knightia* and *Nestegis* began to increase. At the same time as these new forest associations were forming, important taxa from previous forest associations were declining. *Ascarina lucida* went from being one of the most ubiquitous understorey trees in lowland and montane forests to being rare or absent. In the north and west of the country, summers appear to have been drier, and summer water deficits became a regular part of the annual cycle. As a consequence *Dacrydium* declined gradually in many western and northern areas. Winters became wetter in the east and lakes, swamps and peat bogs began to form (McGlone, 1983a; 1988).

Temperature and rainfall have been identified by Leathwick and Rogers (1996) as having a dominant role in determining forest successions after forest disturbance at a regional scale. Temperature because of its obvious effect in determining the range of species potentially able to occur an any particular site; rainfall because of its direct effects on soil moisture and indirectly as it affects soil development and erosion. A study of paleosols, which carry residual evidence of previous conditions, does not indicate post-glacial environments were significantly different from the present (Molloy, 1969). Distance from intact forest, topography, slope and solar radiation become important determinants in forest successions only at a local scale (Leathwick & Rogers, 1996).

McGlone (1988) suggests that there is physical evidence supporting the concept of a general decline in average temperatures over the past 3000 years, with a once mild equable climate giving way to one in which drought, frost and disturbance were common. McGlone believes this trend has been on going since c. 7000 years ago and is due to cool Southern Ocean air masses lowering the temperature. He believes that it is intensifying towards the present. Cooler conditions associated with stronger winds would have favoured the expansion of *Nothofagus*. The spread or increase of *Nothofagus* and *Libocedrus* in the uplands region is advanced by McGlone as a possible reflection of a more continental climate and cooler average temperatures. For the last 3000 years the spread of lowland forest was favoured by disturbance, seasonal climates and edaphic extremes, all of which indicate the present westerly and southwesterly airflow was in place.

Burrows (1982) maintains climate deterioration began several millennium ago. In the last millennium mean temperature has not varied by more than 0.5° C, and recent changes in climate were not great enough to have led to major environmental change (Burrows, 1982). Migrations, replacements and failure of regeneration of certain tree species in some areas could indicate a move to a more drought-prone and possibly colder climate beginning in the first half of the millennium, or earlier; or, alternatively, this could be interpreted in terms of minor alternation of consistently wet periods with drier periods (Burrows & Greenland, 1979).

Although some timberlines show signs of deterioration, there is no clear connection of this with climate. Most of the apparent variations in climate can be explained by latitudinal variations in the positions of pressure systems and changes in the rate of circulation due to a tendency for anticyclones to persist east of New Zealand at relatively low latitudes when there is a more westerly flow over New Zealand. Such changes cause fluctuations in amounts of zonal, compared to meridional low, resulting in fluctuating climatic regimes in different part of the country, bringing increased rain to one area and drought to another. Droughts and floods often occur in the same year (Burrows & Greenland, 1979). From the evidence of vegetation data it is now accepted that the earlier part of the Holocene was a period of generally milder more stable climates, and for the last 6000 years there has been increased seasonability and possibly increased windiness (McGlone et al., 1993).

However, recently podocarps have failed to maintain themselves in surviving lowland forests, except under special conditions; *Dacrydium* regeneration is also inadequate over the whole range of both islands as far north at 36°S . This, according to Elder (1963) rules out temperature, and throws doubt on climate, as the deciding factor for this forest tree.

In this respect Elder (1965) maintains the perceived *Libocedrus bidwillii* and *Halocarpus biformis* replacement by alpine scrub in the area covered by the Taupo Tephra in the northern Ruahine Range can be explained as a conspicuous pattern of old trees with no replacement in sight due to lack of seed source, and not to an unfavourable change in environment for these species within the Ruahine Range. Thus the current situation in the northern Ruahine Range is in effect the mid-point of a much longer period of change operative over the last 600 years but fixed by the 600 year life-span of these two species. The situation today, where over--mature trees are still dominant but with inadequate replacement, is essentially a stage in a fairly continuous sequence; trees with different lifespans would give different results. Evidence from the southern Ruahine Range indicates both species are capable of local recovery, regenerating vigorously on ground opened by fire, slumping, defoliation or eruption (Elder, 1963). It is generally accepted now that forest regeneration occurs as a result of disturbance, and the input of climate conditions in this regeneration is minimal.

Nevertheless, in the most recent decades, a worldwide increase in cyclonic storms and precipitation in general, together with warmer overall temperatures tends to indicate a change to a warmer wetter climate regime has now been entered into. Whether this change is a natural phenomenon, or due to human intervention, is still open to debate.

5.1.2 Late-Holocene Climate History of western Hawkes Bay

On the basis of vegetational history of western Hawkes Bay, the study area can be divided into three climate sectors: a southern sector incorporating the Kashmir and Hinerua areas, a central sector incorporating the Big Hill and Willowford areas and the Hawkstone area up to the time of the Waimihia eruption, and a northern sector containing the post-Waimihia segment from Hawkstone and the Te Pohue area.

In the southern sector a *Nothofagus* forest was established by c. 2800 yrs BP. at Hinerua. There was also a minor *Dacrydium cupressinum*-dominated mixed podocarp forest in the general area at the time. Around 800 yrs BP. when the Kashmir site began accumulating pollen and sediment, a *Nothofagus* forest with a minor *Dacrydium* component was also established in that area. The only difference between this site and Hinerua, fourteen kilometres farther north, was that around 800 yr BP. the mixed podocarp forest at Kashmir was more diverse, and also incorporated a minor *Prumnopitys ferruginea* component. Although both *Dacrydium* and *P. ferruginea* are considered as indicative of warm, moist conditions, the range of temperatures over which these two forest trees are found varies. *P. ferruginea* occurs over temperature ranges greater than 6°, Whereas *Dacrydium* has a more restricted temperature range.

In this respect temperature has been generally accepted as the dominant climate factor determining forest pattern. Forest instability occurs when forest species cannot migrate fast enough to occupy potential new sites and form suitable canopy replacements. One such situation occurs in podocarp forests growing adjacent to, but upslope of, *Nothofagus* forests, on cooler sites. In such a situation podocarp species become affected by low dispersal capacity due to the lowered temperature (Whitehead et al., 1992), effectively destabilising the forest.

At Kashmir the forest was temporarily destroyed c. 600 yr BP. It is just possible this destruction was due to gales associated with the Waihirere Erosional Period (Grant, 1985). However, this destruction cannot be unequivocally separated from possible effects of Polynesian fires or tectonic disturbance. The forest that gradually returned to the region had the same composition as before the disturbance. This indicates that the overall warm, wet conditions (possibly incorporating wide temperature fluctuations) previously indicated for this region, still prevailed after c. 600 yrs BP. Lack of charcoal in the record at this point, together with the return of a forest with the same composition as before, makes it unlikely the destruction of the forest was due to any anthropogenic intervention.

A minor but constant presence of *Pseudowintera*, both before and after the disturbance c. 600 yrs BP., also suggests no major change occurred in the climate regime at that time. *Pseudowintera* is a light demanding small tree found along forest margins where it often forms as extensive scrub areas after forest destruction in areas of higher precipitation. Given that the *Nothofagus* forest growing on the surrounding lowland hills around the site at Hinerua suffered no noticeable climatically related disturbance about 600 yrs BP., a local, short-term climate extreme (Molloy, 1969), possibly incorporating a temporary lowering of the temperature (Whitehead et al., 1992), would account for the temporary destruction of the forest at Kashmir about this time.

Grant (1963) postulates that within the temperature tolerance of each species, it appears that the vigour is related to the moisture factor in the growing season. He also believes that precipitation effectiveness has decreased significantly in the last 300 to 400 years. There is no evidence in the *Nothofagus*/podocarp forests in the southern part of the field area that supports this hypothesis. On the contrary the palaeo-record indicates a thriving forest existed at both sites during this period. Until European forest clearance the lower timber line at Hinerua extended almost to the lowlands. An early settler reports there were extensive areas of black and red beech containing scattered mixed podocarp stands in the Kashmir region from the Morecock Saddle in the south and extending north along the foothills of the Ruahine Range (Grant, 1996). Depressed timberlines such as that found in the southern sector, have been variously explained as, due to existing environmental variations (Wardle, 1963), past fire (Molloy et al., 1963), fog (Zotov 1938), misty cloud cover from the oceans which favour tall podocarp forest expansion (McGlone, 1983a), and catastrophic storms (Elder, 1963).

Tree ferns, which are considered to be favoured by a minimum of seasonal temperature and precipitation fluctuations, were abundant at Kashmir until forest clearance. Tree ferns were also extremely abundant at Hinerua until a site disturbance about 1100 yrs BP. and slightly less abundant over the past 1100 years. The presence of *Dacrydium* as the main podocarp tree at both sites also suggests seasonal temperature and precipitation fluctuations were minimal in this sector.

In contrast, in the central sector of the study area the forest was dominated by *Prumnopitys taxifolia* in conjunction with *Podocarpus totara* and *Dacrycarpus dacrydioides* until this mixed podocarp forest was, first reduced, then destroyed by anthropogenic disturbance about 500 years ago. This forest association is generally accepted as indicating dry conditions. The isolated presence of *Ascarina lucida* in the Big Hill region about 3300 yrs BP., before leaving the vegetation record, also suggests that a once mild, equable climate was giving way to one in which drought and disturbance was common. It may also be an indication that winter temperatures were cooling. *Nestegis* was also an important component of the pre-3300 yrs BP. forest in this region. The almost total elimation of this sub-canopy tree from the record after this date suggests temperatures had become both warmer and drier. The presence of *Dacrydium cupressinum* as only a very minor component of the forest, together with the almost total absence of tree ferns from the vegetational history, is further evidence that dry and variable conditions prevailed in this central sector after 3300 yrs BP.

A minor disturbance to the forest at Big Hill about 600 yrs BP. may have been due to a local, short-term climate extreme (Molloy, 1969) such as, for example, Grant's Waihirere Erosional Period. Microscopic charcoal indicates fire disturbed the *Nothofagus* forest about the same time. This may be due to gale and storm related lightning strike. However, subsequent anthropogenic burning of the area which eventually destroyed the *Prumnopitys taxifolia* forest at Big Hill, has clouded the issue.

There is no indication where the *Nothofagus* forest stands were growing within the central sector. Due to drier warmer conditions prevailing in this region for the last 3000 years, it is surmised this species was established on the higher ground to the west and in the higher reaches of the Ngaruroro River, where a more seasonal climate prevails than at Big Hill. South of Big Hill it is known there was an extensive coverage of *Nothofagus truncata* (hard beech) on the rolling country in the general Wakarara area and as far north as Smedley Station at the foot of the Wakarara Range, as well as within the range itself, when forest clearance began in the area at the turn of the century. Beech stands were also reported as growing within the mixed podocarp forests to the west of the Wakarara forestry settlement area at the same time. *Nothofagus truncata* has been regenerating along the roadsides in the Wakarara area since the turn of the century (Mrs. L. Warsnop pers. comm. 1996). However, these areas, although close to the drier central part of the field area, are situated down wind of it, and as such are unlikely to be the source of the *Nothofagus* pollen in the record at Big Hill. Thus it is accepted that the *Nothofagus* forest stands growing in the central sector during the past c. 3700 years have been situated on the lower eastern slopes of the Ruahine Range to the west and northwest of Big Hill, where Elder (1965) reports they are found today.

The forest growing in the Willowford area about 500 years ago was also a *Prumnopitys taxifolia* -dominated podocarp forest. However, in this forest both *Dacrydium cupressinum* and *Dacrycarpus dacrydioides* had a higher presence than at Big Hill. This suggests a slight increase in annual precipitation in the northern part of this sector, thus indicating a more equable climate regime than at Big Hill. A very large tree fern component supports this. The forest at Willowford was totally destroyed by Polynesian burning about 480 yrs BP. and did not return to the region. This suggests the forest was growing at the actual site along the banks of the Tutaekuri River adjacent to the site. The minor *Nothofagus* component in this forest also declined initially following the fire. So there could also have been isolated beech stands growing at the site, or alternatively, on the nearby Blowhard, where it is still recorded today (Elder, 1965); another possibility is this species was growing on the Kaweka Range to the northwest of Willowford.

The Hawkstone site provides the best evidence for climate change in western Hawkes Bay. The vegetation record indicates that prior to 6000 years ago a *Nothofagus* forest was established in the Hawkstone area. Associated with this forest was a *Prumnopitys taxifolia*-dominated podocarp forest with a minor *Dacrydium cupressinum* component. The understorey component of these forests was made up of pure stands of mixed tree ferns. This association suggests a cool, dry climate but with enough precipitation to support the *Dacrydium* and tree fern components.

This forest was destroyed by fire about 6000 years ago. All three of the above named forest trees were slow to reestablish. The returning forest differed from the previous forest in that all three species were present in equal amounts. This pattern could suggest a slight increase in rainfall; but equally it could suggest a much reduced seed source for all three species following the fire. The forest was affected by major fires twice in the following 2500 years. The tree fern component soon reestablished, albeit with a reduced diversity following each fire. So it is possible these fires are related to volcanic activity, as continuing volcanism would have reduced the seed source for the tree species, thus limiting reafforestation.

Immediately prior to the deposition of the Waimihia Lapilli c. 3300 yrs BP., the forest began expanding, with *Dacrydium cupressinum* emerging as the dominant forest tree. Following deposition of the Wamihia Lapilli, when the area was again affected by fire, *Dacrydium cupressinum* expanded significantly to totally dominate the forest flora within one to two hundred years of the event. *Prumnopitys taxifolia* underwent a more moderate expansion, while at the same time *Nothofagus* declined. This suggests a change to a wetter, warmer climate and, effectively places the Hawkstone region in the northern climatic sector from 3300 yrs BP. up to the present. This forest was again destroyed at the time of the Taupo eruption in 1850 yrs BP. and did not re-establish in the immediate area due to periodic burnings that lasted for several hundred years. It is possible these burnings destroyed the potential seed source for this forest.

The vegetation record at Te Pohue for the past c. 2000 years is indicative of a warm, moderately wet climatic regime, similar to the present, that favoured both *Dacrydium* and, to a slightly lesser extent *Prumnopitys taxifolia* expansion. *Nothofagus* has also been of minor importance over the same period. A healthy *Nothofagus fusca* forest stand exists today on the Te Waka Ridge above the Te Pohue site. It is probable this species has been growing on the ridge for the past 2000 years and its presence could be a reflection of a cooler local topoclimate at this higher altitude.

In summary, the vegetational history of western Hawkes Bay for the late Holocene is, in places, chronologically incomplete. However, on the basis of what is known the region can be divided into three climatic sectors; wetter southern and northern sectors, divided by a drier central sector.

- Prior to 6000 years ago the central sector experienced a cool dry climate, which favoured a *Nothofagus / Prumnopitys taxifolia* -dominated podocarp forest cover at Hawkstone. This forest was destroyed by fire about 6000 yrs BP.
- From about 6000 to 3300 yrs BP. a beech-conifer forest which included equal amounts of *Nothofagus*, *Dacrydium* and *P. taxifolia*, re-established in the Hawkstone area; and a *P. taxifolia / Nestegis* forest with minor beech was growing at Big Hill by 3700 yrs BP.
- There was a change in forest composition about 3300 yrs BP., when *Dacrydium* replaced *P. taxifolia* as the main forest type at Hawkstone, while at the same time minor *Dacrydium* entered the record at Big Hill, and *Ascarina* and *Nestegis* - two species which do not tolerate dry, and/or frosty contitions - declined. This suggests

the climate in the central sector became permanently drier but variable, and the higher rainfall indicated for the Hawkstone region places the region within the wetter northern sector from 3300 yrs BP. to the Present.

- Minor forest disturbance at Kashmir in the southern sector and Big Hill in the middle sector, about 600 yrs BP. could be evidence of a short term climatic extreme (Molloy, 1969), in the form of a stormy period accompanied by gales as proposed by Grant (1985). Two possible explanations as to why this event was not reflected by disturbance in the beech forest at Hinerua, which lies between Kashmir and Big Hill, is that first, this region is protected from the full force of the westerly weather by the Hinerua Ridge to the west of the site, and second, that, as the early European settlers at Hinerua found, beech forest is a lot harder to ignite than podocarp forest.

5.4.1.3 Discussion

While the climate in western Hawkes Bay may have become more variable since 3300 yrs BP., the evidence does not suggest there was a general decline in average temperature and a move to a more continental climate over the past 3000 years as occurred in other parts of New Zealand (McGlone & Moar, 1977; McGlone, 1983a; McGlone et al., 1984; McGlone, 1988). The evidence suggests the region was affected by a northward shift in rainfall patterns, possibly associated with increased westerly airflow, which would also have brought hot dry fohn winds to the region, and account for the increased dryness at Big Hill. The evidence suggests a more seasonal climate prevailed after 3300 yrs BP. This shift could explain the establishment and downward expansion of *Nothofagus* forests on locally exposed ridges in the rugged terrain of the foothills of the ranges since 3300 yrs BP. At Hinerua in the southern sector, beech forest was established by c 2800 yrs BP., and at Te Pohue, in the northern sector, beech was growing

2000 yeas ago. Local topoclimates with slightly cooler temperatures and more elevated precipitation levels than in the central sector are prevalent in these areas today, and there is no evidence that these conditions have not existed for the last 3300 years.

The evidence from western Hawkes Bay agrees with what has been reported from elsewhere in New Zealand concerning a continued expansion of beech forest after 3000 yrs BP. Beech expansion has been reported in Fiordland-western Southland (Harris, 1963; Johnston, 1978; Burrows and Greenland, 1979); and from 5350 yrs BP. in the north of the South Island (McLea, 1996). The expansion of *Prumnopitys taxifolia* at the expense of *Dacrydium* in the central sector since 3000 yr BP. is in agreement with what has been found elsewhere in New Zealand concerning lowland beech-free areas (McGlone & Moar, 1977; McGlone, 1983a; McGlone et al., 1984; McGlone, 1988).

However, the shift towards a greater representation of *Dacrydium* in the northern sector of the field area, appears to go against the general trend. This is probably a reflection of slightly elevated precipitation and a more equable climate in the rolling hill country of this part of western Hawkes Bay.

In the Hawkes Bay region the pre-forest clearance *Dacrydium/Prumnopitys taxifolia* association with a minor *Nothofagus* component in the Te Pohue region was also the type of forest cover in the Tutira region, situated in the rolling hill country east of Te Pohue (Wilmshurst & McGlone, 1997). Both these areas receive the same annual precipitation.

The *Prumnopitys taxifolia* dominant podocarp forest type growing in the central sector of the field area for at least the past c. 4000 years was also the main forest type in the

Poukawa Basin area, due east of the central sector (C. Hannan unpub. data; Pocknall & Millener, 1984; McGlone, 1978).

The *Nothofagus* forest with a mixed podocarp component found in the southern sector of the field area is a reflection of a slightly cooler, more seasonal climate than has been in place in the middle and northern sectors of western Hawkes Bay, for the last 3000 years.

The distribution of these three distinct forest associations, each with differing ecological requirements, tends to indicate that, for the last 6500 years, until anthropogenic disturbance began, climate has been the main forcing factor in determining the type of vegetation cover in western Hawkes Bay.

5.4.2 FIRE AND ANTHROPOGENIC DISTURBANCE

The vegetational history of western Hawkes Bay indicates that the forests in the region have been severely affected by fire at various times during the past 6500 years. These fires have been due to both natural causes and human intervention. The natural fires in the central North Island region, are usually attributed to lightning strike following volcanic activity. However, in western Hawkes Bay the possibility of lightning strike due to storm activity cannot be excluded. Until European occupation, human-induced fires were due to Polynesian burning of the forest to create space for the cultivation of the bracken fern, *Pteridium*. Following the milling of the remaining forests by European settlers, fire was used to clean up the cutover bush. Reports of these fires being fanned by high winds and raging out of control in western Hawkes Bay are numerous.

The distinction between natural and anthropogenic fires is indicated where an area is permanently deforested due to burning, and the forest is replaced by a continuous influx of abundant *Pteridium* accompanied by an equally continuous influx of microscopic and, at times, macroscopic charcoal into the sites.

There is abundant evidence of natural fires at Hawkstone, but evidence of natural fires is not common elsewhere in the vegetational record of western Hawkes Bay. Fire destroyed the forest at Hawkstone after 6000 year BP. This may be due to volcanic activity. The Motutere Tephra of 5430 ± 60 yrs BP. (Froggatt & Lowe, 1990) is a possible cause. Fire again affected this area about 1500 years later and may be related to the Hinemaiaia Tephra of 4510 ± 20 yrs BP. (Froggatt & Lowe, 1990). The area was again disturbed by ash and lapilli from the Waimihia Tephra of 3280 ± 20 yrs BP. (Froggatt & Lowe, 1990). Subsequent fires in the area may be related to the Mangatawai Tephra of

2500 ± 200 yrs BP. (Fergusson & Rafter, 1959), and the Mapara Tephra of 2160 ± 25 yrs BP. (Froggatt & Lowe, 1990). Following each of these fires a restricted forest returned to the area within about two hundred years. This return-time is in keeping with what Wilmshurst and McGlone (1996) have found from a study of Central North Island forests following the Taupo Tephra of 1850 ± 10 yrs BP. (Froggatt & Lowe, 1990). The post-fire forests were similar to those existing before each eruption-related fire. In the Hawkstone region immediately prior to 3300 yrs BP., *Dacrydium* had begun to expand due to a change in climate (5. 4. 1). This expansion continued after the Waimihia eruption of 3280 ± 20 yrs BP., (Froggatt & Lowe, 1990).

Following the Taupo Tephra of 1850 ±10 yrs BP. (Froggatt & Lowe, 1990), forest did not return to the area. Bracken, tree ferns and to a lesser extent grasses invaded. Continual fires for about 400 years kept forest regrowth minimal and *Pteridium* scrub high. Intermittent fires for the ensuing 400 years continued to restrict forest expansion. *Libocedrus* became part of the forest about 1100 yrs BP., possibly forming pure stands in response to the disturbed conditions. At the same time *Pteridium* was slightly suppressed. This is probably a reflection of the moist climate regime, as this fern tends to be suppressed by the returning forest in wetter conditions (Levy, 1923). A major fire occurred between 500 - 600 yrs BP. and *Pteridium* again flourished, as did tree ferns and grasses to a lesser extent. The cause of these latter fires is ambiguous. They do not appear to have had any detrimental affect on the local forest. The expansion of tree ferns in conjunction with the *Pteridium* tends to suggest this was not anthropogenic burning. A possibility is that the continual burning in this area was a direct result of ongoing volcanism associated with the Tufa Trig eruptive phase at Mt Ruapehu (Donoghue et al., 1995). What is most obvious is that endemic fire, probably due entirely to volcanism, has been the limiting factor in the failure of the forest to return to its former extent in the Hawkstone area following the Taupo eruption.

Fire following the deposition of ash and lapilli associated with the Taupo Tephra, also had a severely detrimental affect on the forest in the Te Pohue region. However, although this forest, situated at the base of the Titiokura Saddle, was within the range of the primary ignimbrite flow, the pollen record indicates the forest was not entirely destroyed. *Pteridium* and other seral flora, including *Coriaria* and *Coprosma* flourished immediately after the eruption. However, within two hundred years reafforestation was complete. The returning forest was almost identical in composition to that existing before the eruption. Although there is evidence of disturbance in the Te Pohue area in the post-Taupo forest, there is no evidence that fire was the cause.

In the southern part of the field area there is evidence of fire at Hinerua about 2050 yrs BP. The *Nothofagus* forest regressed slightly as a result, but had fully recovered within 130 years. The fire may be linked to volcanism, with the Mapara Tephra of 2160 ± 25 yrs BP. (Froggatt & Lowe, 1990) as a possible cause. However, given Hinerua's distance from the Taupo Volcanic Zone, it is unlikely this fire was due to volcanism. The fire is therefore attributed to lightning strike and may be an indication of severe drought conditions at the time, or alternatively, linked to the Mapara 2 period of storminess (2090 - 1855 cal yrs BP., Eden & Page, 1998). Charcoal near the top of the site records the historic fire of 1946 that, fanned by gale force winds, is known to have raged over the whole of the Hinerua Ridge following one of the most prolonged droughts recorded in Hawkes Bay.

The 1946 fire is also recorded at Kashmir, and severely affected both the beech and podocarp forest in the area. Land clearance for pastoral farming has restricted forest recovery in parts of the area, however, the record indicates *Nothofagus* is still the dominant forest type.

The fire that started in cutover bush at Norsewood on the plains below the Kashmir area, in the late summer of 1888, is known to have burned out of control for several months, with hot spots continually being rekindled by gale force winds. The fire is known to have reached up as far as the Kashmir area. Physical evidence of trees with burned bark from this fire, that continued to grow and were subsequently destroyed by the fire of 1946, lie on the slopes around the site today. Figure 4.1.7 is an example of a rimu tree that survived the first fire only to be destroyed by the second.

At Big Hill, traces of lapilli associated with the Waimihia eruption of 3280 ± 20 yrs BP. (Froggatt & Lowe, 1990) have been found, but there is no charcoal in the record to indicate fire affected the area at this time. The vegetational record also indicates there was no disturbance to the expanding *Prumnopitys taxifolia* forest at the time. A small amount of <5 μm charcoal has been identified above an erosional event which occurred c. 830 yrs BP. A fire disturbed the area c. 700 yrs BP. As discussed above (4.3.5) this fire is probably due to natural causes, on the basis that the *P. taxifolia* forest at Big Hill was not affected, but the *Nothofagus* forest, which may have been growing in the high country west of Big Hill regressed noticeably. A minor amount of *Pteridium* did grow initially near the site following the fire, and it is possible the fire represents early Polynesian burning of the forest to open up a track into the interior. However, *Pteridium* expansion was not sustained at this point, and this highlights the problem of distinguishing the earliest anthropogenic fires from a background of natural burning.

But there can be no doubt the continual firing of the area around Big Hill commencing about 435 yrs BP., which gradually destroyed the forest cover in the region and encouraged an abundant expansion of both *Pteridium* and *Typha* at the site, was due to Polynesian burning. The burning of the forest to promote the growth of *Pteridium* is also apparent at Willowford, where the forest was destroyed about 480 yrs BP. The sustained presence of charcoal in the record from this point and its association with a marked rise in *Pteridium* , (which is favoured by repeated burnings) at both sites, indicates land in western Hawkes Bay was cleared specifically for the cultivation of this fern root from about 480 yrs BP. Good fern root is not the product of a particular variety of *Pteridium* but of suitable soil conditions. The best roots were produced in loose, rich soils. In central Hawkes Bay the most favoured sites were patches of low-lying rich alluvial ground, and on the banks of the rivers (Best, 1976b). Colenso (1880) remembered travelling over an isolated hill of loose rich earth in the interior of central Hawkes Bay, which had been long farmed for its fine fern-root, and over which several battles had been fought for the use of the hill for the cultivation of *Pteridium* . The Maori were careful to burn off the fern plant from their diggings only in the proper season. Burning caused the bracken to produce finer roots; it also destroyed all other shrubs that had sprung up since the last burning . In Hawkes Bay this burning took place in October or November. A more detailed report of the importance, cultivation methods, and food preparation of this edible fern root, *aruhe*, for the early Maori, has been compiled from reports of early travellers in New Zealand and included as appendix 3.

Typha angustifolia (raupo) was also important for the early Maori. The pollen was collected and made into a farina from which meal-cakes were made and cooked in steam ovens (Best, 1977). The baked cakes were sweetish and light and tasted like gingerbread (Colenso, 1880). The starchy rhizome was also used for food in times of scarcity. Sometimes the root was eaten raw, or cooked and beaten to produce a farina from which cakes were made; alternatively the root was placed in gourds and steamed in pits. As in the case of *Pteridium* a cultivation site was selected where conditions favoured the growth of raupo in order to obtain fine, large roots. Poor growing conditions produced small, hard fibre-packed roots of no use as food. The pollen was collected at the site where it was sifted in close-plait baskets, and stored in baskets lined with leaves for transport. Raupo leaves were used extensively to line the walls of various types of buildings. The leaves were also tied together in bundles to make rafts. These rafts, which were both light and dry and strong, and initially very buoyant, were used as a means of transport both up and down the local rivers. Raupo was plentiful, when the rafts eventually became water-logged they were discarded and new ones built. A more detailed report of the importance of raupo for the early Maori, compiled from reports of early travellers in New Zealand, is included as appendix 4.

The sudden introduction of *Typha* to the vegetation at Big Hill following Maori burning of the area and its subsequent sustained growth, could be interpreted as on-site cultivation and harvest of this reed. Lack of charcoal, and a coincidental almost total absence of *Pteridium* and its replacement by native grasses, indicates cultivation of this fern root ceased in the early 1800s. This abandonment of the site could be a reflection of the growing importance of the introduced potato to the economy of the local Maori. The vegetation record suggests the cultivation of *Typha* may have continued after *Pteridium* cultivation ceased. This in turn could reflect an increasing use of raupo as a buildling material both in the construction of food storage huts, and the construction of transport craft for use on the rivers, both necessary to meet the requirements of increasing trade with early Europeans.

The vegetation record at Willowford, also indicates the fern root was cultivated in this area near the Tutaekuri River until the early to mid-1800s, when sheep were introduced and left to free-range graze the general area.

The dates for Polynesian land clearance in western Hawkes Bay in this thesis support the short chronology model of New Zealand prehistory advanced by Davidson (1981; 1984), The dates obtained by Wilmshurst et al. (1997) for Tutira and Rotonuiana in northern Hawkes Bay also support this model. However, what these dates represent is not Polynesian colonisation in the region, but the onset of pa (fort) building by early Maori settlers.

Radiocarbon determinations for Hawkes Bay archaeological samples measured at the University of Waikato Radiocarbon Dating Laboratory between 1975 and 1995 also support the short chronolgy model regarding Polynesian colonisation of New Zealand. These determinations were done on marine and estuarine shells, with material that originated from areas where there may be a high risk of oceanic upwelling or old carbon dissolution having been rejected (Higham & Hogg, 1997). The dates obtained indicate that colonisation in Hawkes Bay occurred probably no more that 850 yr BP., with colonisation by c. AD 1100 as proposed by Anderson (1991) most likely.

For clarity of argument, the radiocarbon dates obtained for the Hawkes Bay region have been presented graphically, based on oldest dates for each site, to give an indication of the date of the first colonisation at each site (Figure 5.1). A full list of all radiocarbon dates obtained for the Hawkes Bay region by Higham & Hogg (1997) is included as appendix 5. The radiocarbon dates suggest that Polynesian occupation first occurred in the Inner Harbour area, and gradually spread inland in a southwesterly direction over the ensuing 350 years. The older date of 1040 ± 60 at Parangatau Pa, near Cape Turnagain, may represent an early landfall, or be an anomaly.

The bracken root *arhue*. was stored in the Pa as a food source in times of social unrest. Comparison of the above dates with radiocarbon dates obtained for land clearance in conjunction with the cultivation of the bracken root in Hawkes Bay, indicate Polynesians had been settled in the region for at least 350 years, before intertribal wars, associated with fortified pa building, broke out.

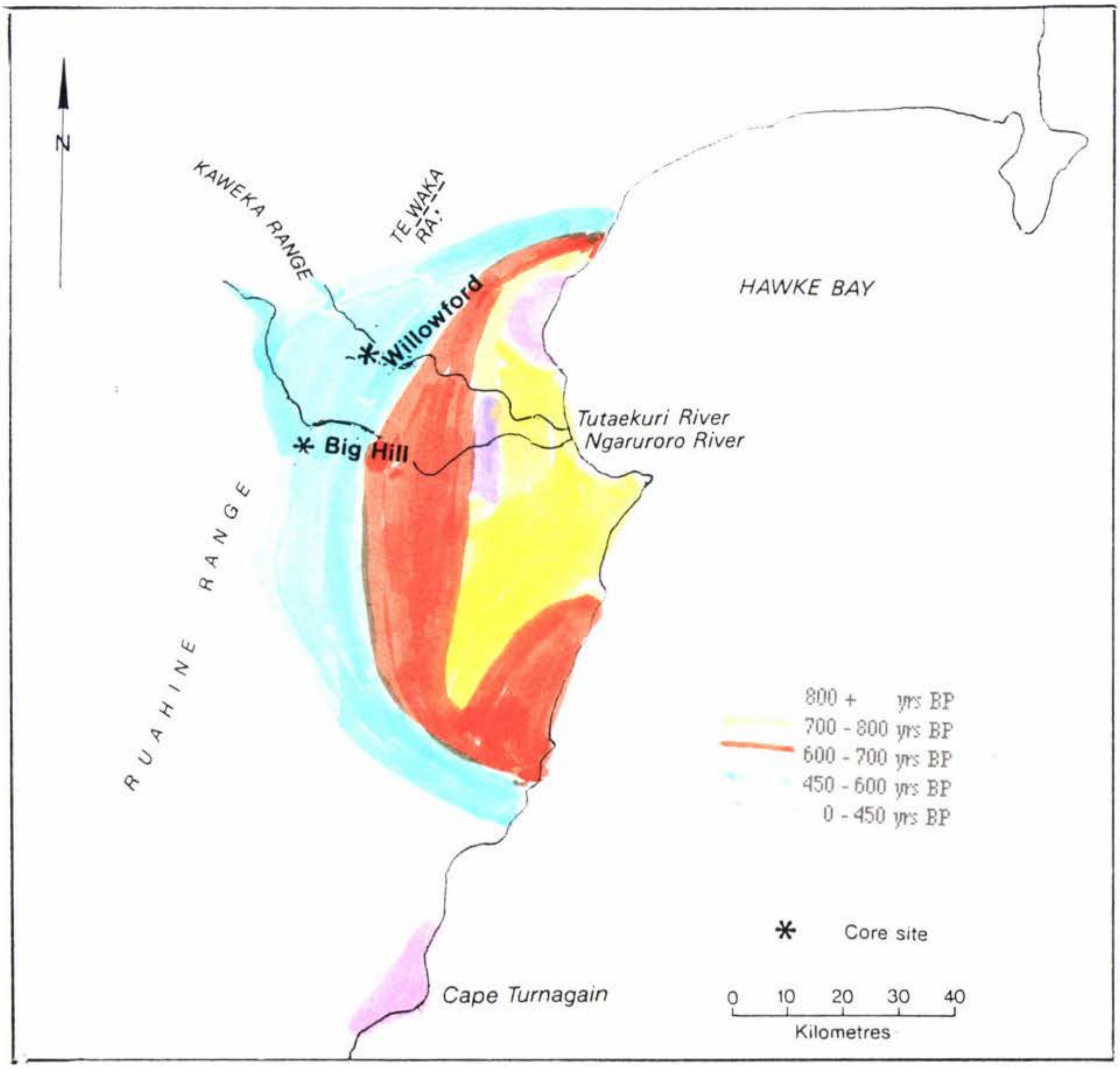


Figure 5.2 Polynesian colonisation of Hawkes Bay, based on oldest radiocarbon dates obtained from shells submitted from each site (adapted from Higham & Hogg, 1997)

5.4.3. INTERACTION BETWEEN EROSION AND VEGETATION DISTURBANCE

The role erosion has had in vegetation disturbance, and conversely, the role vegetation disturbance, in the form of forest destruction has had in promoting accelerated erosion, is hotly debated. Within the field area the situation is further complicated by the close proximity of the Mohaka Fault. This section deals with the identification of possible storm-induced erosion at the sites.

Grant (1985) proposes that periodically over the last 2000 years there have been high frequencies of intense cyclonic rainstorms resulting in widespread landsliding in the hinterland. McFadgen (1985; 1989) suggests this periodic instability is also recognisable in coastal sequences, where episodes of sand movement and deposition generally coincide with Grant's periodic alluvial aggradation. However, Grant proposes there were seven stable periods when soil formation occurred and McFadgen only two such periods. The situation is further complicated by Pearse and Watson (1986) who point out that several hundred years are required for the products of inland erosion to filter down to the coast. Nevertheless, Page et al., (1994) have linked one of the eight stormy periods they have identified in the sediment record at Tutira in the last 2200 years, with Grant's Matawhero Erosional Period (330 - 460 yrs BP.).

McFadgen (1985) does not believe instability at the coast can be attributed to human occupation. McGlone (1983b) on the other hand believes that Polynesian burning of the forest may have initiated subsequent erosive episodes, and that all deforestation by humans has led to soil erosion and it is most unlikely this has not affected coastal dune systems. O'Loughlin et al., (1982) have shown that removing forest in small catchments can lead to slope erosion. However, from their study of hillslope morphology, Page and

Trustrum (1997) have found that landsliding was also the major process in hillslope development under indigenous forest. Crozier (1996) lists seismic activity, fluvial undercutting, human effects, and changes in the non-climatic threshold for landsliding due to stress release, weathering or tectoncially induced base level changes, as all being possible potential triggering factors in landsliding. De Rose et al., 1993) report that large magnitude storms are, nevertheless, the main agents of sediment generation and account for most of the slope failures on steep ground.

In the steep erosion-prone terrains of the eastern Ruahine Range, soils which form on the shattered greywacke substrate are generally of a skeletal nature, due to the low return-time between erosional episodes. High rainfall and periodic storms have been identified as the main triggers for erosion. The situation is compounded by remarkably high uplift rates along the easternmost flank of the range of up to 4 mm/year. Recent increased erosion, due to forest deterioration caused by introduced animals, has further worsened the situation, with decay of the former tree root systems now leaving the slopes more vulnerable to mass movement (Cunningham, 1981). Large daily rains greater than 25 mm have the potential to cause sheet and gully erosion. General surface losses may occur with every run-off producing rain. This wastage over a long period may account for a greater regional soil loss than do catastrophic mass movements (Grant, 1966).

To separate storm-induced erosion from earthquake-induced erosion along the trace of the Mohaka Fault, is not possible unless each erosional event identified along the fault can be linked to other known erosional events in the western Hawkes Bay region. Localised erosional events have been identified at each of the sites when sediment pulses of sand, gravelly sand, or gravel occur. At times these pulses are found as discrete layers within accumulating peat; as a layer terminating peat accumulation; or in conjunction with a paleosol or charcoal layer. Contact with the sediments above and below may be wavy but distinct, gradational, or abrupt.

In the field area, site specific erosion can be identified when there is a change signalled in vegetation that grows on or around the margins of the site, while at the same time, no change is signalled in the regional forest. This could involve changes such as a temporary, total, or partial elimination of site vegetation, followed by a change to seral vegetation indicative of site disturbance, or a subsequent return of the previous vegetation site; or a combination of the two. The site specific vegetation change is due to either localised storm damage, or an earthquake event. The re-establishment of stable conditions at the site is indicated when the seral component disappears from the record, or the local vegetation stabilises. However, when the change coincides with a change in the regional forest compositon, this is interpreted as a local, short-term climate extreme as defined by Molloy (1969). As a consequence the only way to decide whether a site-specific erosional event reflects a climate or an earthquake event is to link the event to other known, or presumed events of similar origin, in western Hawkes Bay.

At Kashmir there are several erosional events in the 800 year history of the site. The first erosional event occurred about 600 yrs BP. This is signalled by a gravelly pulse in the stratigraphic column at 1.75 m depth. This event was accompanied by a regression in both the *Nothofagus* and mixed podocarp forest in the region, and is interpreted as a further local short term climate extreme. The event may be linked to the Waihirere Erosional Period (550 -660 yrs BP.) (Grant, 1985). The second erosional event is signalled by a gravel lens in the stratigraphic column at 1.31. m. At this point there was a minor regression in the regional forest, but a marked increase in tree ferns around the site.

This suggests conditions were marginally warmer and wetter than previously. This event may be linked the Matawhero Erosional Period (340 - 460 yrs BP.) (Grant, 1985). About 1770 AD. a 10 mm pulse of detrital sand was deposited at the site (0.80 m depth). The depth of sediment indicates a major erosional event, and may be associated with a single cyclonic storm or a stormy period. The regional forest was not affected at this time, but there was a further substantial increase in tree ferns at the site, possibly indicating a warmer, wetter period. It is possible this event may be linked to the Wakarara Erosional Period (150 - 180 yrs BP.) (Grant, 1985).

At Hinerua a pebbly lens in the stratigraphy at 1.50 m depth indicates an erosional event occurred about 2500 yrs BP. Following the event tree ferns increased markedly. This increase was sustained until about 1100 yrs BP. when the site was severely affected by an earthquake. This notable presence of tree ferns may be an indication of a localised climate warming, but, alternatively it could reflect a beech forest with a dense tree fern understorey component. A buried soil about 600 yrs BP. (0.61 m depth) with a log of wood embedded in the sediments immediately above, indicates a further erosional event occurred. Increased Cyperaceae suggests the site was wetter than before, but there is no change to the *Nothofagus* forest. This event is interpreted as a local short-term climate extreme, and may be linked to the Waihirere Erosional Period (Grant, 1985).

At Big Hill there is an erosional event about 750 yrs BP. (0.72 - 0.73 m depth). On the grounds that it does not fit any known coseismic event along the Mohaka Fault, nor does it fit any of the sustained storm periods identified by Eden and Page (1998) or Grant (1985), this event is interpreted as a local short term climatic extreme, that is, an isolated cyclonic storm.

There is no evidence at the Willowford site that relates erosion to storm damage. Equally, there is no evidence at Hawkstone that links any erosion to storm damage. All disturbances at these two sites are related to burning - anthropogenic in the case of Willowford, and volcanic, in the case of Hawkstone.

At Te Pohue there is a disturbance in the stratigraphy at 0.90 m depth signalled by a sharp natural break in the stratigraphy. Just prior to this there is a notable minor increase in *Pteridium* (0.94 m depth), while at the same time tree ferns temporarily diversify. There is no change to the forest in the region. This disturbance occurred about 600 - 700 yrs BP., and reflects locally disturbed conditions due to increased storminess. This storminess could be associated with the Waihirere Erosional Period (Grant, 1985).

5.4.4 EVIDENCE OF EARTHQUAKE EVENTS

Tectonic uplift in western Hawkes Bay has resulted in many of the steeper hill-slopes being prone to mass wasting and earth flow processes. For this reason many of the steeper slopes have loosely compacted cover beds made up of slope-wash of loessial and tephric origin. Coseismic shaking is one means of remobilising these poorly consolidated colluvial deposits. The resulting erosion produces a predominance of rockfalls on steeper scarp slopes and debris avalanches on dip-slopes. These deposits are found interbedded with limestone and mudstone blocks of Neogene age, which crop out upslope. In forest and scrub-covered areas these soil and regolith failures are usually episodic, and are associated with high intesity rainfall events or earthquake shaking. Deep-seated tectonic movement in the region also causes mass creep of the highly shattered greywacke sandstone and argillite strata along the eastern slopes of both the Ruahine and Kaweka Ranges. The creep process is identifiable by tension cracks across steep slopes. Long linear debris avalanche scars are common in the steeplands on the upper reaches of the river basins in western Hawkes Bay. The product of all types of erosion is eventualy introduced into the local drainage system, and stored along various reaches of the fluvial system. Transfer and distribution of these erosion products are controlled locally by the incising ability of each individual fluvial system (Hammond, 1997).

Ground breaking associated with high magnitude earthquakes can be the trigger in initiating erosion in an area already destabilised due to storm impact. In this way matters are compounded farther downstream where the erosion products convert to aggradation sediments and are deposited over the lowlands in the form of valley infilling, fans and piedmont plains. In Lake Tutira, earthquakes between 2000 and 2300 yrs BP. may have contributed to the magnitude, if not the frequency of some storm sediment-pulses in the Mapara 2 period (Eden & Page, 1998). Ground shaking may also increase the susceptibility of soils to later storm erosion.

Site specific erosion is common at all sites that make up this study. In each case the triggering factor could be seasonally heavy rains, a periodic cyclonic storm, continuous soil creep, ground shaking due to coseismic activity, or any combination of the above. Identification of erosional events in this study as evidence of possible earthquake events at various times in the past, is dependent on linking each coseismic event identified, to a dated earthquake recorded elsewhere along the trace of the Mohaka Fault by other workers. It is assumed a movement along the Mohaka Fault was responsible for the initial formation of each of the sites that make up this study. Each site will be discussed individually.

Not long before 800 yrs BP. an earthquake along the segment of the Mohaka Fault at Kashmir is assumed to have resulted in the formation of the site. Corroborating evidence are earthquakes recorded on the Wellington-Mohaka Fault, in Wellington c. 800 yrs BP. (van Dissen et. al., (1992); post-860 yrs BP. at Pahiatua (Beanland & Berryman, (1987); on McCool farm South of Big Hill, c. 805 yr BP. (Neall & Hanson, 1995); and a large erosional event along the Mohaka Fault in the West Tamaki River area c, 770 ± 60 yrs BP. (Hubbard & Neall, 1980) which is interpreted here as representing the same earthquake as that which affected Kashmir.

A gravel lens in the stratigraphy at 0.43-0.44 m depth records a further earthquake at Kashmir in 1864 AD. This historical earthquake was felt at Ashley Clinton, on the plains immediately northeast of Kashmir, by early settlers.

At the Hinerua site a movement along that segment of the Mohaka Fault c. 2800 yrs BP. is assumed to be responsible for the formation of the site. On Trotters farm in the Kumeti area earthquakes in trench #1 pre-2090 yrs BP. and/or post 3110 yrs BP. in trench #2, (Neall & Hanson, 1995) may be related to this event.

A 50 mm log in the stratigraphy at 0.90 - 0.95 m depth accompanied by a severe reduction in tree ferns and other near site taxa, is interpreted as evidence of a further earthquake along the Hinerua segment of the Mohaka Fault, c. 1100 yr BP. Corroborating evidence of movement along the fault at this time is recorded at Pahiatua between 1010 and 1160 yrs BP. (Beanland & Berryman, 1987); an earthquake dated post-1105 yrs BP. at Inglis farm at Woodville (Neall & Hanson, 1995); and an earthquake recorded post-1165 ± 50 yrs BP. on the Mohaka Fault in the Wakarara Range area (Raub et al., 1987).

About 600 yrs BP. the Hinerua site was again affected by an erosional event that buried the then current topsoil. This erosion may have been storm or earthquake generated. The date of this event is close to that of Grant's Waihirere Erosional Period; the vegetation record indicates tree ferns temporarily decreased following the event. There is an erosional event recorded just south of Big Hill in the Mc Cool farm trench between 805 and 605 yrs BP. (Neall & Hanson, 1995), that is interpreted by these writers as earthquake or storm related. It would appear that the two events are related in time, but there is no clear indication as to whether the erosional episode was storm or earthquake generated.

At Big Hill the formation of the site about 3700 ± 90 yrs BP., is probably due to a movement along the Mohaka Fault. Beanland & Berryman (1987) report a movement on the Pahiatua segment of the fault c. 3840 yrs BP.; Neall & Hanson report a post-4335 yr BP. earthquake in their #3 trench on Inglis farm, near Woodville; as well as a post-5000 yr to pre-2090 yr BP. movement in their #1 trench on Trotter farm at Kumeti; and post-4295 to pre-3280 yrs BP. movement in their trench on Mc Cool farm near Big Hill.

The Big Hill site was destroyed by a large erosional event after the Waimihia Tephra was deposited c. 3300 yr BP. and before 3075 yrs BP. This is interpreted as a large magnitude earthquake on the basis that the site was totally destroyed by a 190 mm influx of greywacke colluvium, and no sediment or water accumulated at the site for about 2000 years. Possible corroborating evidence of this event is a pre-2090 yrs BP. movement in the Trotter #1 trench; a post-3110 yrs BP. movement at Trotter #2 trench and a pre-3280 yrs BP. movement in the McCool trench near Big Hill (Neall & Hanson, 1995).

At Big Hill after a c. 2000 year period when no sediment accumulated at the site, and following a further movement along the Mohaka Fault c. 1150 yrs BP. the site again began collecting sediment. Corroborating evidence of an earthquake about this time comes from Beanland & Berryman (1987) who report a 1010 to 1160 yrs BP. movement along the fault at Pahiatua; Neall & Hanson (1995) report a post-1105 yrs BP. movement in their #4 trench on Inglis farm near Woodville; and Raub et al. (1987) report a post-1165 ± 50 yrs BP. event within the Wakarara Range.

About 830 yrs BP. there was a 10 mm influx of gritty, coarse, sand into the site at Big Hill, (0.72 - 0.73 m depth). No pollen accumulated at the time, but the vegetation record indicates there was no change in the *Prumnopitys taxifolia* forest growing in the area. However, *Myoporum* flourished at the site following the event. This small tree is found along forest margins and in isolated exposed sites. Its appearance after the erosional event suggests the former vegetation growing around the site -

predominantly *Nestegis*, *Pittosporum* and *Leptospermum* - was destroyed during the event. These three latter species are opportunist early colonisers. Their disappearance after the event does not suggest widespread storm damage, which would have favoured their expansion, but rather localised site specific damage, that destroyed the vegetation growing at the site. Such damage would occur following a large coseismic movement along the Mohaka Fault at Big Hill.

Corroborating evidence that there was a large magnitude earthquake along the Mohaka Fault about 830 yrs BP. is the evidence cited above for the coseismic movement that resulted in the formation of the Kashmir site. It would appear this movement can definitely be traced from Pahiatua in the south to Big Hill in the north, and possibly as far south as Wellington. The evidence suggests that the segment of the Mohaka Fault from Pahiatua to Big Hill has moved as an intergral unit twice in the recent past, once about 1010 to 1165 yrs BP. and again about 800 yrs BP.

At Willowford the Mohaka Fault trace is not clear and there is no local evidence of coseismic activity. However, it is assumed the site formed following an earthquake about or earlier that 500 yrs BP. This event may be related to post-1850 yrs BP. events recorded by Neall and Hanson (1995) in their trenches on Syme farm at Hawkstone, and on Wedd farm at Te Pohue, but the link is extremely tenuous.

At Hawkstone a movement along the Mohaka Fault about 8770 yrs. BP. (Neall & Hanson, 1995) blocked the drainage at the site. By 6750 yrs BP. a topographical depression had formed at the site and peat began accumulating. There is no evidence of any further disturbance that could be explained as coseismic activity until about 660 - 700 yrs BP. (0.35 m depth) when the site was disturbed by an erosional event and sandy silt began accumulating. *Pteridium* , *Cyathea dealbata* and the aquatic Cyperacese, all increased after this disturbance. This vegetation association does not suggest Polynesian burning of the area in furtherance of the cultivation of the bracken root.

At Te Pohue, 18 kilometres to the north, there is no disturbance that can be attributed to coseismic activity apart from a site specific event that occurred around 700 yrs BP. (0.95 m depth). At this point there is no change in the podocarp forest other than that caused by natural senescence that has been discussed elsewhere. However, there is evident of a decline in tree ferns and corresponding increase in *Pteridium*; but there is no evidence that fire disturbed the site at this time.

As discussed above (5. 3) this disturbance to the vegetation may be linked to a short term period of increased storminess. However, the disturbance, which appears to have affected only the vegetation around the lake, could also be linked to a movement on the fault. On the Wedd farm on nearby Puketitiri Road, as well as on the neighbouring Duno farm, one post-1850 yrs BP. earthquake is recorded on the Te Waka Splinter Fault. One post-1850 yr BP. earthquake is also recorded in the Syme trench along the Mohaka Fault at Hawkstone.

Given the close proximity of the estimated dates, it is very possible these localised disturbances to both the accumulating sediments and the near site vegetation at Hawkstone and Te Pohue record one and the same event. It is quite possible this event was coseismic in nature.

Two fault movements have also occurred since 1900 yrs BP. along the Mohaka Fault near the Hautapu River, north of Te Pohue. One c. 1200 yrs BP., caused large landslides in the Mohaka River at Maungataniwha (Hull, 1983). It is also possible these coseismic events on the main fault and splinter fault are linked and represent a phase of coseismic activity in the wider Te Pohue area.

About 800 yrs BP. appears to have been a very active coseimic period along the Mohaka Fault in western Hawkes Bay. Unfortunately for interpretation purposes, the period also appears to coincide with the commencement of a time of increased storminess (Grant, 1989). Earthquakes around 700 yrs BP. may have contributed to the magnitude if not the frequency of some storm sediment pulses found in the sediments at some of the sites. Ground shaking also may have increased the susceptibility of the soils and sediments of the slopes around the sites to later erosion.

About 1150 yrs BP. also appears to have been a very active coseismic period along the Mohaka Fault in western Hawkes Bay. This period does not coincide with a known time of increased storminess. Nevertheless, sedimentological changes at two of the sites is notable about this time. Mirroring this change are site specific changes in vegetation composition that indicate ecological disturbance.

It would appear that, by very careful sifting of the evidence, and the meticulous elimination of other possibilities, some small scale disturbances that affect both the accumulating sediments and the site specific vegetation in an area adjacent to a fault, could be interpreted as evidence of earthquake activity. The linking of an identified disturbance to a known coseismic event along the same fault trace would be an added interpretive bonus. The disturbances in the stratigraphy of the sites in this study which have been interpreted as possible earthquake events are presented in Table 5.1.

NATURE OF EVENT	KASHMIR	HINERUA	BIG HILL	HAWKSTONE	TE POHUE
Historical earthquake	1864 AD				
Storm or coseismic event	c 600 yrs BP	c 600 yrs BP			
Storm or coseismic event				660-700 yrs BP	c. 700 yrs BP
Earthquake	c.800 yrs BP	c. 800 yrs BP	c. 830 yrs BP		
Earthquake	Pre 800 yrs BP	c. 1100 yrs BP	c.1100 yrs BP		
Earthquake		c. 2790 yrs BP			
Earthquake			c. 3200 yrs BP		
Earthquake			c. 3700 yrs BP		
Earthquake				pre 6750 yrs BP	

Table 5. 1 Faulting events identified on the Mohaka Fault trace in western Hawkes Bay (this study)

CHAPTER SIX : CONCLUSIONS

The pollen and charcoal records of sediments from (a) a flush, two peat mires and two ponds from a 94 km transect along the Mohaka Fault trace, set in the eastern foothills of the Ruahine Range, in western Hawkes Bay, and from (b) a lake at Te Pohue in north-western Hawkes Bay, indicate that from the late Holocene to the present, the region may be divided into three climate sectors: a dry central sector (Big Hill site, Willowford site and the lower - earlier - part of the Hawkstone site); flanked by moister southern (Kashmir and Hinerua sites) and northern sectors (Te Pohue and the upper, more recent, part of the Hawkstone site).

The regional vegetation in the southern climate sector was dominated by a *Nothofagus* -mixed podocarp forest in the Kashmir region from c. 800 yrs BP. up to when the site was affected by fire in 1888. In the Hinerua region, 14 km farther north, *Nothofagus fusca*, with a minor *Dacrydium cupressinum* dominated/mixed podocarp forest, was established by c. 2790 yrs BP. This forest remained undisturbed until the region was cleared for intensive farming by European settlers in the late nineteenth century.

In the central sector from c. 3700 to 3000 yrs BP. the regional vegetation was predominantly a *Prumnopitys taxifolia*/mixed podocarp forest. There was also a notable *Nothofagus* component in the region. A c. 1900 year hiatus in the vegetation record occurred between c. 3000 and 1150 yrs BP. when no sediment accumulated at the Big Hill site. At c. 1150 yrs BP., when sediment accumulation resumed at Big Hill the regional forest of the central sector was still a predominantly *Prumnopitys taxifolia*-dominated/ mixed podocarp forest. *Nothofagus* however, was less important in this latter forest, and was confined to the cooler, moister, higher terrain to the west of Big Hill where it is well established today. At Willowford, 18 kms north of Big Hill, a *Prumnopitys* *taxifolis*-dominated mixed podocarp forest was also established by 500 yrs BP. when the site was formed. At Hawkstone, 10 kms north of Willowford, a *Nothofagus*/ *P. taxifolia* -dominated mixed podocarp forest was established by 6500 yrs BP. About 3400 yrs BP. (immediately prior to the deposition of 200 mm of pumice and lapilli from the Waimihia eruption in the Hawkestone bog) *Dacrydium cupressinum* replaced *P. taxifolia* as the dominant podocarp, thus placing the Hawkstone region within the wetter northern climatic sector from this date up to the present.

The regional vegetation of the northern sector from 1850 yrs BP., when ignimbrite from the Taupo eruption was deposited on the presumed lake bed at Te Pohue, until European land clearance in the late 19th century in the Te Pohue area, was a *Dacrydium cupressinum* - dominated/mixed podocarp assemblage with a notable *Prumnopitys taxifolia* component. Currently, *Dacrydium* annual growth rings are in the region of 10 mm per year and those of *P. taxifolia* only 1-2 mm per year (P. King pers. comm.). This tends to support the conclusion that the current climate regime, that favours *Dacrydium* over *P. taxifolia*, has been in place in the northern sector for the last 3400 years.

Several erosional events have been identified in the stratigraphy of the sites. It has been possible tentatively to link some of these events to Grant's (1985) hypothesis of periodic climate-forced erosional events having partially destroyed the forest cover in western Hawkes Bay, by estimating the age of these events utilising sediment accumulation rates of the sites in question. Some erosional events, however, have been identified as earthquake generated by using radiocarbon dates from this study, often in conjunction with estimated sediment accumulation rates, and linking these events to known and radiocarbon dated movements along the Mohaka Fault trace in western Hawkes Bay.

It is assumed the five sites along the Mohaka Fault formed following fault movements which disrupted the local drainage patterns so that sediment and runoff accumulated. The lake at Te Pohue formed following the blocking of the old Mangaone headwaters by a massive, pre-Waimihia Tephra landslide off the Te Waka Ridge. A large landslide at Big Hill, soon after the Waimihia Tephra was deposited, destroyed the site. Both landslides were due to co-seismic events. Following a movement on the Mohaka Fault c. 1150 yrs BP., sediment accumulation resumed at Big Hill.

In the northern part of western Hawkes Bay volcanicity has been identified as a factor influencing forest cover. Microscopic charcoal had been identified at several levels throughout the 6500 year pollen record of the Hawkstone site. These fires are interpreted as due to volcanic activity and in each case the forest quickly recovered. A 20 mm layer of reworked lapilli from the Waimihia eruption (3280 ± 20 yrs BP.) was recorded at this site, but no fire or disturbance to the vegetation was recorded following this event. However, fire is continually recorded at the site above the Taupo Tephra (1850 ± 10 yrs BP.) This prevented reafforestation in the region. Primary ignimbrite from the Taupo eruption forms the base of the Te Pohue site. The regional forest was destroyed by fire following this eruption, and *Pteridium* invaded the site. Within c. 230 years a forest similar to that present before the event, re-established. This is in agreement with the findings of Wilmshurst & McGlone (1996) regarding forests in the central North Island destroyed by the Taupo eruption.

Polynesian deforestation is identified by the advent of high frequencies of *Pteridium* and microscopic charcoal in the pollen record in the Willowford region c. 480 ± 170 yrs BP. and in the Big Hill region c. 430 ± 140 yrs BP. Wilmshurst (1997) records similar dates for Polynesian deforestation in the Tutira region in northeastern Hawkes Bay. A decline of indigenous forest species, coincident with the appearance of exotic pollen types such as *Pinus, Taraxacum* and pasture grasses near the top of the Te Pohue and Hinerua profiles is interpreted at indicating European land clearance and settlement.

Envoi

The rational for the attachment of an envoi to this thesis is that the two photographs reproduced here are representative of two very different types of seral vegetation assemblages that can precede full reafforestation in New Zealand. Both assemblages are from sites reported on in the body of this work. Figure A shows the current, extremely diverse nature of the vegetation in the vicinity of the Kashmir site and Figure B shows a stand of kanuka encroaching on to farmland in the vicinity of the Big Hill site.

A

At Kashmir a rich variety of lowland small trees and shrubs has covered an area destroyed by fire in 1946. Burnt stumps of the original forest still protrude through the shrubland. Identified in Figure A are several varieties of *Coprosma*, *Griselinia* (broad leaf), *Hebe stricta*, *Melicytus macrophyllus* (mahoe) *Weinmannia racemosa* (kamahi), the liane *Rubus cissoides* (bush lawyer), *Phormium tenax* (N.Z. flax), the monolete fern *Blechnum capense*, and the cabbage tree *Cordyline indivisa* (broad-leaved toi) which is very predominant in the area. A young beech sapling (*Nothofagus fusca*) (arrowed) is also evident to the right of the broad-leaved toi. A full list of the regenerating small trees and shrubs in the Kashmir area is found in Table 4. 1 of the text.

On the upper right of the Figure is a *Pinus radiata* forest planted in an effort to stem erosion in the area, with a thought to future harvesting of the timber. This plan has since been abandoned as uneconomical. Beyond the *Pinus* forest is evidence of how erosion has scarred the steeplands of western Hawkes Bay once they were cleared of their indigenous forest cover by European settlers.

B

In contrast, in the Big Hill region the indigenous vegetation is predominantly *Leptospermum* ~~type~~ (kanuka). The cabbage tree is also evident. The type that grows in this drier region is the lowland species, *Cordyline australis*. At Big Hill kanuka is currently encroaching on to pasture land in areas less intensively grazed. On steeper slopes, near the Ngaruroro River kanuka has taken over entirely, and attempts to control it have been abandoned. As yet *Prumnopitys taxifolia* (matai) has not regenerated naturally, possibly due to a lack of seed source. Attempts by the current land owners to grow beech trees have failed, and plantings of *Dacrydium cupressinum* (rimu) have only been successful in shaded areas on the east facing slopes of Big Hill Stream.

At Kashmir rainfall is in the vicinity of 2200 mm/yr; soils are a steepland association of the Brown Soils group and are a reflection of the local rainfall regime and topography. At Big Hill rainfall is in the vicinity of 1416 mm/yr; soils are eroding Pallic Soils and their associated steepland variants. These soils are also a reflection of the local rainfall regime and topography.

Absolute pollen counts for the Kashmir site (Figure 4. 1. 9) indicate that there was a rich and varied small tree and shrub component to this forest in the recent past. On the other hand absolute pollen counts for the Big Hill site (Figure 4. 3. 5) show that from c. 1000 yrs BP to the present, the small tree and shrub component in this region was much less varied than at Kashmir.

Thus when the current vegetational cover of these two sites is compared with the vegetation record of each respective site, as discussed in this thesis, it is evident that what we see in the present is the key to the past. The present-day vegetation at both sites indicates that climate in general and more specifically rainfall, is the dominant factor determining vegetational cover in western Hawkes Bay. The current vegetation also indicates that both Pallic and Brown Soils are forest soils and that if the land were allowed to return to fallow, reafforestation would occur naturally and quickly, provided there was a sufficient seed source for the tall tree component of the forest.

Balls Clearing Scenic Reserve is an example of a 400 - 500 year old *Dacrydium*-dominated, mixed podocarp forest, with a minor beech component, at Puketitiri in western Hawkes Bay (Frontispiece). Figured are the trunks of five tall, closely spaced podocarps together with *Pseudopanax*, and the trunk of a tree fern, both of which make up the understorey component of the forest reserve. This forest remnant stands as an example of the form forest cover would take, if forest were allowed to return naturally to the moister areas of western Hawkes Bay.

REFERENCES

Allen, H.H., (1961) *Flora of New Zealand*, Vol. 1, Government Printer, Wellington, 1085 pp.

Anderson, A.J., (1991) The Chronology of colonization in New Zealand, *Antiquity*, **65**: 767-795.

Anderson, S.T., (1960) Silicone oil as a Mounting Medium for Pollen Grains, *Danmarks Geologiske Undersøgelse* IV, Vol. **4**, No 1.

Anon., (1973) Rainfall Normals for New Zealand 1941 to 1970, N.Z. Meteorological Service Miscellaneous Publication **145**.

Aston, B. C., (1914) Notes on the Phanerogamic flora of the Ruahine mountain chain, with a list of the plants observed thereon, *Transactions and Proceedings of the New Zealand Institute*, **46**: 40-55.

Bagnall, A.G., & Pedersen, G.E., (1948) *William Colenso printer, missionary, botanist, explorer, politician : his life and Journeys*, A.H. & A.M. Reed, Wellington, 493pp.

Bannister, S.C., (1988) Microseismicity and velocity structure in the Hawke's Bay region, New Zealand: fine structure of the subducting Pacific Plate, *Geophysical Journal*, **95**: 45-62.

Bates, C.D., Coxon, P. & Gubbard, P.L. (1978) A new method for the preparation of clay-rich sediment samples for palynological investigation, *New Phytologist*, **81**: 459-463.

Beanland, S. & Beryman, K.R., (1987) Ruahine Fault Reconnaissance, Geological Survey Report, EDS. **109**.

Benninghoff, W.S., (1967) Calculation of pollen and spores density in sediments by addition of exotic pollen in known quantities, *Pollen et Spores*, **2** (2).

Berryman, K.R., (1990) Late Quaternary movement on the Wellington Fault in the Upper Hutt area, New Zealand, *New Zealand Journal of Geology & Geophysics*, **33**: 257-267.

Berryman, K.R., (1988) Tectonic geomorphology at a plate boundary: a transect across Hawke Bay, New Zealand, *Z. Geomorph N.F.* Suppl. Bd: **69**: 69-86.

Berryman, K.R., Ota, Y. & Hull, A., (1989) Holocene paleoseismicity in the fold and thrust belt of the Hikurangi subduction zone, eastern North Island, New Zealand, *Tectonophysics*, **163**: 185-195.

Best, E., (1977) *Forest Lore of the Maori*, E.C. Keating, Government Printer, Wellington, New Zealand. Reprint, 421 pp.

Best, E., (1976a) *The Maori Canoe*, A.R. Shearer, Government Printer, Wellington, New Zealand. Reprint, 452 pp.

Best, E., (1976b) *Maori Agriculture*, A.R. Shearer, Government Printer, Wellington, New Zealand. Reprint, 315 pp.

Best, E., (1974) *Maori Storehouses and Kindred Structures*, A.R. Shearer, Government Printer, Wellington, New Zealand. Reprint, 116 pp.

Beu, A.G., (1995) Pliocene Limestones and their Scallops: Lithostratigraphy, Pectinid Biostratigraphy and Paleogeography of Eastern North Island Late Neogene Limestone, *Institute Geological & Nuclear Sciences*, Lower Hutt, 243 pp.

Beu, A.G., Browne, G.H. & Grant-Taylor, T.L., (1981) New *Chlamys delicatula* localities in the central North Island and uplift of the Ruahine Range, *New Zealand Journal of Geology & Geophysics*, **24**: 127-132.

Bondy, F., (1950) Droughts in New Zealand, *New Zealand Journal of Science & Technology*, **32** Sec. B: 1-10.

Brooker, S.G., Cambrie, R.C. & Cooper, R.C., (1987) *New Zealand Medicinal Plants*, Reed Books, Auckland, Revised 2nd Edition, 268 pp.

Browne, G.H., (1986) Basement-cover relationships and tectonic significance of Mt Miroroa, western Hawke's Bay, *Journal of Royal Society of New Zealand*, **16**: 381-402.

Buchanan, J. D.H., (1973) *The Maori History and Place Names of Hawke's Bay*, A.H. & A.W. Reed, Wellington, 215 pp.

Burke, W.D., (1974) Regeneration of Podocarps on Mt Tarawera, Rotorua, New Zealand, *New Zealand Journal of Botany*, **12**: 219-226.

Burrows, C.J., (1982) On New Zealand climate within the last 1000 years, *New Zealand Journal of Archaeology*, **4**: 157-167.

Burrows, C.J. & Greenland, D.E., (1979) An Analysis of the Evidence for Climate Change in New Zealand in the last thousand years: Evidence from Diverse Natural Phenomena and from Instrumental Records, *Journal of the Royal Society of New Zealand*, **9**: 321-373.

Bussell, M.R., (1988) Mid and late-Holocene pollen diagram and Polynesian deforestation, Wanganui district, New Zealand, *New Zealand Journal of Botany*, **26**: 431-451.

Cameron, R.J., (1964) Destruction of the indigenous forest for Maori agriculture during the nineteenth century, New Zealand, *New Zealand Journal of Forestry*, **9**: 98-109.

Cashman, S.M., & Kelsey, H.M., (1990) Forearc uplift and extension, Southern Hawke's Bay, New Zealand: Mid-Pleistocene to Present, *Tectonics*, **9**: 23-44.

Cashman, S.M., Kelsey, H.M., Erdman, C.F., Cutten, H.N.C. & Berryman, K.R., (1992) Strain partitioning between structural domains in the forearc of the Hikurangi subduction zone, New Zealand, *Tectonics*, **11**: 242-257.

Clarkson, B.D. & Clarkson, B.R., (1994) Vegetation decline following recent eruptions on White Island (Whakaari) Bay of Plenty, New Zealand, *New Zealand Journal of Botany*, **32**: 21-36.

Clarkson, S.D., Clarkson, B.R. & McGlone, M.S., (1986) Vegetation history of some west Taupo mires, *In* Veal, B. & Innes, J. (Eds.), *Ecological research in the central North Island*, New Zealand Forest Service, Rotorua, 34-37.

Cole, J.W. & Lewis, K.B., (1981) Evolution of the Taupo-Hikurangi subduction system, *Tectonophysics*, **72**: 1-21.

Colenso, W., (1884) *In Memoriam, An account of visits to and crossings over, the Ruahine mountain range, Hawke's Bay, New Zealand; and of the natural history of that region*, Daily Telegraph, Napier.

Colenso, W., (1880) On the vegetable food on ancient New Zealanders before Cook's visit, *Transactions and Proceedings of the New Zealand Institute*, **13**: 3-39.

Connor, H.E. & Edgar, E., (1987) Name changes in the indigenous New Zealand Flora, 1960-1986 and *Nomina Nova* IV, 1983-1986, *New Zealand Journal of Botany,* **25**: 115-70.

Coulter, J.D., (1962) Easterly and westerly rainfalls in Hawke's Bay, New Zealand Meteorological Service Technical Note **146**.

Cranwell, L.M., (1952) New Zealand Pollen Studies: The monocotyledons, *Bulletin of the Auckland Institute and Museum,* **3**.

Crozier, M.J., (1996) The climate-landslide couple: a Southern Hemisphere perspective, *Palaeoclimate Research,* ESF Special Issue **12**: 329-350.

Cunningham, A., (1981) Introduction, In: Neall, V.E., (Ed.), *Field Excursion Guide to southern Ruahines,* New Zealand Society of Soil Science 25th Jubilee Conference, Bulls. 6-8

Cunningham, A., (1979) A Century of change in the forests of the Ruahine Range, North Island, New Zealand - 1870-1970, *New Zealand Journal of Ecology,* **2**: 11-21.

Cunningham, A., (1975) Storm Damage, eastern Ruahine Range, New Zealand Forest Service Report, Napier, (unpublished).

Cutten, H.N.C., Beanland, S. & Berryman, K.R., (1988) The Rangiora Fault, an active structure in Hawkes Bay, *In* Boyle, S., (Ed.), Research notes 1988, New Zealand Geological Survey Record **35**: 65-72.

Davidson, J., (1984) *The prehistory of New Zealand,* Longman Paul, Auckland, 270 pp.

Davidson, J., (1981) The Polynesian Foundation, *In* Oliver, W.H. & Williams, B.R., (Eds.), *The Oxford History of New Zealand*, Oxford University Press, Wellington, 3-17.

De Rose, R.C., Trustrum, N.A. & Blaschke, P.M. (1993) Geomorphic change implied by regolith-slope relationships on steepland hillslopes, Taranaki, New Zealand, *In* Crozier, M.J., (Ed.), *Geomorphology in Unstable Regions, Catena,* **18**: 131-144.

Deevey, E.S., Gross, M.S., Hurchinson, G.E. & Kraybill, H.L., (1954) The natural $^{C}14$ content of materials from hard-water lakes, *Proceedings of the National Academy of Sciences,* **40**: 258-288.

de Lisle, J.F., (1971) Climate and Weather, In: Hawkes Bay region, National Resource Survey, Part V, Government Printer, Wellington, 233 pp.

de Lisle, J.F. & Patterson, D.I., (1971) The climate and weather of the Hawke's Bay region, New Zealand, New Zealand Meteorological Service Miscellaneous Publication, **115**.

Donoghue, S.L., Neall, V.E. & Palmer, A.G., (1995) Stratigraphy and chronology of late Quaternary andesitic tephra deposits, Tongariro Volcanic Centre, New Zealand, *Journal of the Royal Society of New Zealand*, **25**: 115-126.

Donoghue, S.L., Stewart, R.B. & Palmer, A.S., (1991) Morphology and chemistry of olivine phenocrysts of Mangamate Tephra, Tongariro Volcanic Centre, New Zealand, *Journal of the Royal Society of New Zealand*, **21**: 225-236.

Druce, A.P., (1940) *cited in* Elder, N.L., (1958) Southern Ruahine Range: ecological report, New Zealand Forest Service Report (unpublished).

Eden, D.N., Froggatt, P.C., Trustrum, N.A. & Page, M.J., (1993) A multiple-source Holocene tephra sequence from Lake Tutira, Hawke's Bay, New Zealand, *New Zealand Journal of Geology & Geophysics*, **36**: 232-242.

Eden, D.N. & Page, M.J., (1998) Palaeoclimatic implications of a storm erosion record from late Holocene lake sediments, North Island New Zealand, *Palaeogeography, Palaeoclimatology, Palaeoecology*, **139**: 37-58.

Elder, N.L., (1965) Vegetation of the Ruahine Range: an introduction, *Transactions of the Royal Society of New Zealand*, **3**: 13-66.

Elder, N.L., (1963) Evidence of climate change from the vegetation of the North Island, *Proceedings of the New Zealand Ecological Society*, **10**: 45-48.

Elder, N.L., (1959) Vegetation of the Kaweka Range, *Transaction of the Royal Society of New Zealand*, **87**: 9-26.

Erdman, C.F. & Kelsey, H.M., (1992) Pliocene and Pleistocene stratigraphy and tectonics, Ohara Depression and Wakarara Range, North Island, New Zealand, *New Zealand Journal of Geology & Geophysics*, **35**: 177-192.

Faegri, K. & Iversen, J., (1989) *Text book of Pollen Analysis*, IV edition (revised by Faegri, K., Kaland, P.E. & Kazywinski, K.), J. Wiley & Sons, Chichester, 328 pp.

Fergusson, G.J. & Rafter, T.A., (1959) New Zealand C14 Age measurements, *Zealand Journal of Geology & Geophysics*, **2**: 208-241.

Fitzharris, B.B., (1989) A Review of Topoclimatology in New Zealand, *Weather & Climate*, **9**: 7-12.

Froggatt, P.C. & Lowe, D.J., (1990) A review of late Quaternary silicic and some other tephra formations from New Zealand: their stratigraphy, nomenclature, distribution volume and age, *New Zealand Journal of Geology & Geophysics*, **33**: 89 - 109.

Gordon, N.D., (1986) The Southern Oscillation and New Zealand weather, *Mon. Weather Review*, **114**: 371-387.

Grant, B.E., (1939) Hawke's Bay Flood, 23rd-25th April, 1938, *New Zealand Institution of Engineers Proceedings*, **25**: 55-64.

Grant, P.J., (1996) *Hawke's Bay forests of yesterday: a description and interpretation*, P.J. Grant, Havelock North, 273pp.

Grant, P.J., (1991) Disturbance in the forests of the Ruahine Range since 1770, *Journal of the Royal Society of New Zealand*, **21**: 385-404.

Grant, P.J., (1989) Effects on New Zealand Vegetation of late Holocene erosion and alluvial sedimentation, *New Zealand Journal of Ecology*, **12**: 131-144.

Grant, P.J., 1985) Major periods of erosion and alluvial sedimentation in New Zealand during the Late Holocene, *Journal of the Royal Society of New Zealand*, **15**: 67-121.

Grant, P.J., (1984) Drought effects on high-altitude forests, Ruahine Range, North Island, New Zealand, *New Zealand Journal of Botany*, **22**: 15-27.

Grant, P.J., (1981) Major periods of erosion and sedimentation in the North Island, New Zealand, since the 13th century, *In* Davies, T.R.H. & Pearce, A.J. (Eds.), *Erosion and Sediment Transport in Pacific Rim Steeplands*, Proceedings of the Christchurch Symposium, International Association of Hydrological Sciences Publication, **132**: 208-304.

Grant, P.J., (1969) Rainfall patterns on the Kaweka Range, *Journal of Hydrology*, **8**: 17-34.

Grant, P.J., (1968) Variations of rainfall frequency in relation to drought on the East Coast, *Journal of Hydrology*, **7**: 124-135.

Grant, P.J., (1966) Variations of rainfall frequency in relation to erosion in eastern Hawkes Bay, *Journal of Hydrology*, **8**: 17-34.

Grant, P.J., (1965) Major Regime changes of the Tukituki River, Hawke's Bay, since about A.D. 1650, *Journal of Hydrology*, **4**: 17-30.

Grant. P.J., (1963) Forests and recent climate history of the Huiarau Range, Urewera region, North Island, *Transactions of the Royal Society of New Zealand* (Botany), **12**: 143-171.

Grant, P.J., Hawkins, N.V. & Christie,W., (1978) Rainfalls and Floods of Cyclone Alison March 1975 on the north-eastern Ruahine Range, Water and Soil Miscellaneous Publication **1**: 14pp.

Grapes, R.H., Hardey, E.F. & Wellman, H., (1984) *The Wellington Mohaka and Wairarapa Faults*, Geology Department, Victoria University of Wellington, Wellington. Special Publication.

Grindley, G.W., (1960) Sheet 8 Taupo (1st edition) Geological Map of New Zealand, 1:250 000, DSIR, Wellington.

Hammond, A.P., (1997) The Quaternary Landscape Evolution of western Hawkes Bay, PhD thesis (unpublished), Massey University, Palmerston North.

Harris, W.F., (1963) Paleo-ecological evidence from pollen and spores, *Proceedings New Zealand Ecological Society*, **10**: 38-44.

Hewitt, A.E., (1992) *New Zealand Soil Classification*, DSIR Land Resources Scientific Report, **19**.

Higham, T.F.G. & Hogg, A.G., (1997) Evidence for late Polynesian colonization of New Zealand: University of Waikato radiocarbon measurements, *Radiocarbon*, **39**: 149-192.

Hocking, G.H., (1946) Drought in Hawkes Bay, *New Zealand Journal of Forestry*, **5**: 230-231.

Hogg, A.G., (1982) Radiocarbon dating at the University of Waikato, New Zealand; Occasional report No **8**; University of Waikato, Department of Earth Science, Hamilton.

Hubbard, C.B. & Neall, V.E. (1980) A reconstruction of late Quaternary erosional events in the West Tamaki River catchment, southern Ruahine Range, North Island, New Zealand, *New Zealand Journal of Geology & Geophysics*, **23**: 587-593.

Hull, A.G., (1990) Tectonics of the 1931 Hawke's Bay earthquake, *New Zealand Journal of Geology & Geophysics*, **33**: 309-320.

Hull, A.G., (1987) A late Holocene marine terrace on the Kidnappers coast, North Island, New Zealand: Some implications for shore platform development processes and uplift mechanism, *Quaternary Research*, **28**: 183-195.

Hull, A.G., (1986) Pre-A.D. 1931 tectonic subsidence of Ahuriri Lagoon, Napier, Hawke's Bay, New Zealand, *Journal of Geology & Geophysics*, **29**: 75-82.

Hull, A.G., (1983) Trenching of the Mohaka Fault near Hautapu River, Hawkes Bay, Intermediate Report New Zealand Geological Survey, **968/31 /831**.

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

Johnson, P., & Brooke, P., (1989) *Wetland Plants in New Zealand*, DSIR Publishing, Wellington, 317 pp.

Kamp, P.J.J., (1992) Landforms of Hawke's Bay and their origin: A plate tectonic interpretation, *In* Soons, J.M. & Selby, M.J. (Eds.), *Landforms of New Zealand*, Longman Paul, Auckland, 343-366.

Kelsey, H.M., Cashman, S.M., Beanland, S. & Berryman, K.R., (1995) Structural evolution along the inner forearc of the obliquely convergent Hikurangi margin, New Zealand, *Tectonics*, **14**: 1-18.

Kelsey, H.M., Erdman, C.F. & Cashman, S.M., (1993) Geology of southern Hawkes Bay from the Maraetotara Plateau and Waipawa westward to the Wakarara Range and the Ohara Depression, *Institute of Geological & Nuclear Sciences Science Report*, **93/2**.

Kennedy, C.D., (1914) Shingle action in Hawkes Bay and particularly as affecting the mouth of the Ngaruroro River, Institute of Local Government Engineers Proceedings, Vol. **2**.

Kingma, J.T., (1962) Sheet 11 Dannevirke. Geological Map of New Zealand, 1: 250 000, *Department of Scientific Industrial Research.*

Kingma, J.T. (1959) The Tectonic history of New Zealand, *New Zealand Journal of Geology & Geophysics,* **2**: 1-55.

Kingma, J.T., (1958) Geology of the Wakarara Range, Central Hawkes Bay, New Zealand, *New Zealand Journal of Geology & Geophysics,* **1**: 76-91.

Kingma, J.T., (1957a) The Tectonic setting of the Ruahine-Rimutaka Range, *New Zealand Journal of Science & Technology,* **B38**: 858-861.

Kingma, J.T., (1957b) The geology of the Kohurau Fault Block, Central Hawkes Bay, New Zealand, *New Zealand Journal of Science & Technology,* **B38**: 342-353.

Large, M.F. & Braggins, J.E., (1991) *Spore Atlas of New Zealand ferns and fern allies,* SIR Publishing, Wellington, 167 pp.

Leathwick, J.R. & Rogers, G.M., (1996) Modelling relationships between environment and canopy composition in secondary vegetation in the central North Island, New Zealand, *New Zealand Journal of Ecology,* **20**: 147-164.

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

Lensen, G.J., (1958) A method of Horst and Graben Formation, *Geology,* **66**: 579-587.

Levy, E.B., (1923) The Grasslands of New Zealand Series II, The Taranaki back-country, New Zealand, *Journal of Agriculture,* **27**: 138-156.

Lewis, K.B., (1989) A reversal of throw and change of trend on the Wellington Fault in Wellington Harbour, *New Zealand Journal of Geology & Geophysics,* **32**: 293-2998.

Lewis, K.B., (1980) Quaternary sedimentation on the Hikurangi oblique-subduction and transform margin, New Zealand, *International Association of Sedimentologists,* Special Publication **4**: 171-189.

Lillie, A.P., (1953) The geology of the Dannevirke Subdivision, *New Zealand Geological Survey Bulletin*, **46**.

Lowe, D.J., McFagen, B.G., Higham, T.F.G., Hogg, A.G., Froggatt, P.C. & Nairn, I.A., (1998) Radiocarbon age of the Kaharoa Tephra, a key marker for late-Holocene stratigraphy and archaeology in New Zealand, *The Holocene*, **8**: 487-495.

Macgregor, M., (1970) *Early Stations of Hawke's Bay*, A.H. & A.W. Reed, Wellington, 313 pp.

Marden, M., (1984) Geology and the relationship to erosion in the southern Ruahine Range, North Island, New Zealand, PhD thesis (unpublished) Massey University, Palmerston North.

Marden, M., (1977) Relationship of Geology to Erosion in the West Tamaki Catchment, south-eastern Ruahine Range, *In* Neall, V.E., (Ed.), *Field Excursion Guide to southern Ruahines*, New Zealand Society of Soil Science, 25th Jubilee Conference, Bulls. 9-15.

Marden, M. & Neall, V.E., (1980) Dated Ohakean terraces offset by the Wellington Fault, near Woodville, New Zealand, *Journal of Geology & Geophysics*, **33**: 449-453.

McDonald, D. & Norton, D.A., (1992) Light environments in temperate New Zealand podocarp rainforests, *New Zealand Journal of Ecology*, **16**: 15-22.

McFadgen, B.G., (1989) Late Holocene depositional episodes in coastal New Zealand, *New Zealand Journal of Ecology*, **12**: 145-149.

McFadgen, B.G., (1985) Late Holocene stratigraphy of coastal deposits between Auckland and Dunedin, New Zealand, *Journal of the Royal Society of New Zealand*, **15**: 27-65.

McFadgen, B.G., (1982) Dating New Zealand Archaeology by radiocarbon, *New Zealand Journal of Science*, **25**: 379-392.

McGlone, M.S., (1989) The Polynesian settlement of New Zealand in relation to environmental and biotic changes, *New Zealand Journal of Ecology*, **12** (supplement): 115-129.

McGlone, M.S., (1988) New Zealand, *In* Huntley, B. & Webb, III, T., (Eds.), *Handbook of Vegetation Science volume 7 Vegetation History*, Kluwver Academic Publishers, Dordrech. 557-599.

McGlone, M.S., (1983a) The history of New Zealand forests since the last glaciation, *In* Thompson, K., Hodder, A.P.. & Edmonds, A.S., (Eds.), *Lowland forests in New Zealand,* University of Waikato, Hamilton, 1-17.

McGlone, M.S., (1983b) Polynesian deforestation of New Zealand: A Preliminary Synthesis, *Archaeology Oceania,* **18**: 11-25.

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

McGlone, M.S., Anderson, A.J. & Holdaway, R.N., (1994) An ecological approach to the Polynesian settlement of New Zealand, *In*: Sutton, D.G., (Ed.), *The origins of the first New Zealanders,* Auckland University Press, Auckland, 136-163.

McGlone, M.S., & Moar, N.T., (1977) The *Ascarina* decline and post-glacial cliamtic change in New Zealand, *New Zealand Journal of Botany,* **15**: 485-489.

McGlone, M.S., Nelson, C.S. & 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**: 20-28.

McGlone, M.S., Salinger, M.J. & Moar, N.T., (1993) Paleovegetation Studies of New Zealand's Climate since the Last Glacial Maximum, *In* Wright, H.E.Jnr., Kutzbach, J.E., Webb, T. III, Ruddiman, W.F., Street-Perrott, F.A. & Bartlein, P.J. (Eds.), *Global Climates since the Last Glacial Maximum*, University of Minnesota, Minneopolis.

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**: 749-760.

McGlone, M.S. & Wilmshurst, J.M., (1997) Dating initial Maori environmental impact in New Zealand, *Quaternary International,* In Press.

McIntyre, D.J., (1963) Pollen Morphology of New Zealand species of Myrtaceae, *Transactions of the Royal Society of New Zealand,* **2** (7) 83-107.

McKay, W.A., (1902) Report of a copper lode in the Ruahine Range near Norsewood, New Zealand. *Mines Record*, No **4**: 415-417.

McKay, W.A., (1888) On the copper ore at Maharahara, near Woodville, New Zealand, *Geological Survey Reports of Geological Exploration 1877-1888,* **19**: 6-9.

McLea, W.L., (1996) The late-Quaternary pollen record of south-east Nelson, South Island, New Zealand, *New Zealand Journal of Botany*, **34**: 523-538.

Moar, N.T., (1993) *Pollen grains of New Zealand Dicotyledonous Plants*, Manaaki Whenua Press. Christchurch, New Zealand, 200 pp.

Moar, N.T., (1967) Contributions to the Quaternary History of the New Zealand Flora 5. Pollen Diagrams from No Man's Land bog, northern Ruahine Range, *New Zealand Journal of Botany*, **5**: 394-399.

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 Botany*, **4**: 350-359.

Molloy, B.P.J., (1969) Evidence for Post-glacial climate changes in New Zealand, *Journal of Hydrology*, **8**: 56-63.

Molloy, B.P.J., Burrows, C.J., Cox, J.E., Johnston, J.A. & Wardle, P., (1963) Distribution of subfossil forest remains in eastern South Island, New Zealand, *New Zealand Journal of Botany*, **1**: 68-77.

Moore, L.B. & Edgar, E., (1976) *Flora of New Zealand*, Vol. 2, Government Printer, Wellington, 354 pp.

Moore, P.D. & Webb, J.A., (1978) *An Illustrated guide to Pollen Analysis*, Hodder & Staughton, London, 133 pp.

Moore, P.D., Webb, J.A. & Collinson, M.E., (1991) *Pollen Analysis*, II edition, Blackwell Scientific Publications, Oxford, 216 pp.

Morton, J., Ogden, J. & Hughes, A., (1984) *To Save a Forest 'Whirinaki'*, David Bateman, Auckland, 111 pp.

Neale, J.L, & Walker, D., (1996) Sampling Sediment Under Warm Deep Water, *Quaternary Science Review*, **15**: 581-590.

Neall, V.E. & Hanson J.A. (1995) *The Neotectonics of the Ruahine and Mohaka Faults, between the Manawatu Gorge and Puketitiri*, Final Progress Report submitted to the Earthquake and War Damage Commission (unpublished), 75 pp.

Nelson, A., (1991) *Nga Waka Maori Maori Canoes*, Macmillan, Auckland, 126 pp.

Newnham, R.M., Lowe, D.J. & Green, J.D., (1989) Palynology, vegetation and climate of the Waikato lowlands, North Island New Zealand, since c. 18 000 years ago, *Journal of the Royal Society of New Zealand,* **2**: 127-150.

Ogden, J., (1985) An introduction to plant demography with special reference to New Zealand trees, *New Zealand Journal of Botany,* **23**: 751-772.

Ogden, J., Basher, L. & McGlone, M., (1998) Fire, Forest Regeneration and Links with Early Human Habitation: Evidence from New Zealand, *Annals of Botany,* **18**: 687-696.

O'Loughlin, C.L., Rowe, C.L. & Pearce, A.J., (1982) Exceptional storm influences on slope erosion and sediment yield in small forest catchments, North Westland, New Zealand. First National Symposium of Forest Hydrology, *Institute of Engineers,* Melbourne, Australia.

Page, M.J. & Trustrum, N.A., (1997) A late Holocene lake sediment record of the erosion response to land use change in a steepland catchment, New Zealand, *Z. Geomorph, N.F.,* **41**: 369-392.

Page, M.J., Trustrum, N.A. & De Rose, R.C., (1994) A high resolution record of storm-induced erosion from lake sediments, New Zealand, *Journal of Paleolimnology,* **11**: 333-384.

Parsons, P., (1998) The Ahuriri Block: Maori customary interests, Report WAI 400, prepared for the Waitangi Tribunal (unpublished), 156 pp.

Parsons, P., (1997) *In the Shadow of Te Waka,* Te Pohue History Committee, Te Pohue, Hawkes Bay, 246 pp.

Patterson, W.A. III, Edwards, K.J. & Maguie, D.J., (1987) Microscopic charcoal as a fossil indicator or fire, *Quaternary Science review,* **6**: 3-23.

Pearse, A.J. & Watson, A.J. (1986) Earthquake induced landslide, *Geology,* **14**: 52-55.

Pettinga, J.R., (1982) Upper Cenozoic structural history, coastal southern Hawke's Bay, New Zealand, *Geology,* **11**: 292-297.

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

Pocknall, D.T., (1981b) Pollen morphology of *Phyllocladus* L.C. et A. Rich., *New Zealand Journal of Botany,* **19**: 259-266.

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

Pocknall, D.T. & Millener, P.R., (1984) Vegetation near Lake Poukawa prior to the Taupo Eruption, *Journal of the Royal Society of New Zealand,* **14**: 151-157.

Pullar, W.A., (1965) Chronology of floodplains, fans and terraces in the Gisbourne and Bay of Plenty districts, *In: Proceedings of Fourth New Zealand Geography Conference, Dunedin*, New Zealand Geographical Society, 77-81.

Raine, J.I. & Tremain, R., (1990) Apparatus for rapid Sieving of Palynological Residues (unpublished).

Raub, M.L., (1985) The neotectonic evolution of the Wakarara area, southern Hawke's Bay, New Zealand, M.Phil. thesis (unpublished), University of Auckland, Auckland, New Zealand.

Raub, M.L., Cutton, H.N. & Hull, A.G., (1987) Seismotectonic hazard analysis of the Mohaka Fault, North Island, New Zealamd, *Pacific Conference on Earthquake Engineering Paper* (5-8 August, 1987) Wairaki, New Zealand.

Riley, M., (1994) *Maori Healing and Herbal*, Viking Sevenseas, Paraparauma, New Zealand, 528 pp.

Rogers, G.M., (1989) Beech and Conifer Comminity Interaction in Moawhango Ecological Region, North Island, New Zealand, *New Zealand Journal of Ecology,* **12**: 47-61.

Rogers, G.M. & McGlone, M.S., (1989) A postglacial vegetation history of the soutern-central uplands of North Island, New Zealand, *Journal of the Royal Society of New Zealand,* **19**: 229-248.

Salinger, M.J., (1980) New Zealand climate; 2 Temperature patterns, *Mon. Weather Review*, **114**: 1905-1912.

Spörli, K.B. & Bell, A.B., (1976) Torless Mélange and Coherant sequences, eastern Ruahine Range, North Island, New Zealand, *New Zealand Journal of Geology & Geophysics*, **19**: 427-447.

Stephens, P.R., (1977) Erosion in the Upper West Tamaki Carchment, *In* Neall, V.E., (Ed.), *Field Excursion Guide to southern Ruahines*, New Zealand Society of Soil Science, 25th Jubilee Conference, Bulls. 27-35.

Stevens, G.R., (1957) Geomorphology of the Hutt Valley, New Zealand, *New Zealand Journal of Science & Technology*, **B38**: 297-327.

Stevens, G.R., (1956) Geomorphology of the Hutt Valley, New Zealand, *New Zealand Journal of Science & Technology*, **B38**: 201-235.

Stirling, W., (1992) Holocene beach ridges displaced by the Wellington Fault in Lower Hutt, New Zealand, *New Zealand Journal of Geology & Geophysics*, **35**: 337-453.

Stockmarr, J., (1971) Tablets with spores used in absolute pollen analysis, *Pollen et Spores*, **8** (1): 615-621).

Stuiver, M. & Polack, H.A., (1977) Discussion : Reporting of $^{C}14$ data, *Radiocarbon*, **19**: 353-363.

Taylor, N.M., (1958) Soil Science and New Zealand Prehistory, *New Zealand Science Review*, **16**: 71-79.

Thompson, C.S., (1987) The climate and weather of Hawke's Bay, *New Zealand Meteorological Service Miscellaneous Publication* **115**.

Van Dissen, J.R., Berryman, K.R., Pettinga, J.R. & Hill, N.L., (1992) Paleoseismicity of the Wellington-Hutt Valley segment of the Wellington Fault, North Island, New Zealand, *New Zealand Journal of Geology & Geophysics*, **35**: 165-176.

Walcott, R.I., (1978) Geodetic Strains and large earthquakes in the axial tectonic belt of North Island, New Zealand, *Journal of Geophysical Research*, **83**: 4419-4429.

Wardle, P., (1991) *Vegetation of New Zealand*, Cambridge University Press, Cambridge, 672 pp.

Wardle, P., (1963) Vegetation studies on Secretary Island, Fiordland, Part 5: Population structure and growth of rimu (*Dacrydium cupressinum*), *New Zealand Journal of Botany,* **1**: 208-214.

Webb, C.J., Sykes, W.R. & Garnock-Jones, P.J., (1988) *Flora of New Zealand Naturalised Pteridophytes, Gymnosperms, Dicotyledons,* Government Printer, Wellington, 1305 pp.

Wellman, H.W., (1953) Data for the study of recent and late Pleistocene faulting in the South Island of New Zealand, *New Zealand Journal of Science & Technology,* **B34**, 270-228.

West, R.G., (1977) *Pleistocene Geology and Biology,* Longman Group, London, 440pp.

Whitehead, D., Leathwick, J.R. & Hobbs, J.F.F., (1992) How will New Zealand's forests respond to climate change? Potential changes in response to increasing Temperature, *New Zealand Journal of Forestry Science,* **22**: 39-53.

Widdowson, D., (1960) Beech regeneration and deer in the northeast Ruahine Range, *New Zealand Journal of Forestry,* **8**: 335-336.

Wilmshurst, J.M., (1997) The impact of human settlement on vegetation and soil stability in Hawke's Bay, New Zealand, *New Zealand Journal of Botany,* **35**: 97-111.

Wilmshurst, J.M. & McGlone, M.S., (1996) Forest Disturbance in the central North Island, New Zealand, following the 1850 BP Taupo eruption, *The Holocene,* **6**: 399-411.

Wilmshurst, J.M. & McGlone, M.S. & Partridge, T.R., (1997) A late Holocene history of natural disturbance in lowland podocarp/hardwood forest, Hawke's Bay, New Zealand, *New Zealand Journal of Botany,* **35**: 76-96.

Wilson, C.J.N. (1993) Stratigraphy, chronology, styles and dynamics of late Quaternary eruptions from Taupo volcano, New Zealand, *Phil. Transactions Royal Society,* London, **A343**: 205-305.

Wilson, J.C., (1939) *History of Hawkes Bay,* A. H. & A.W. Reed, Dunedin, 469 pp.

Wright, M., (1985) The early sawmilling industry in Hawkes Bay, Forest Service Report (unpublished).

Zotov, V.D. (1938) Some correlation between vegetation and climate in New Zealand, *New Zealand Journal of Science & Technology,* **19**: 474-487.

Miscellaneous Publications & References

Anon. (1972) Wakarara School 75th Jubilee (booklet).

Balls Clearing Scenic Reserve (Department of Conservation information board at the site).

Kashmir Scenic Reserve (Department of Conservation information pamphlet, 1996).

Logan, R.M., (1974) A Brief History of the Township of Otane (pamphlet).

Gazetted Reports to Parliament on Sawmilling in Hawkes Bay for 1905 & 1907.

Appendix 1.

Electronically scanned pollen figures of some of the more important flora of western Hawkes Bay. The diagnostic features used to identify each pollen grain follow those of Moar (1993), Cranwell (1952), and Pocknall (1981a, b & c).

1a; 1b	*Dacrydium cupressinum*
2a; 2b	*Prumnopitys taxifolia*
3a; 3b	*Prumnopitys ferruginea*
4a; 46	*Dacrycarpus dacrydioides*
5a; 5b	*Podocarpus totara*
6a; 6b	*Halocarpus biformis*
7a; 7b	*Lepidothamnus*
8a; 8b	*Lagarostrobos colensoi*
9a; 9b	*Nothofagus fusca*
10a 10b	*Nothofagus truncata*
11a; 11b	*Nothofagus menziesii*
12a; 12b	*Ascarina lucida*
13a; 13b	*Laurelia novae-zelandiae*
14a; 14b	*Knightia excelsa*
15a; 15b	*Nestegis cunninghamii*
16a; 16b	*Eugenia maire*
17a; 17b	*Weinmannia racemosa*
18a; 18b	*Dracophyllum latifolium*
19a; 19b	*Carpodetus serratus*
20a; 20b	*Gaultheria rupestris*
21a; 21b	*Pseudowintera colorata*
22a; 22b	*Cordyline australis*
23a; 23b	*Rhopalostylis sapida*
24a; 24b	*Macropiper excelsum*
25a; 25b	*Corynocarpus laevigatus*
26a; 26b	*Myoporum laetum*
27a; 27b	*Hebe odora*
28a; 28b	*Aristotelia serrata*
29a; 29b	*Coprosma lucida*
30a; 30b	*Coprosma foetidissima*
31a; 31b	*Coriaria arborea*
32a; 32b	*Dodonaea viscosa*
33a; 33b	*Elaeocarpus dentatus*
34a; 34b	*Griselinia lucida*
35a; 35b	*Lophomyrtus obcordata*
36a; 36b	*Muehlenbeckia australis*
37a; 37b	*Phormium tenax*
38a; 38b	*Pittosporum crassifolium*
39a; 39b	*Pittosporum tenuifolium*
40a; 40b	*Pseudopanax arboreus*
41a; 41b	*Pseudopanax crassifolium*
42a; 42b	*Rubus cissoides*
43a; 43b	*Schefflera digitata*
44a; 44b	*Melicytus ramiflorus*
45a; 45b	*Myrsine australis*
46a; 46b	*Quintinia serrata*
47a; 47b	*Hoheria populnea*
48a; 48b	*Plagianthus divaricatus*
49a; 49b	*Typha muelleri*
50a; 50b	*Typha orientalis*
51a; 51b	*Astelia fragrans*
52a; 52b	*Astelia solandri*
53a; 53b	*Pimelia longifolia*
54a; 54b	*Potomageton cheesemani*
55	*Pteridium aquilinum*

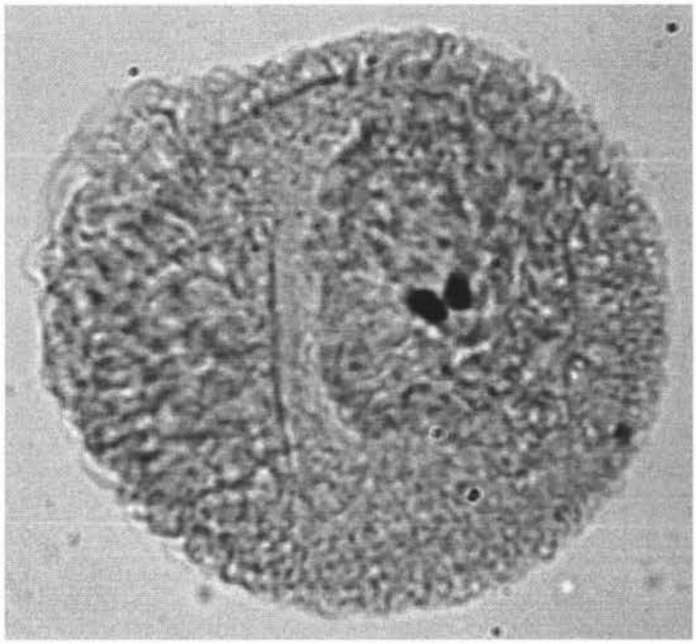


Figure Ap.1.1a *Dacrydium cupressinum* - Diagnostic features :- two small sacci with distinct radial patterning seen here in polar view as hemispheric and folded over a heavily tuberculate-rugulate patterned cappa

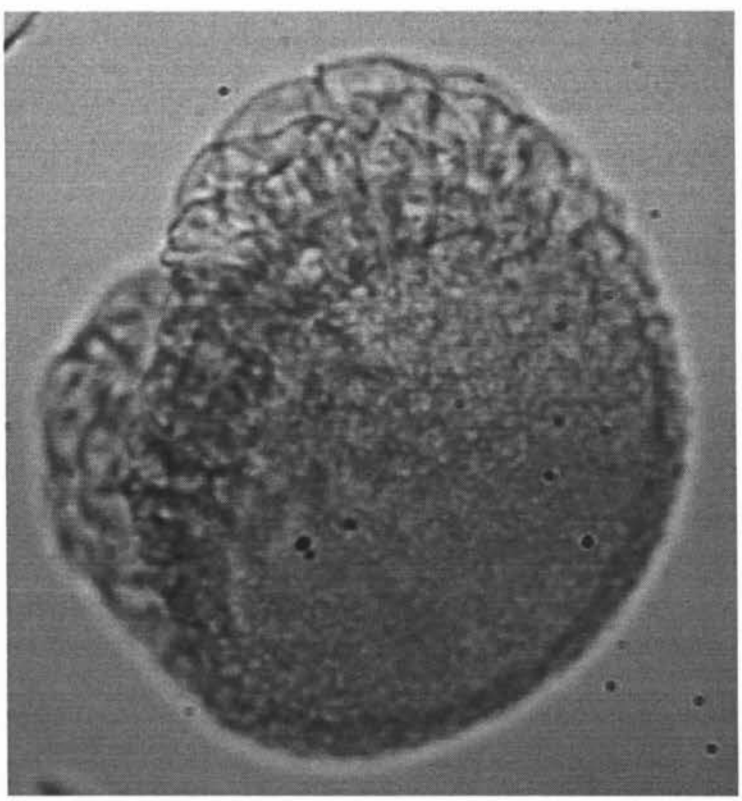


Figure Ap.1.1b *Dacrydium cupressinum* - A second equatorial view showing the coarsely tuberculate-rugulate cappa with a distinct rugulate marginal ridge.

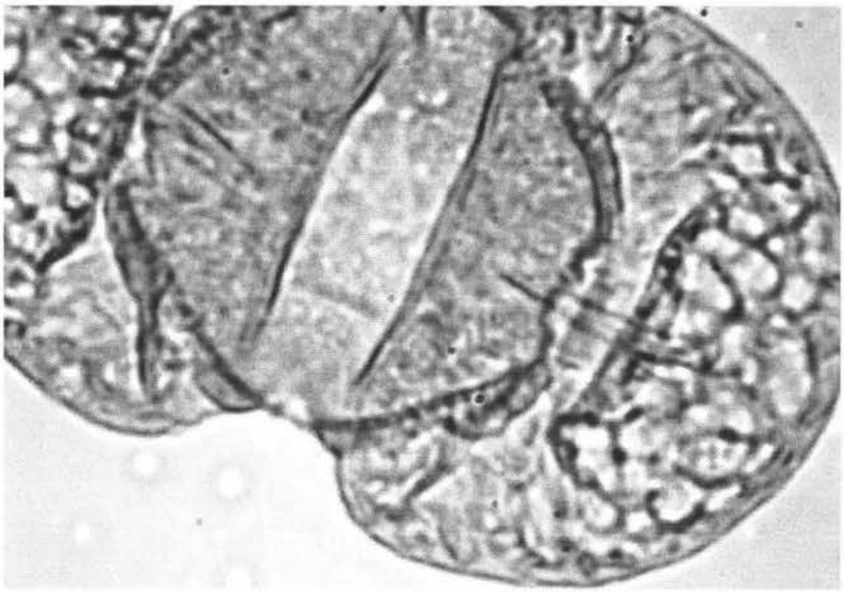


Figure Ap.1.2a *Prumnopitys taxifolia* - Equatorial view showing a rhomboidal corpus with finely charenate-rugenate sculpturing on the cappa merging into a pronounced marginal ridge; sacci reticulate, small lumina, more-or-less complete polygons

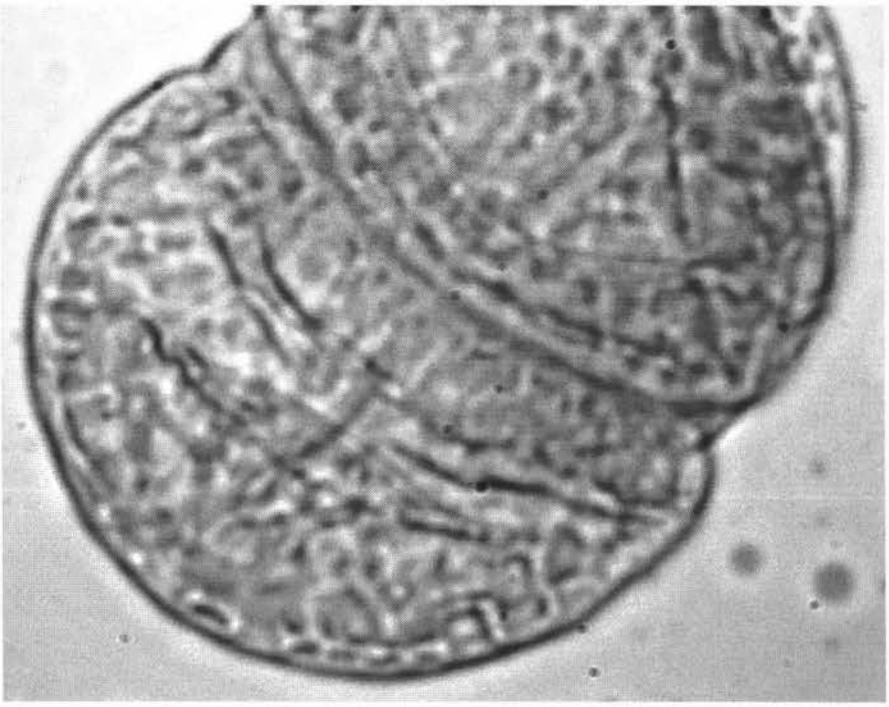


Figure Ap.1.2b *Prumnopitys taxifolia* - A second equatorial view showing the more-or-less polygon shape of the lumina on the sacci and the habit of one saccus to be bent over the cappa due to poor axis strength on the saccus

Figure Ap.1.3a - *Prumnopitys ferruginea* - Tuberculate-rugulate cappa with large ear-like folds projecting from the proximal points of the junction with the corpus and pronounced relatively smooth marginal ridge

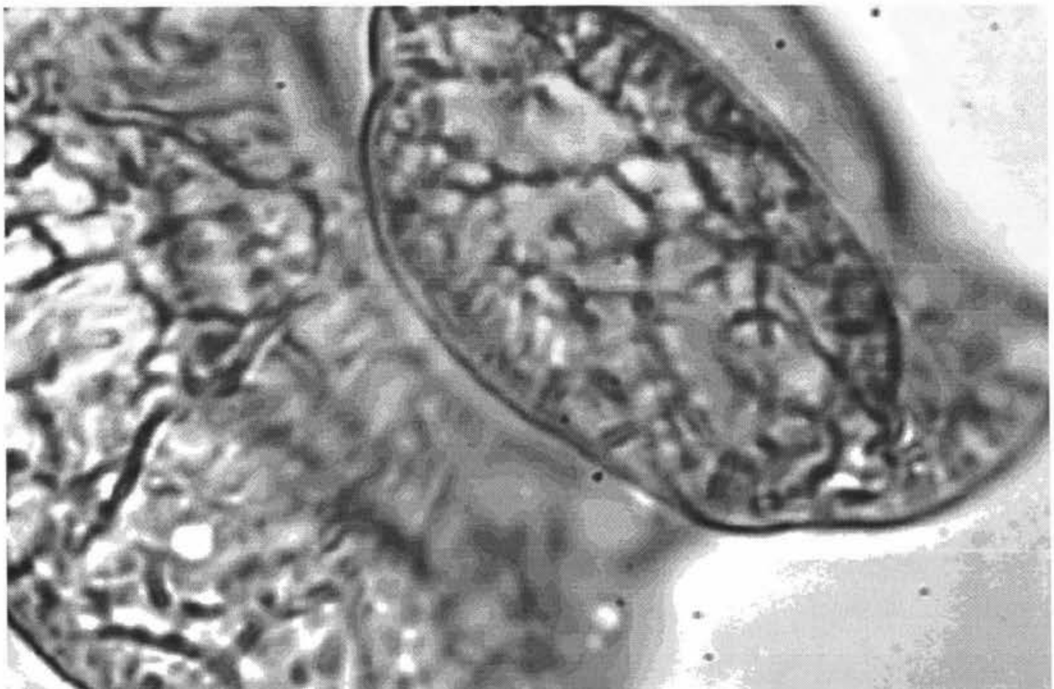


Figure Ap. 1.3b *Prumnopitys ferruginea* - View of reticulated sacci with large lumina with well defined muri forming a blindly branching system; sacci hemispherical with clear outline protruding beyond the corpus in polar view

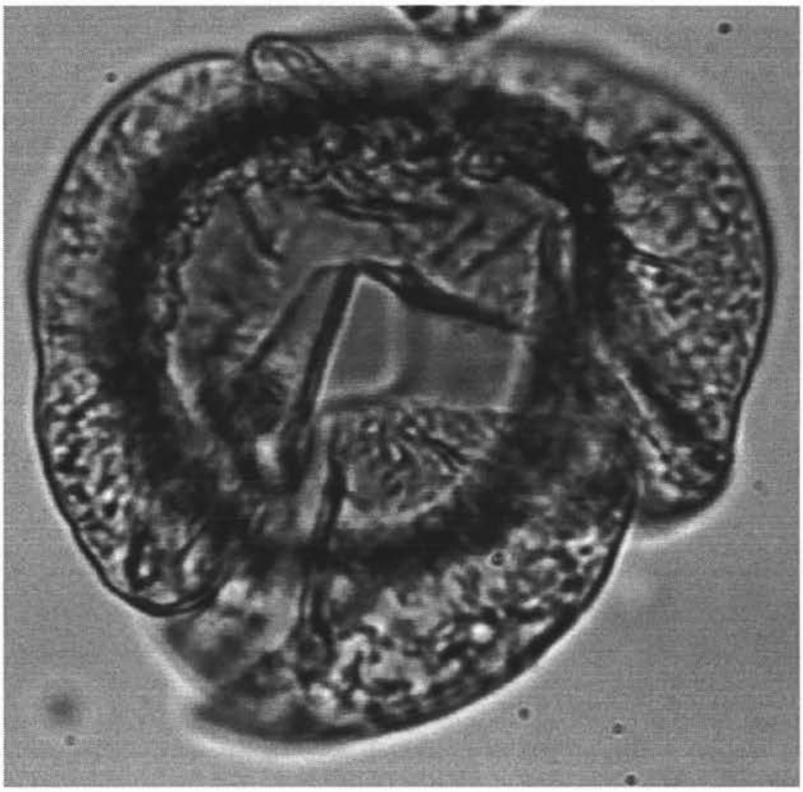


Figure Ap.1.4a *Dacrycarpus dacrydioides* - Polar view showing the finely tuberculate cappa terminating in a distinct coarsely rugulate marginal ridge, and the trisaccate, reticulate and hemispherical aspects of the sacci

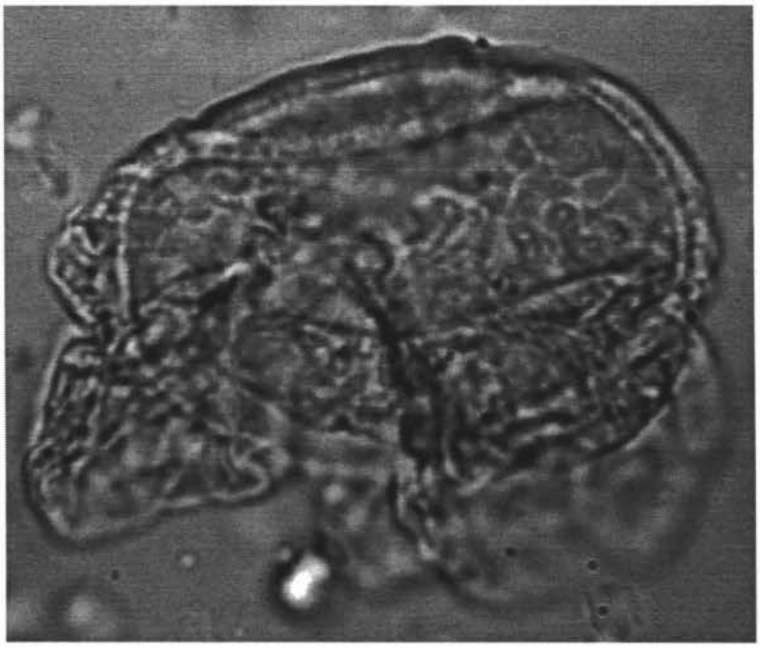


Figure Ap.1.4b *Dacrycarpus dacrydioides* - Lateral longitudinal view showing the lens shaped corpus with a distinct marginal ridge; the sacci are compressed, but the large lumina with well defined muri are still evident

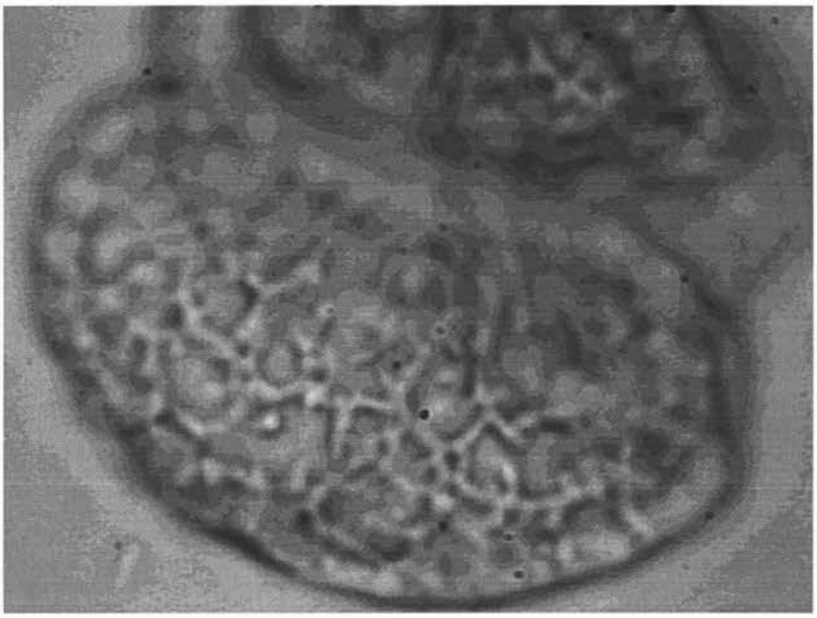


Figure Ap.1.5a *Podocarpus totara* - View of reticulated saccus with distinct, irregularly sized, randomly distributed lumina with well defined muri, which results in a perfectly round, regularly hemispherical saccus

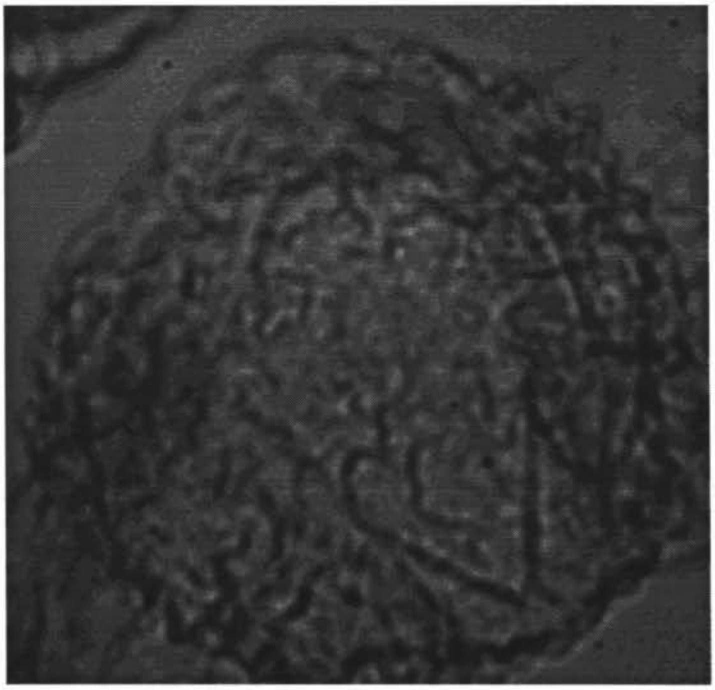


Figure Ap.1.5b *Podocarpus totara* - View of the cappa showing the finely rugulate sculpturing and the distinct wavy marginal ridge.

Figure Ap.1.6a *Halocarpus biformis* - Tuberculate sculpturing over cappa, distinct marginal edge; sacci large, clearly defined muri, overall shape of grain spherical

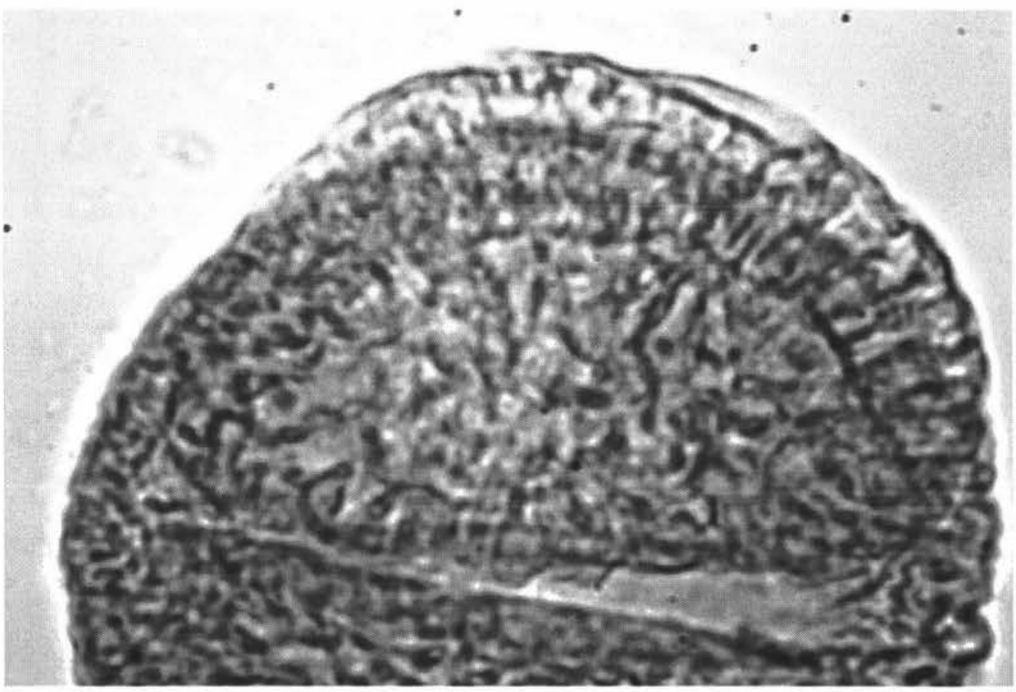


Figure Ap.1.6b *Halocarpus biformis* - Second view of cappa showing tuberculate patterning on saccus and clearly defined radial muri with more-or-less regular patterning

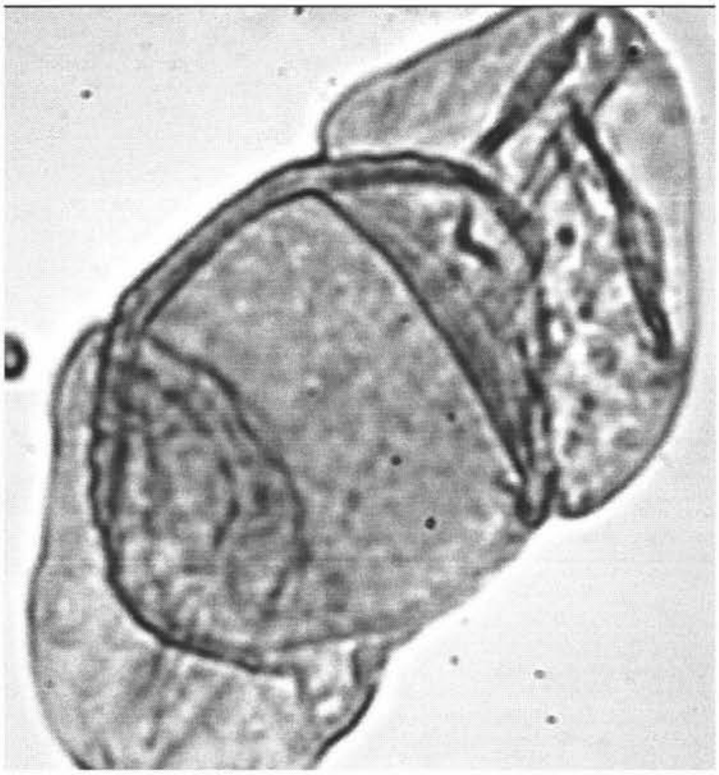


Figure Ap1.7a *Lepidothamnus* - Cappa finely sculptured with distinct marginal edge; sacci reticulate, muri with small irregularly shaped lumini

Figure Ap.1.7b *Lepidothamnus* - Second view showing fine sculpturing on cappa and poorly defined irregularly shaped thin muri on sacci; sacci weakly supported due to poor axis strength of the sacci

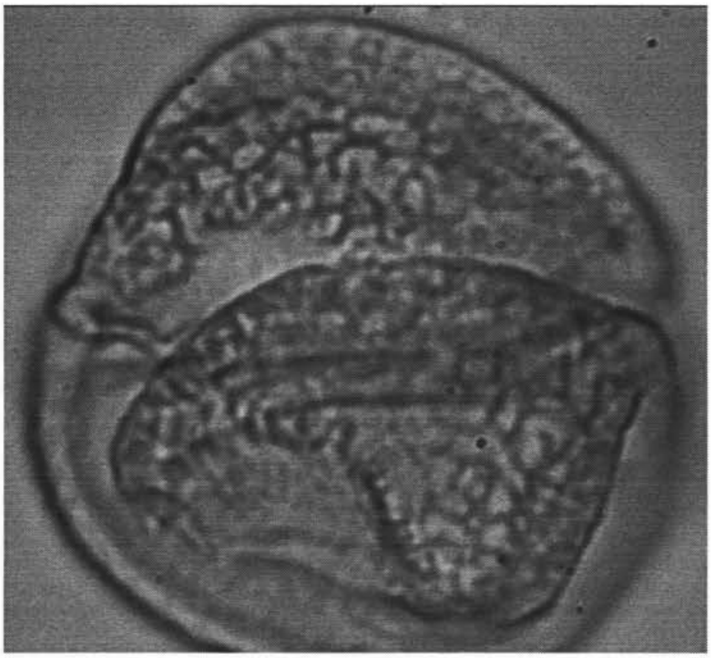


Figure Ap.1 8a *Lagarostrobos colensoi* - Corpus spheroidal to ellipsoidal; cappa finely tuberculate sacci reticulate with small lumina; lumina more-or-less complete

Figure Ap.1.8b *Largarostrobos colensoi* - Lateral longitudinal view showing "cauliflower-like" protrusions on a finely tuberculate cappa

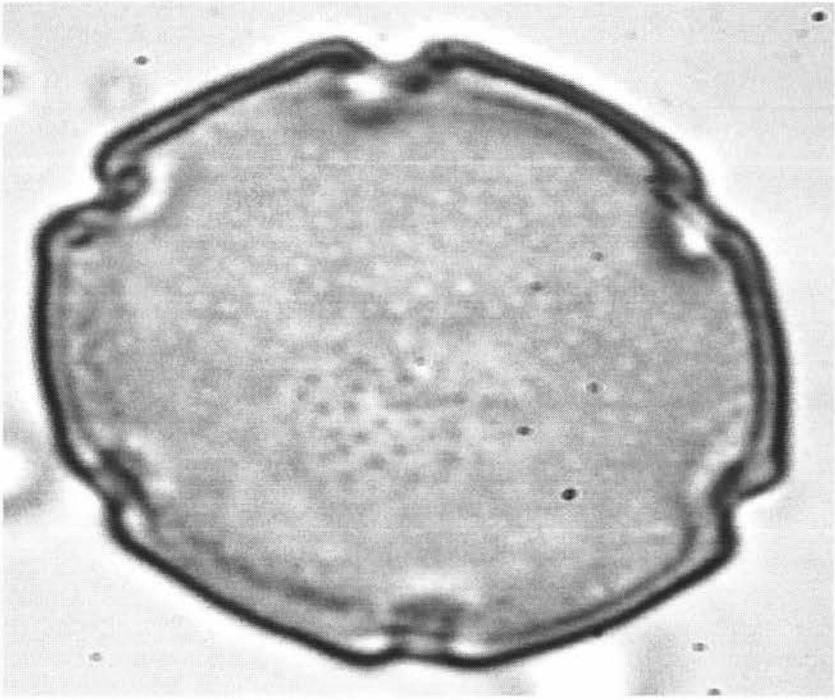


Figure Ap.1.9a *Nothofagus fusca* - Polar view of colpate nature of grain (5 colpi in view) with short narrow clearly defined ectoapertures, with exine markedly thickened round apertures; tectate

Figure Ap.1.9b *Nothofagus fusca* - Equatorial view showing two of the clearly defined ectoapertures and tectum bearing very short evenly distributed spinules

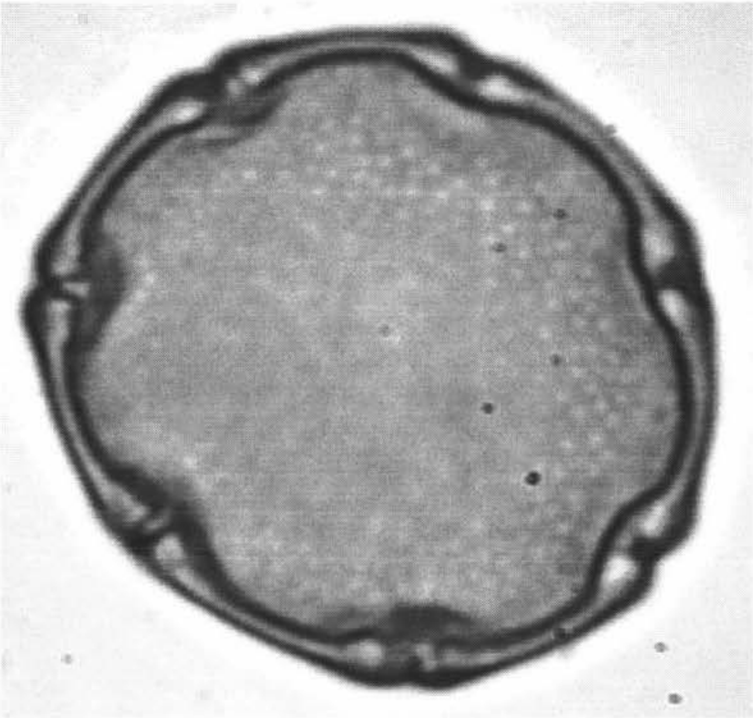


Figure Ap.1.10a - *Nothofagus truncata* - Polar view showing seven clearly defined ectoapertures with exine markedly thickened round apertures (Grains may have between five and eight apertures)

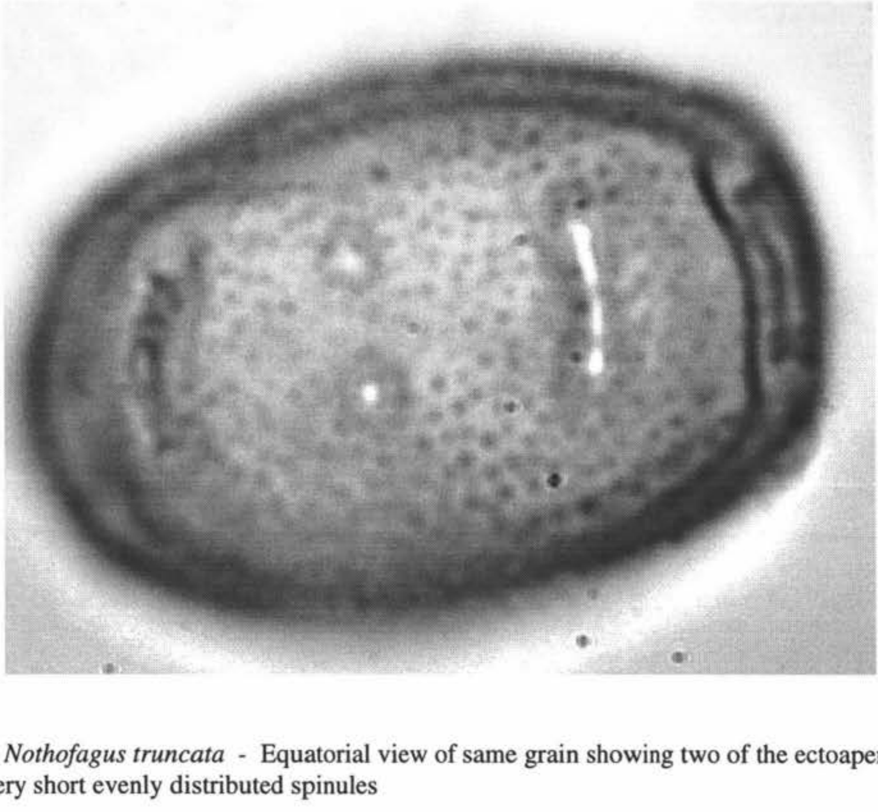


Figure Ap.1.10b *Nothofagus truncata* - Equatorial view of same grain showing two of the ectoapertures, and the tectum bearing very short evenly distributed spinules

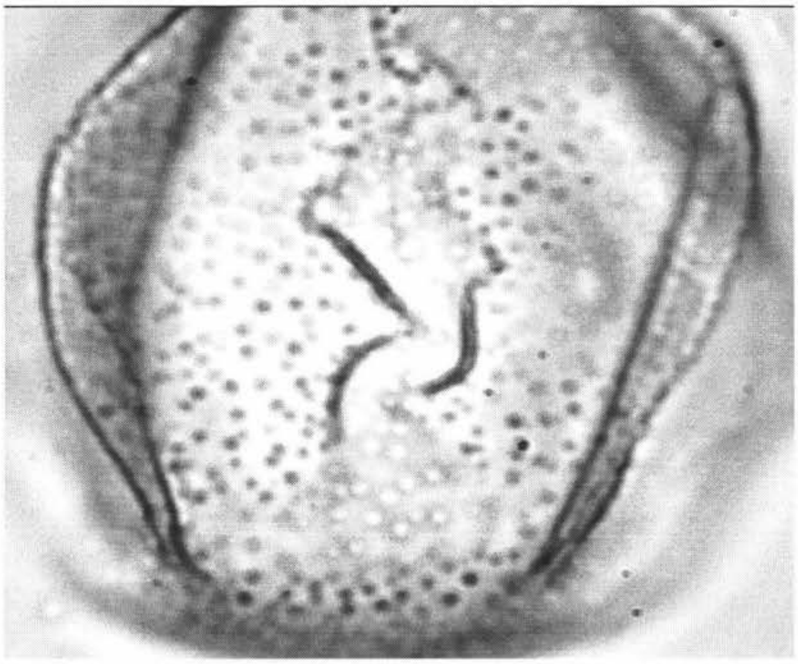


Figure Ap.1.11a *Nothofagus menziesii* - Very roughly defined exine, very thin tectate with tectum bearing very short evenly distributed spinules

Figure Ap.1.11b *Nothofagus menziesii* - Second view of grain at lower magnification, stephenocolpate aspect of grain not visible

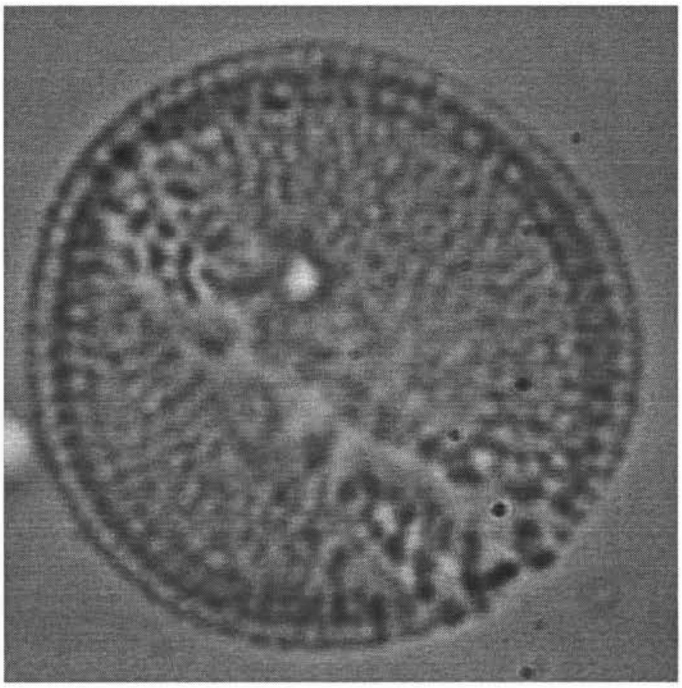


Figure Ap.1.12a *Ascarina lucida* - Monocolpate, colpus long, more like a slit than a colpus; distinctive surface patterning; clavate, with clavae arrranged in a reticuloid pattern

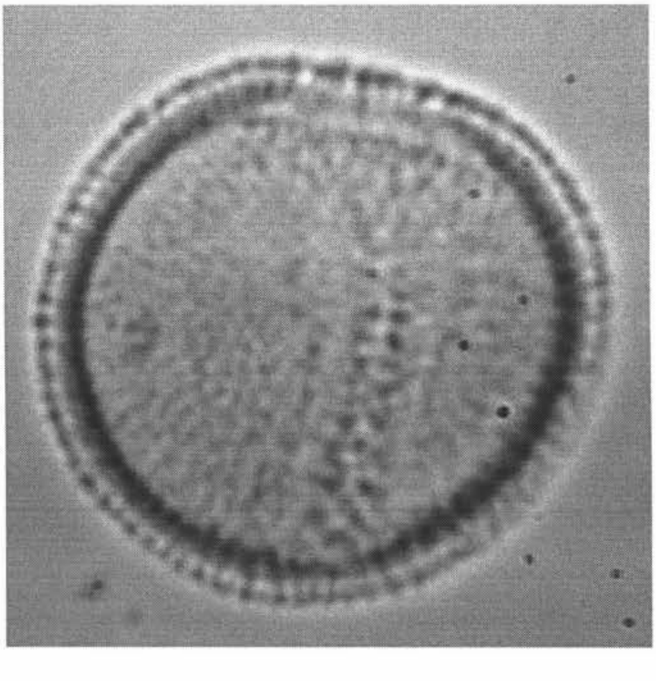


Figure Ap.1.12a *Ascarina lucida* - Second view grain showing the +/- spheroidal shape in the short equatorial plane; muri very thick, with diagnostic thick inner layer

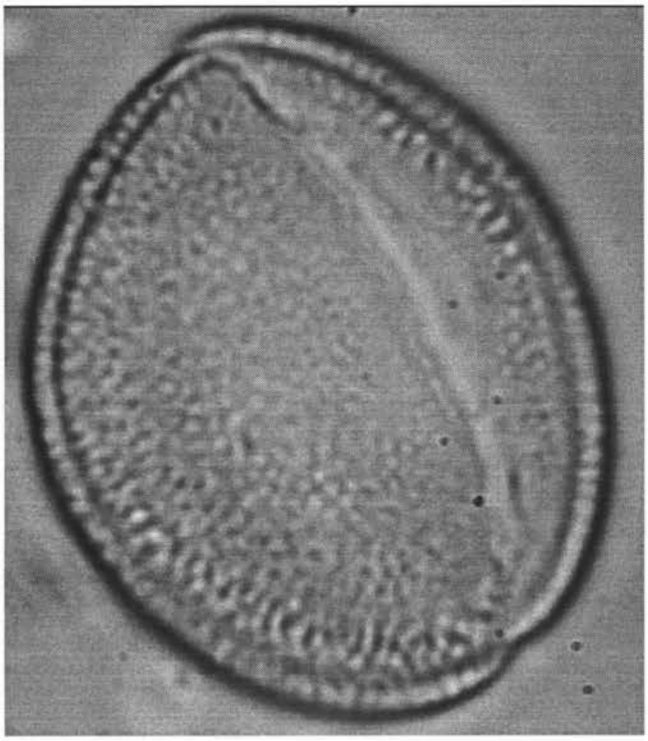


Figure Ap.1.13a *Laurelia novae-zelandiae* - Dicolpate, colpi extending almost to poles; exine thinning towards poles and colpi edges; shape ellipsoidal; fine reticulate patterning

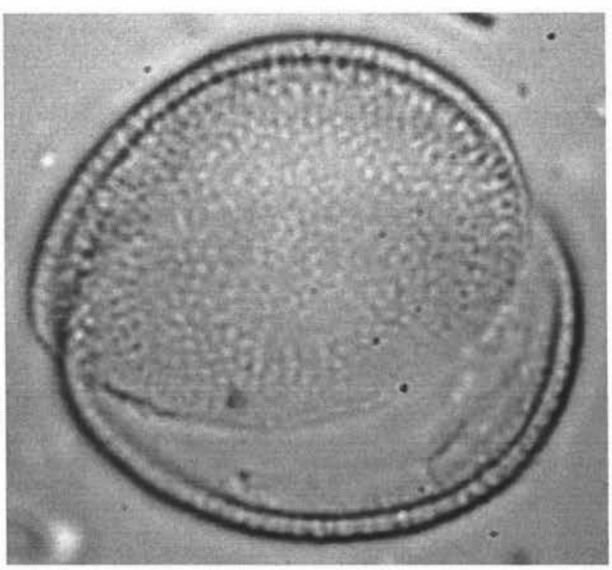


Figure Ap.1.13b *Laurelia novae-zealandiae* - Second view showing semi tectate aspect; baculate, baculae fusing to form the fine reticulum; shape +\- spherical due to grain spreading along the split in the colpus

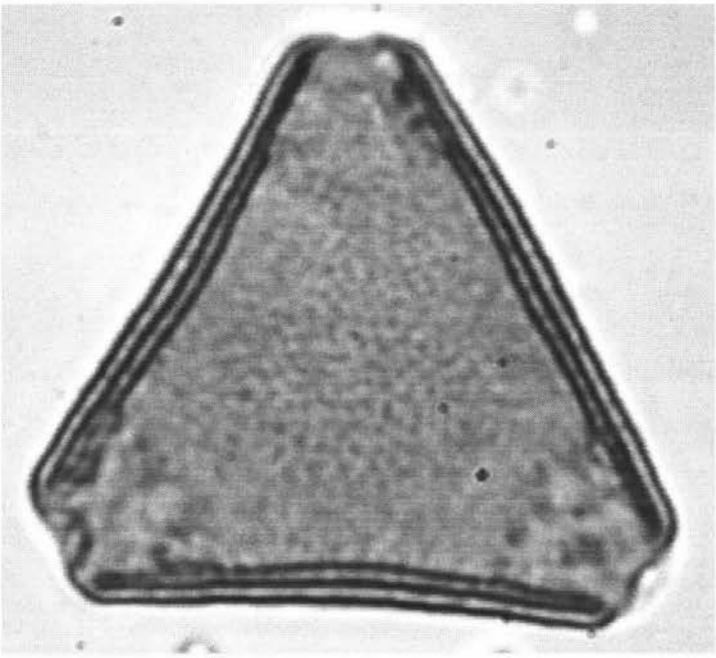


Figure Ap.1.14a *Knightia excelsa* - Tricolporate, angulaperturate, apertures slightly lalongate or nearly circular; exine thick, semi-tectate, shape triangular in polar view, one amb more concave than other two

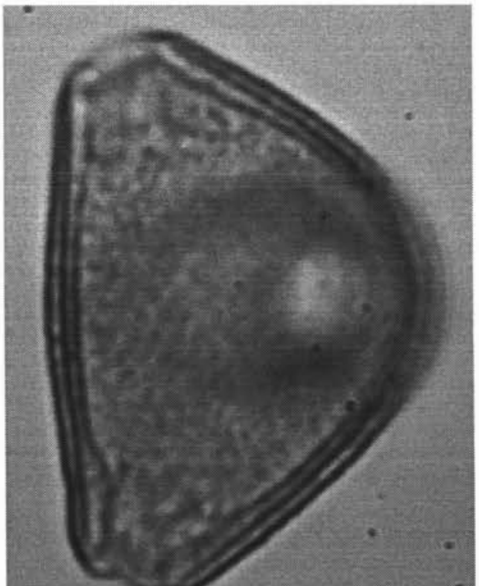


Figure Ap.1.14b *Knightia excelsa* - A second equatorial view of grain, shape more elliptical than triangular; baculate, baculae reticulate and clearly visible in optical section; muri relatively broad

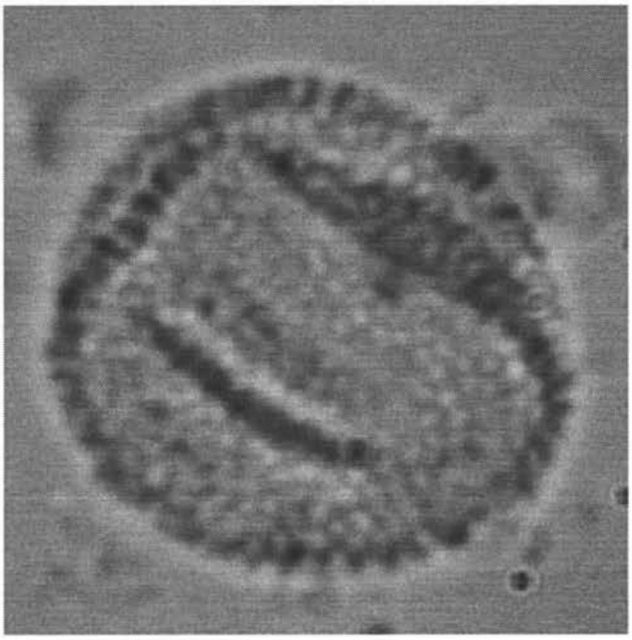


Figure Ap.1.15a *Nestegis cunninghamii* - Tricolpate, ectoapertures short, narrow and usually recessed; polar area large; exine very thin, semitectate, reticulate and baculate, baculae relatively coarse

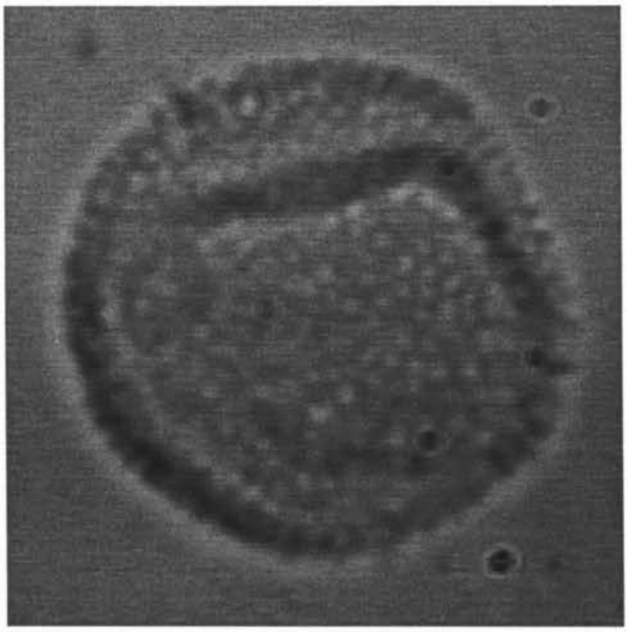


Figure Ap.1.15b *Nestegis cunninghamii* - Second view of grain showing lumina forming irregular, relatively open reticulum; muri very narrow, dicolpate aspect still distinguishable

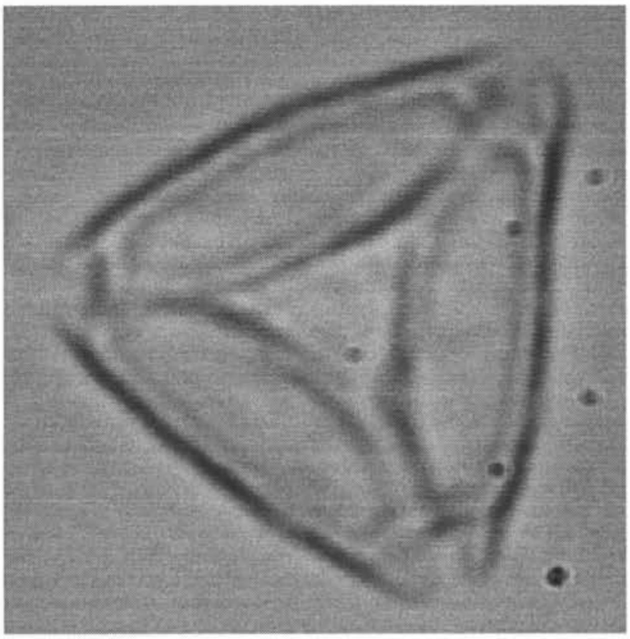


Figure Ap.1.16a *Eugenia maire* - Tricolporate, angulaperturate, endoapertures clear and lalongate, shape triangular in polar view, angles acute with amb straight, but as is evident, can be convex or concave

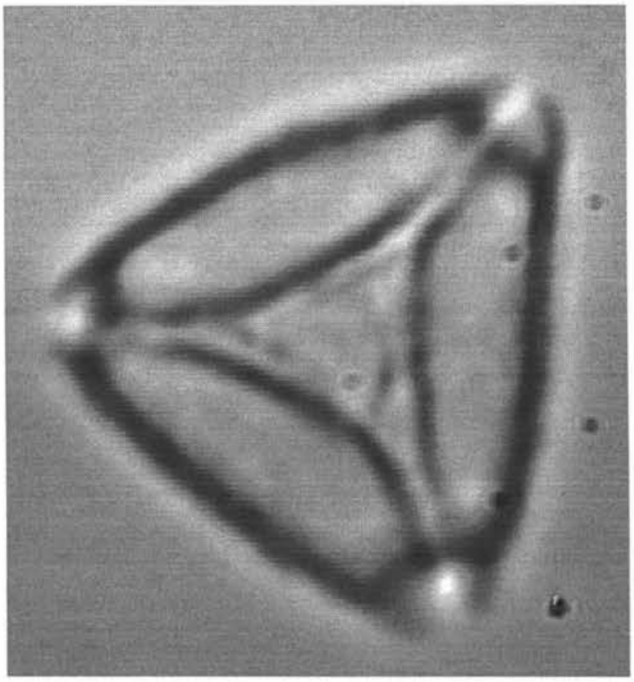


Figure Ap.1.16b *Eugenia maire* - A second view of grain, showing tectate aspect, tectum surface verrucate in apocolpia and sometimes in mesocolpia

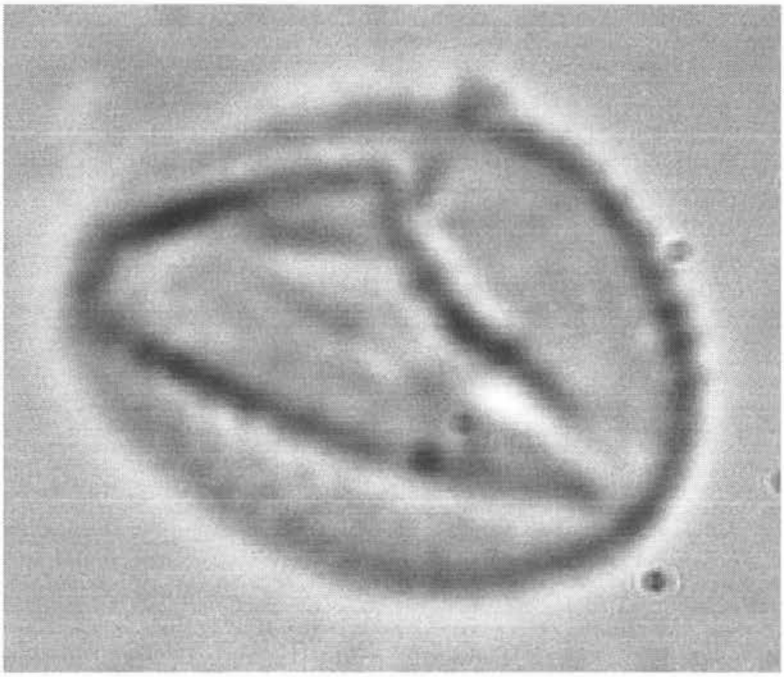


Figure Ap.1.17a *Weinmannia racemosa* - Tricolporate, ectoapertures very long, slightly sunken and constricted at equator; finely costate; polar area small. exine very thin, reticulate, muri very fine

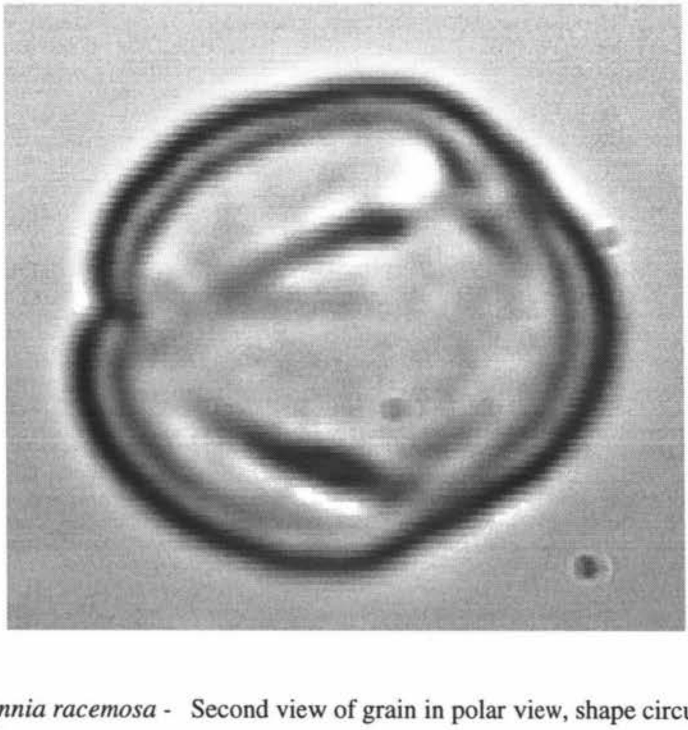


Figure Ap.1.17b *Weinmannia racemosa* - Second view of grain in polar view, shape circular; sunken aspect of ectoapertures very evident.

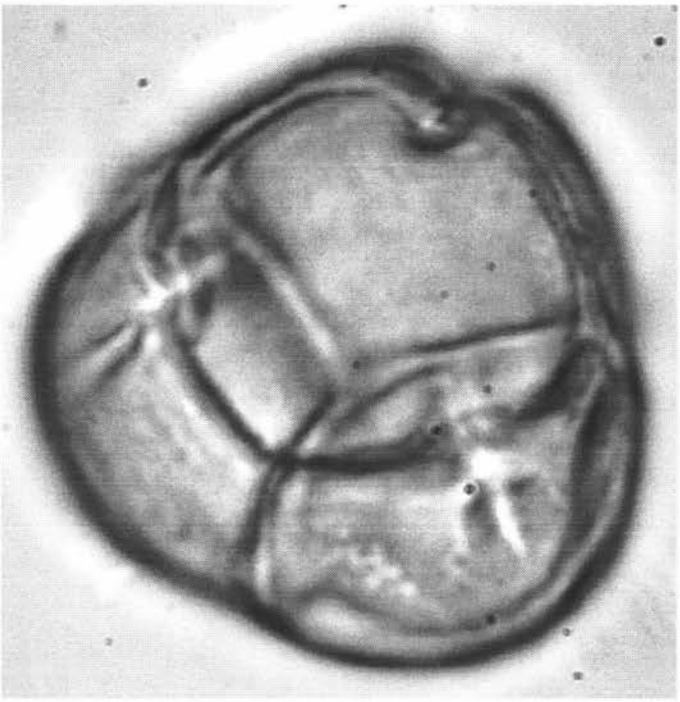


Figure Ap.1.18a *Dracophyllum latifolium* - Tetrahedral tetrad; tricolporate; ectoapertures relatively long, narrow, confluent with adjoining grain; endoapertures lalongate, forming a distinctive notch in endexine

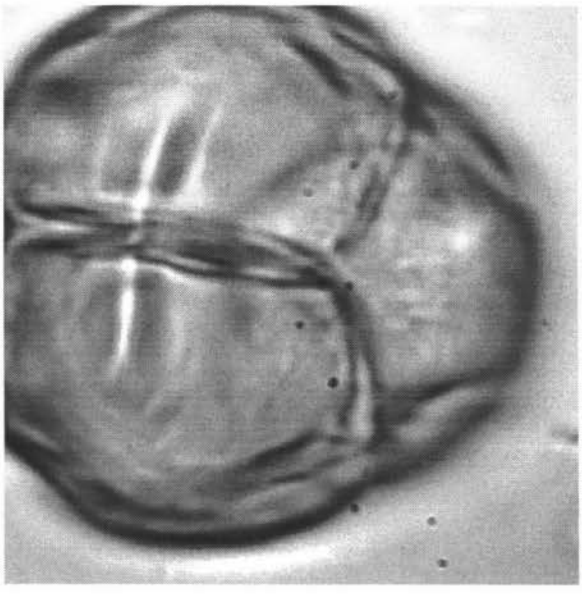


Figure Ap.1.18b *Dracophyllum latifolium* - Second view, tectate, baculate, bacula not easily resolved, tectum smooth; large intectate patch between ectoapertures; endocracks numerous; shape slightly lobed

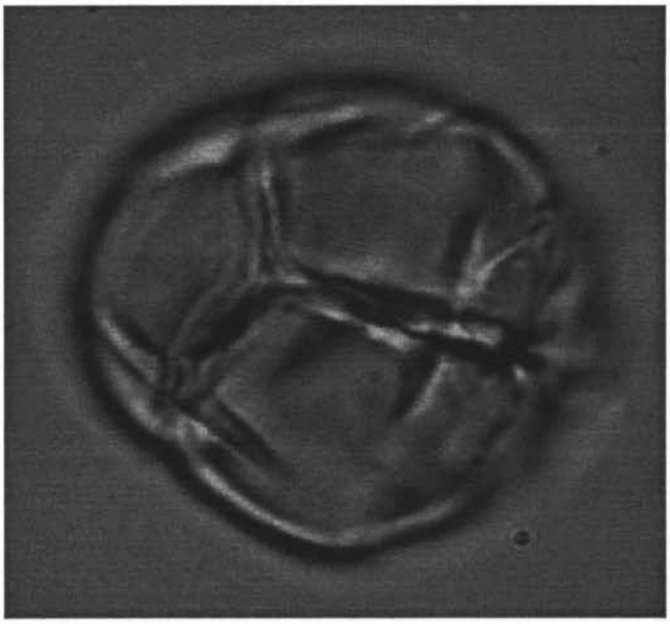


Figure Ap.1.19a *Carpodetus serratus* - Tedrad, anisopolar, basically tricolporate; both endoapertures and ectoapertures relatively long and narrow;

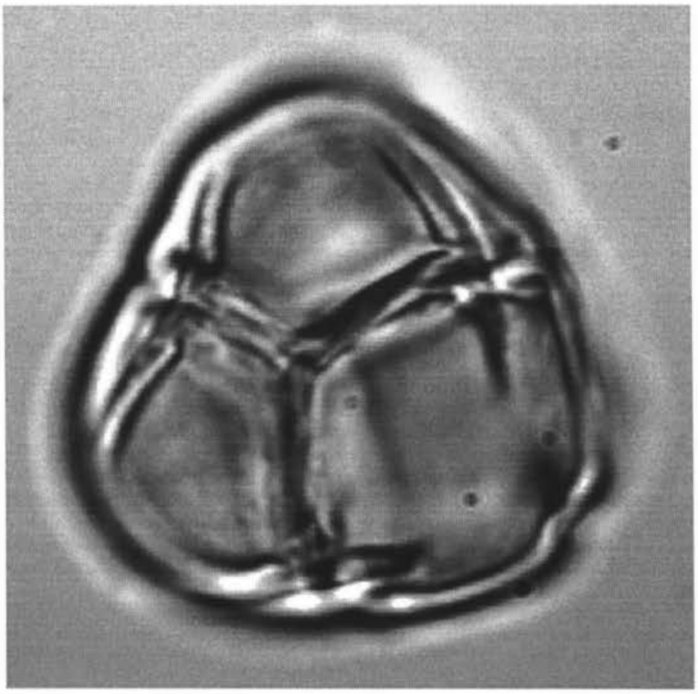


Figure Ap.1.19b - *Carpodetus serratus* - Second view showing tectate aspect, structure obscure; endocracks and circular thinning obvious in endexine; surface faintly rugulate; shape slightly lobed

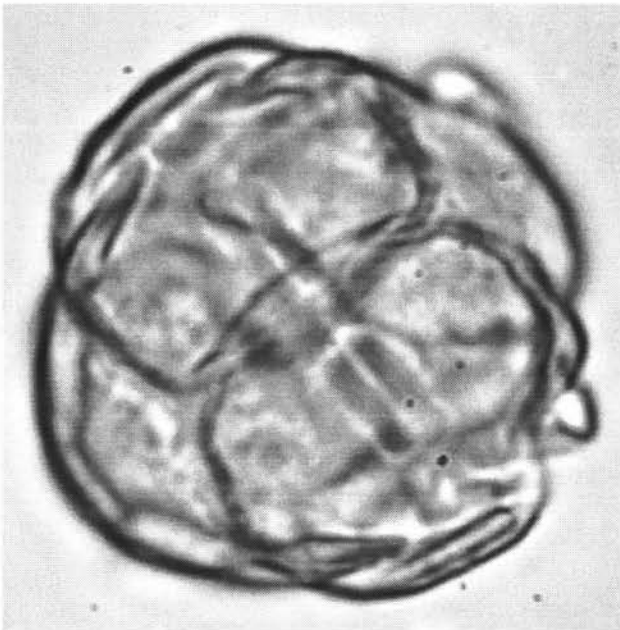


Figure Ap.1.20a *Gaultheria rupestris* - Tetrahedra; tetrad, tricolporate, angulaperturate or planaperturate, ectoapertures narrow, can be short or long; sometimes bifurcate at ends; costate

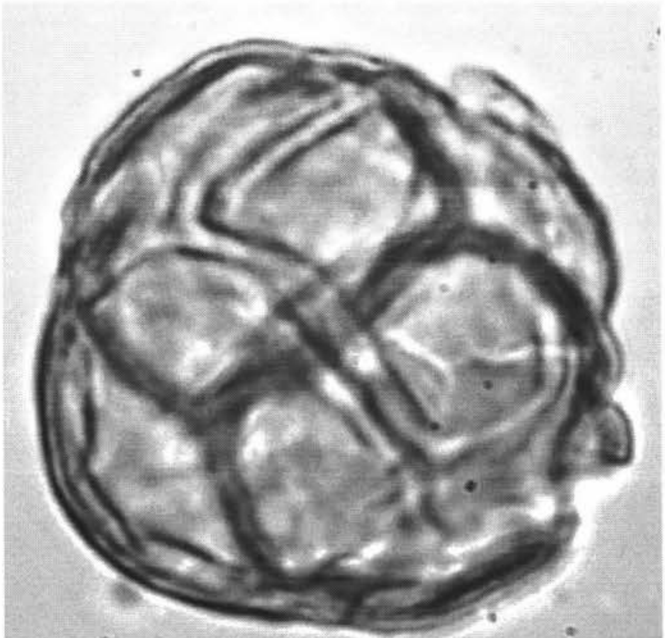


Figure Ap.1.20b *Gaultheria rupestris* - Exine moderately thick at ectoapertures, tectate, baculate, bacula very short; tectum surface faintly rugulate; endocracks, often bold at distal pole and about ectoapertures

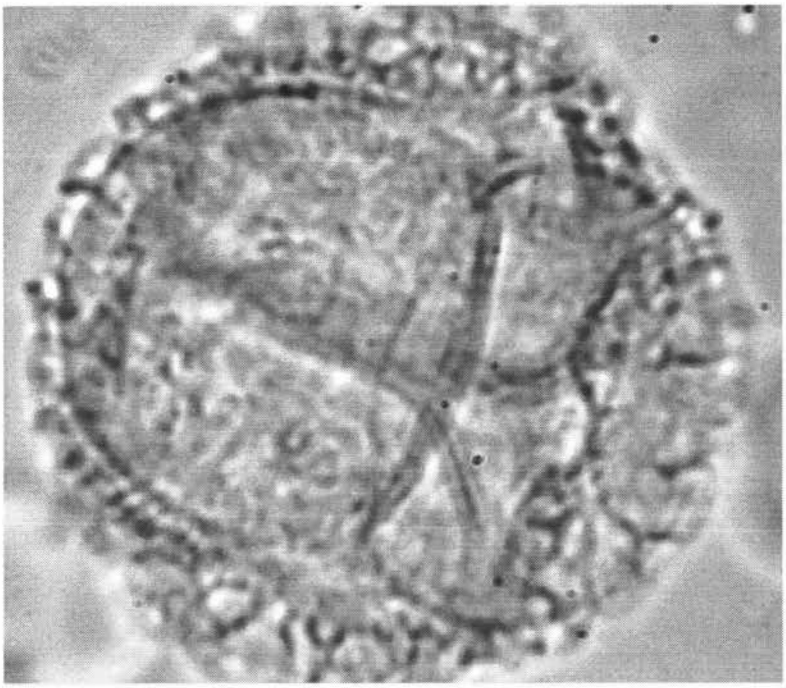


Figure Ap.1.21a *Pseudowintera colorata* - Tetrahedral terad; each grain monoporate; aperture more-or-less circular on distal surface; endexine thickened round the apertures

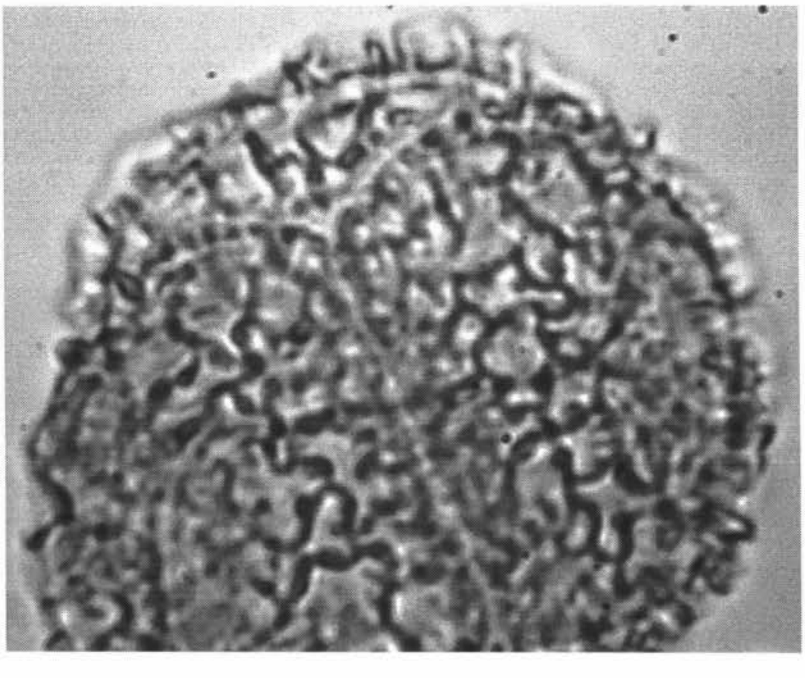


Figure Ap.1.21b *Pseudowintera colorata* - Exine semitectate, coarsely reticulate, baculate, membrane roughened ; muri narrow, shape is circular

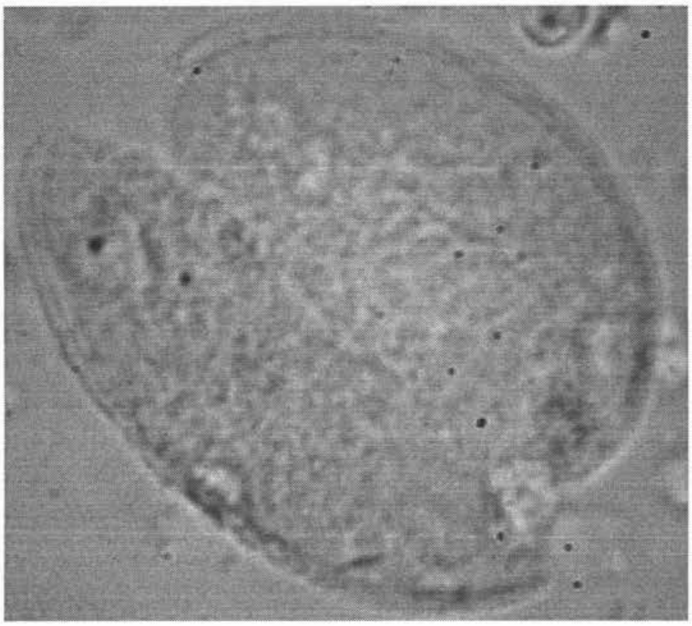


Figure Ap.1.22a *Cordyline australis* - Monocolporate, shape oblate, proximally flattened, furrow exceeds the long axis of the grain, bulging on furrow side often apparent; exine coarsely reticulate as a rule

Figure Ap.1.22b *Cordyline australis* - Second view showing exine surface roughened, especially on proximal side and intine thick under the furrow plus further view of furrow exceeding the long axis

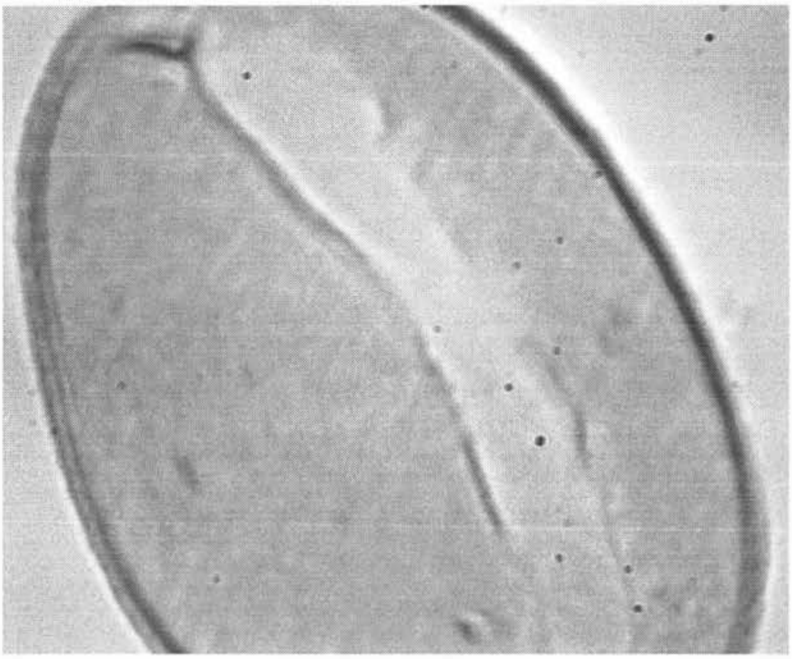


Figure Ap.1.23a *Rhopalostylis sapida* - Monocolpate, ellipsoidal and deeply channelled can be globose when expanded; proximal side usually flatter than distal side; furrow very long, markedly broader at ends

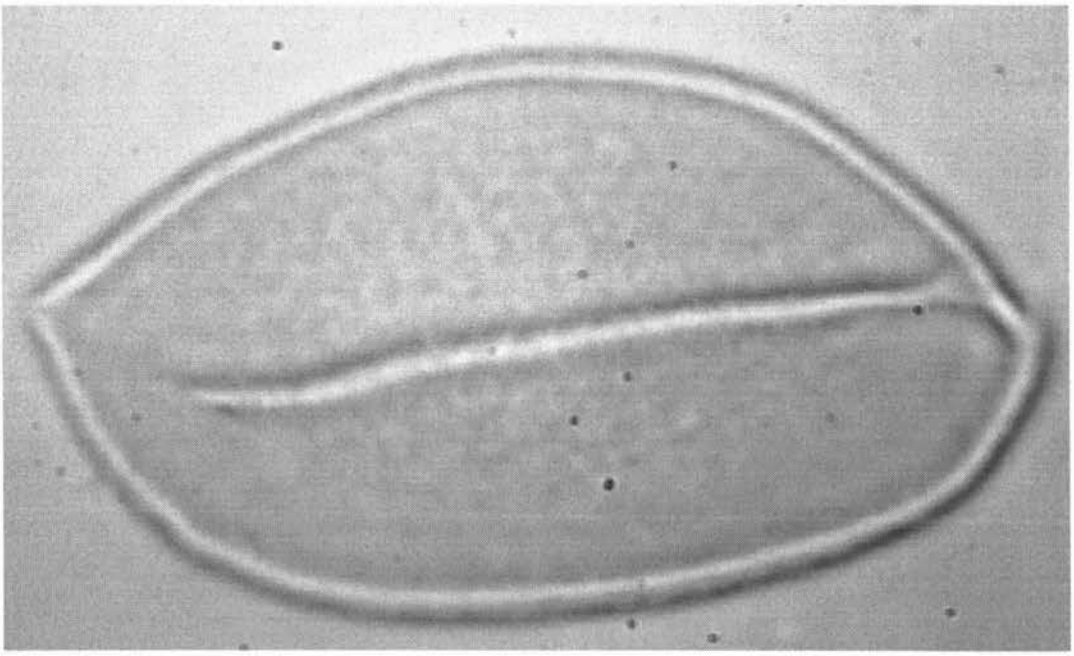


Figure Ap.1.23b *Rhopalostylis sapida* - Exine almost smooth, fairly thick, with a small radial elements forming a fine reticulum of clavate-like rods; endexine colourless, extending over the furrow membrane

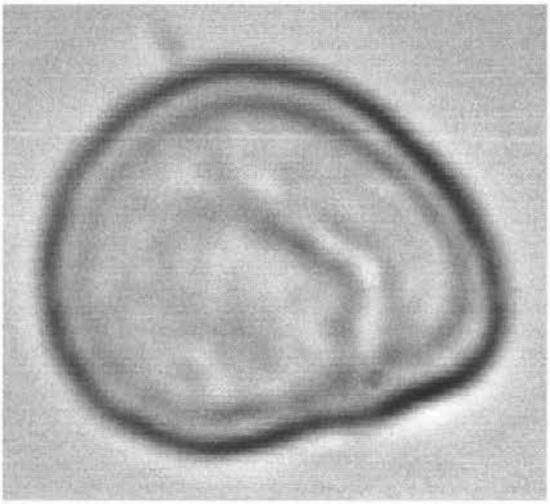


Figure Ap.1.24a *Macropiper excelsum* - Monocolpate, anisopolar, bilaterally symmetrical apertures large, circular; exine very thin; shape spheroidal

Figure Ap.1.24b *Macropiper excelsum* - Equatorial view, exine very thin, surface broken up into ± polygonal areas separated by narrow channels; shape oblate

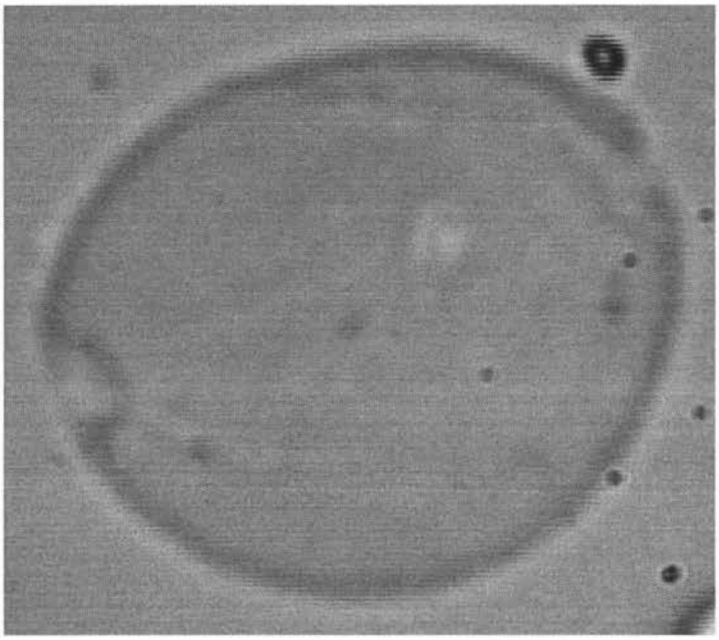


Figure Ap.1.25a *Corynocarpus laevigatus* - dicolporate, heteropolar, one pole flattened the other rounded; ectoapertures long and vaguely defined on rounded pole; endoapertures lalongate, oval

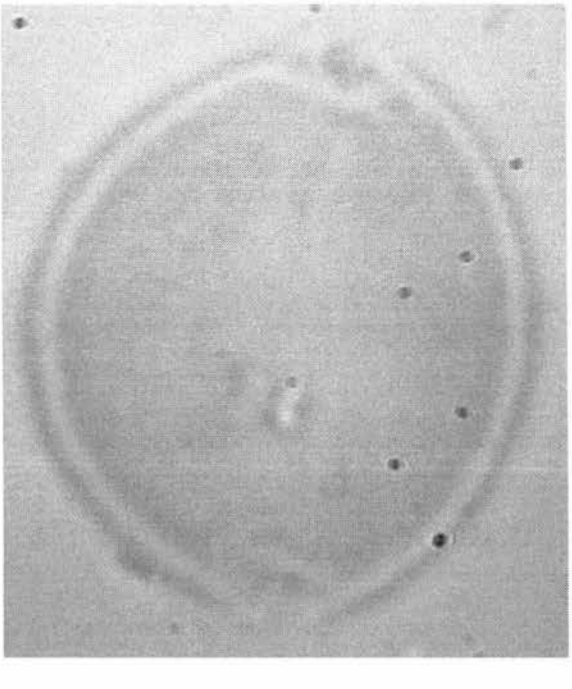


Figure Ap.1.25b *Corynocarpus laevigatus* - Tectate, baculate, structure difficult to resolve; tectum smooth or scabrate, slightly perforate at poles; shape elliptical in polar view (subtriangular in equatorial view)

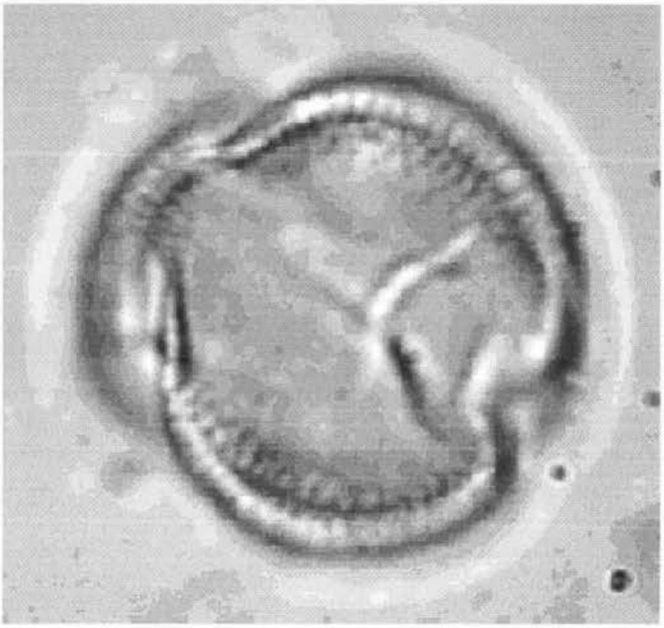


Figure Ap.1.26a *Myoporum laetum* - Tricolpate, each colpus diorate; angulaperturate, ectoapertures slightly sunken, broader at equator tapering to acute or rounded ends, polar area small; shape subprolate

Figure Ap.1.26b *Myoporum laetum* - Membrane split in two equally spaced narrow slit-like, lalongate fissures, often including ectexine, fissures may be absent; exine semi-tectate, reticulate, muri variable

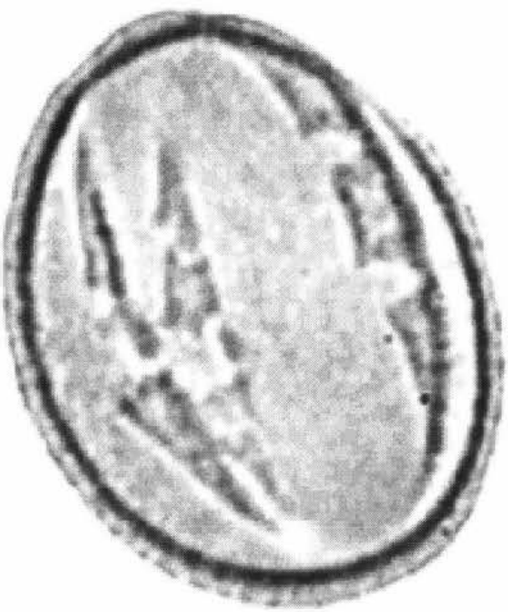


Figure Ap.1.27a *Hebe odora* - Tricolpate, ectoapertures slightly sunken 2/3 length of grain, tapering to rounded ends at poles; polar area medium, exine thin, thinning more towards the furrows, semitectate

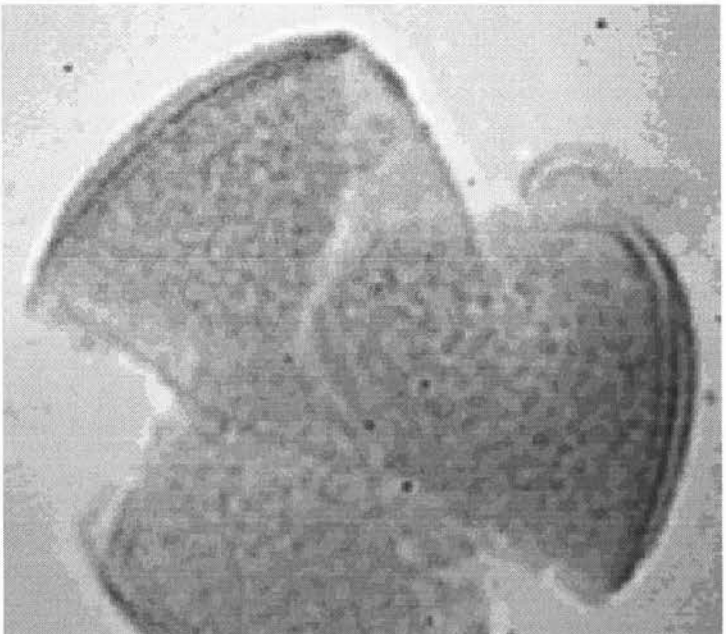


Figure Ap.1.27b *Hebe odora* - Membrane thin easily ruptured, with fine exinous granules scattered over surface; finely reticulate, pattern variable; lumina very small, muri very narrow; shape prolate-spheroidal

Figure Ap.1.28a *Aristotelia serrata* - Tricolporate, ectoapertures very long, reaching almost to poles, protruding slightly at the equator; endoapertures obscure; shape subprolate, rounded at poles

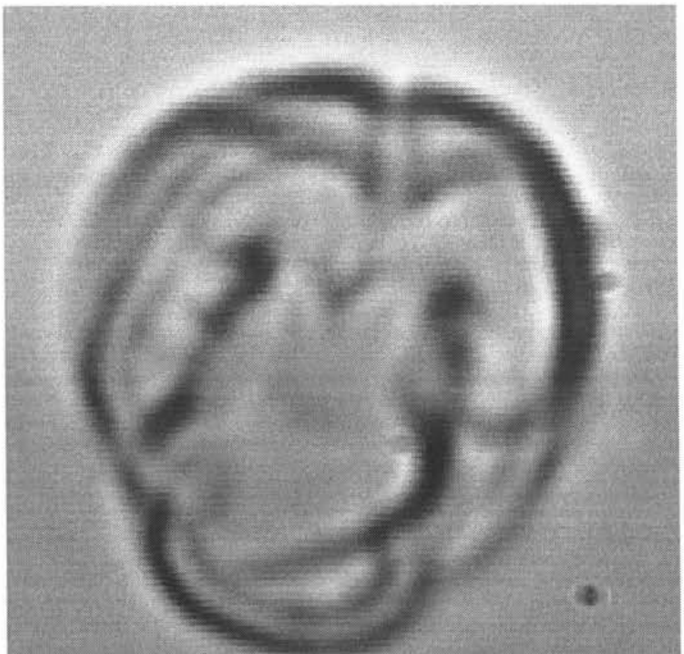


Figure Ap.1.28b *Aristotelia serrata* - Polar view, circular in shape; exine structure obscure; surface faintly and finely reticulate

Figure Ap.1.29a *Coprosma lucida* - Tricolporate; tectum rugulate, but can appear smooth, bearing minute spinules; shape usually subtriangular in polar view, amb very strongly convex

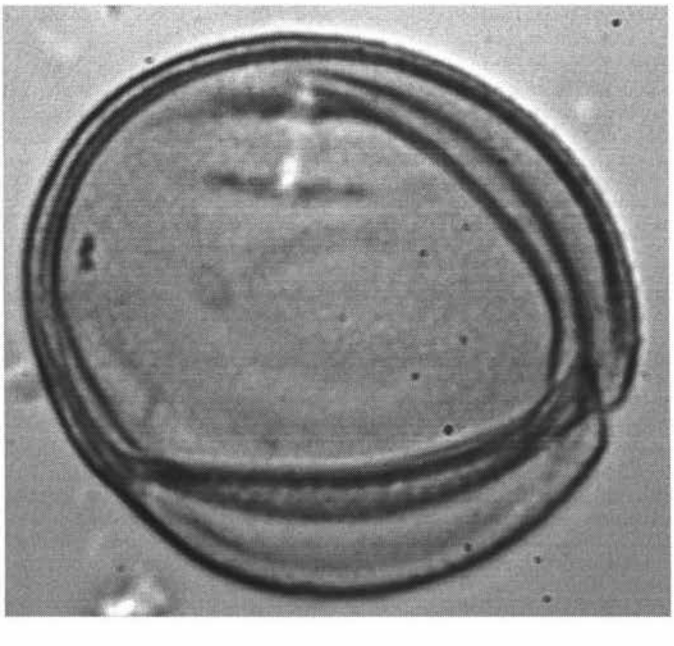


Figure Ap.1.29b - *Coprosma lucida* - Equatorial view showing distinctive pattern formed by the pore; shape oblate; endocracks in the inner surface of the endexine may develop

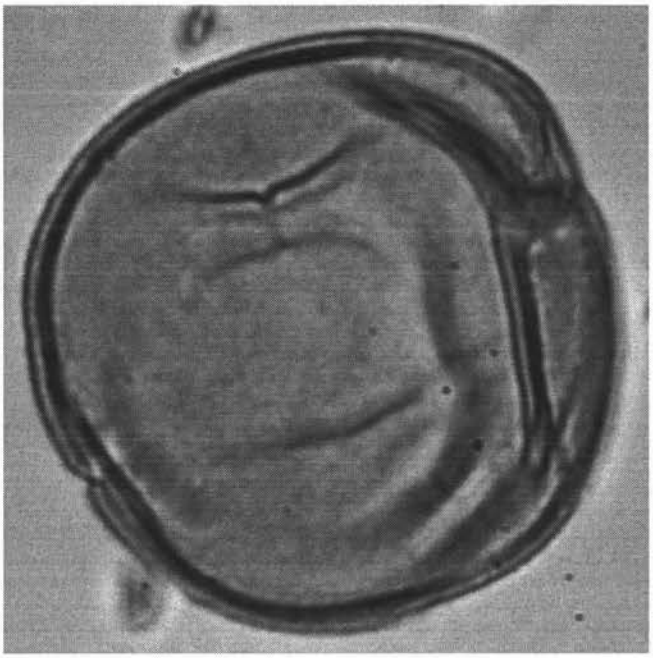


Figure Ap.1.30a *Coproma foetidissima* - Tricolporate; shape subspheroidal, flattened at the pores, distinctive pattern made by pore very evident; tectum rugulate, may appear as smooth

Figure Ap.1.30b *Coprosma foetidissima* - Polar view, shape circular, ectexine clearly visible; exine very finely rugulate (this grain may also be tetracolporate)

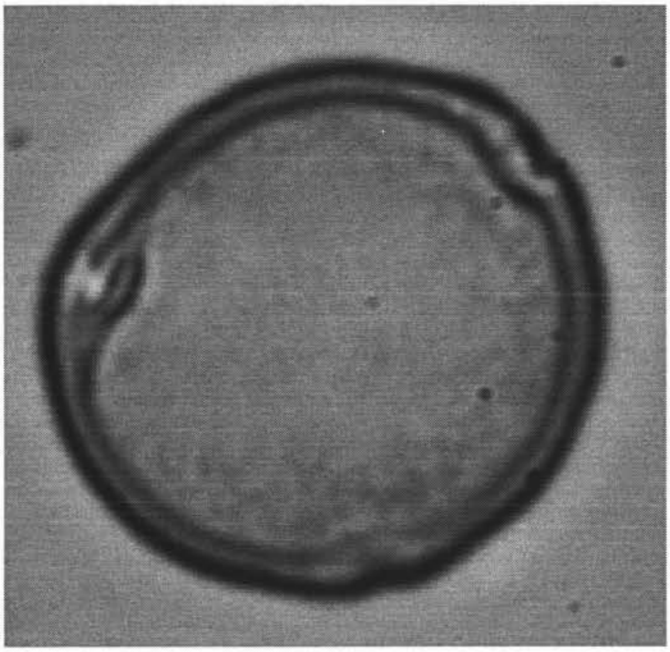


Figure Ap.1.31a *Coriaria arborea* - Tricolporate, extoapertures narrow, slit-like, and short; polar area large; endoapertures about as long as broad; margins slightly thickened; shape spheroidal

Figure Ap.1.31b *Coriaria arborea* - Equatorial view, exine tectate, baculate. bacula rarely resolved; tectum scabrate, perforate, bearing minute spinules; shape spheroidal, amb convex; size variable

Figure Ap. 1.32a *Dodonaea viscosa* - Tricolporate, angularaperturate; ectoapertures long, obscure towards the poles; costate, membrane with scattered extexinous elements; polar area medium; shape subprolate

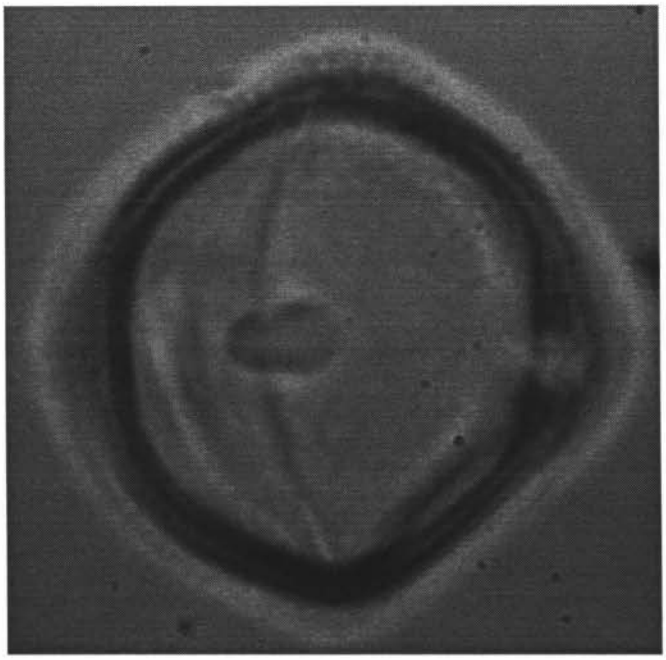


Figure Ap.1.32b *Dodonaea viscosa* - Equatorial view, endoapertures lalongate, relatively small, rectangular, clearly defined; tectum perforate, faintly scabrate; bacula very short; shape oval

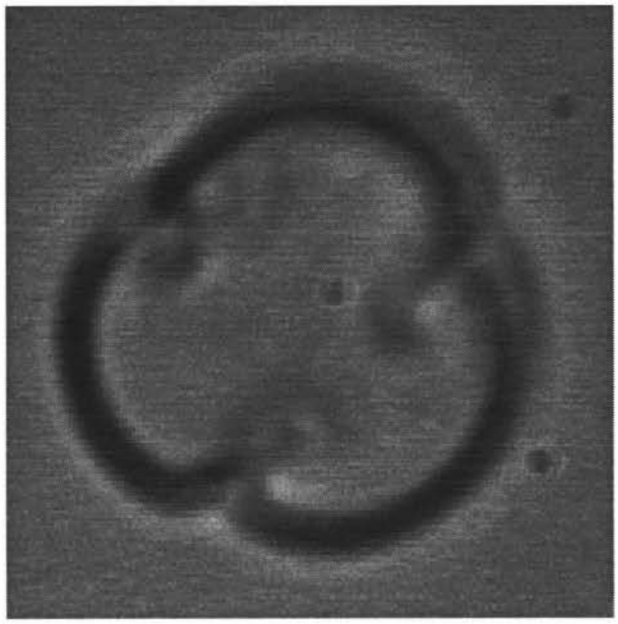


Figure Ap. 1.33a *Elaeocarpus dentatus* - Tricolporate; ectoapertures narrow, protruding slightly at equator; costae; polar area medium; shape circular in polar view

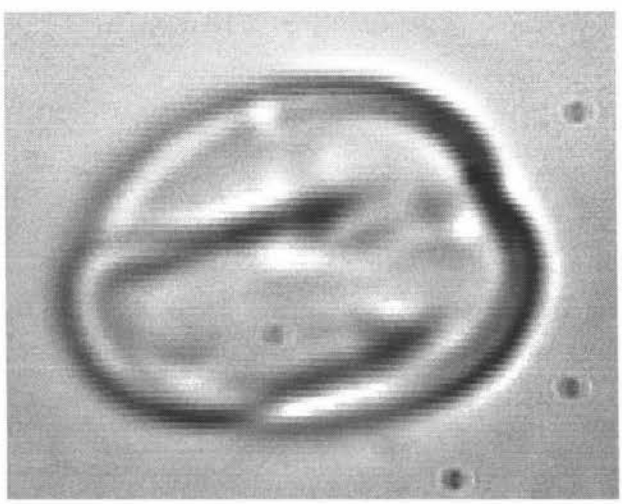


Figure Ap.1.33b *Elaeocarpus dentatus* - Equatorial view, endoapertures lalongate, narrow (not always visible); exine structure obscure, surface smooth, shape subprolate, rounded at poles

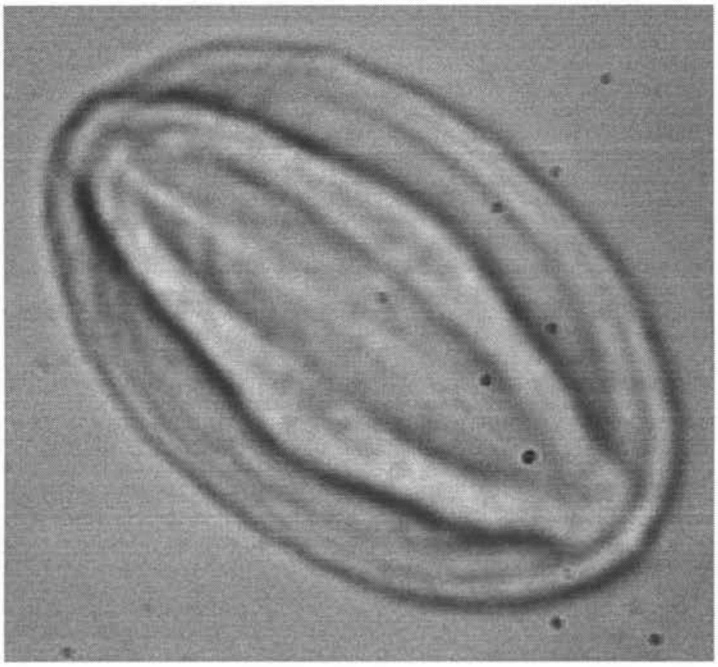


Figure Ap.1.34a *Griselinia lucida* - Tricolporate; angulaperturate; endoapertures small, lalongate, slit-like, often obscure; costate, margins smooth; polar area small; shape prolate, rounded slightly at poles

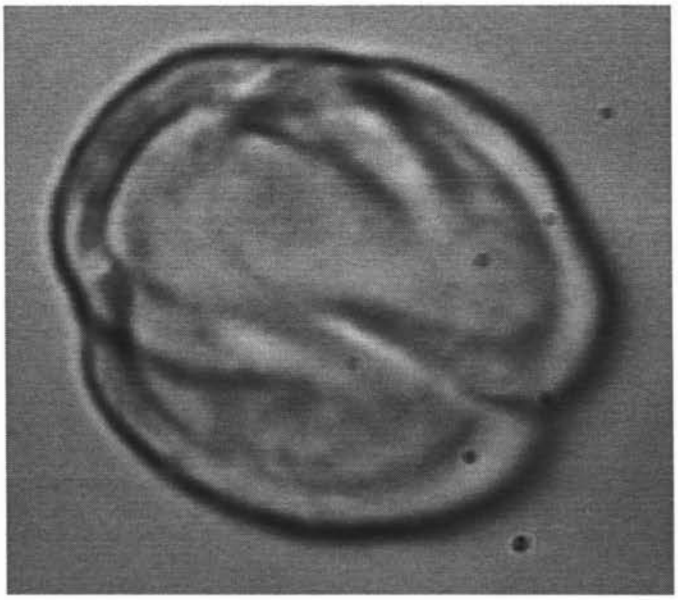


Figure Ap.1.34b *Griselinia lucida* - Polar view, ectoapertures very long, almost to poles; tectum perforate, boldly striate, often extending across the poles; shape subrounded

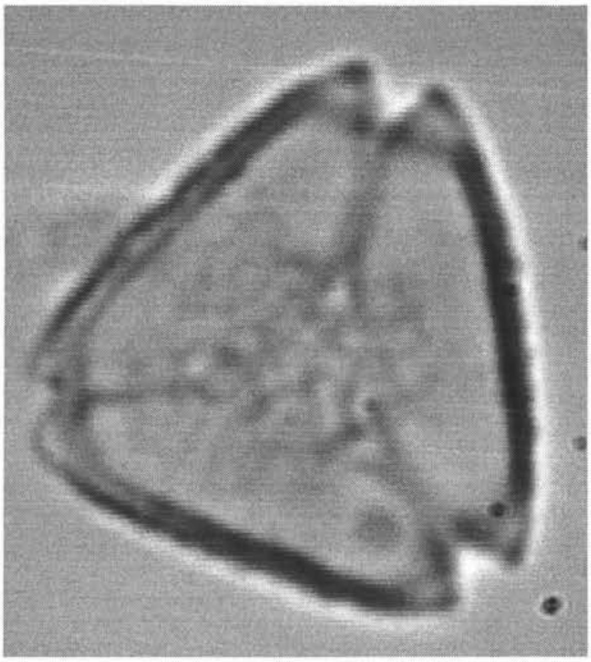


Figure Ap.1.35a *Lophomyrtus obcordata* - Tricolporate, angulaperturate; ectoapertures very long, rarely parasyncolpate; shape triangular in polar view, angles rounded, amb slightly concave or convex

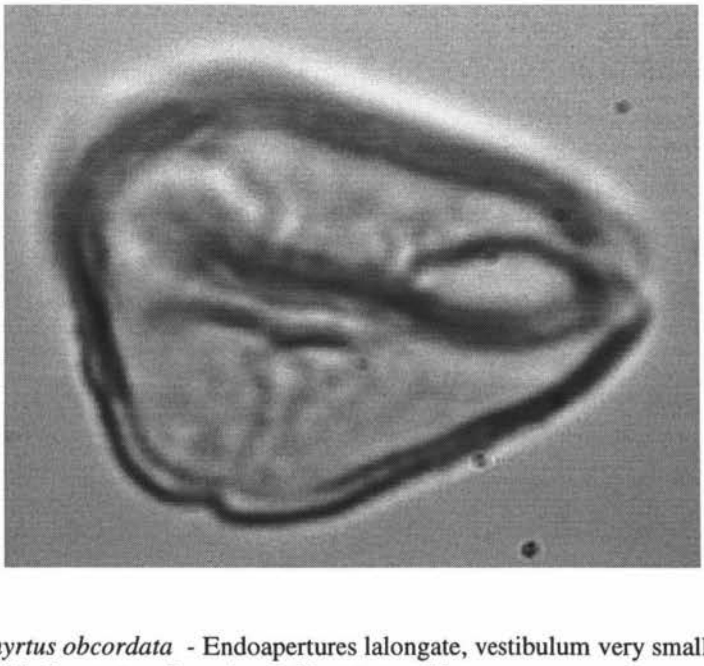


Figure Ap.1.35b *Lophomyrtus obcordata* - Endoapertures lalongate, vestibulum very small; exine structure obscure; tectum surface verrucate, faintly so at angles; shape oblate to peroblate

Figure Ap. 1.36a *Muehlenbeckia australis* - Tricolporate; ectoapurtures very long, reaching almost to poles; rarely syncolpate; narrow; costate, slightly recessed; polar area small; endoapertures lalongate; shape oblate

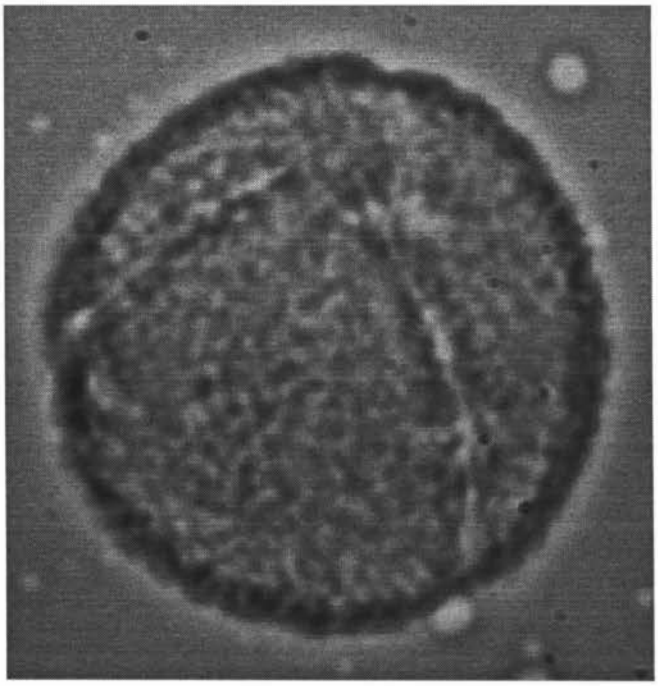


Figure Ap.1.36b *Muehlenbeckia australis* - Tectum perforate, ridges arranged in supratectal striate-reticulate patterns; baculate, bacula fine usually arranged in clusters; shape subprolate. rounded at poles

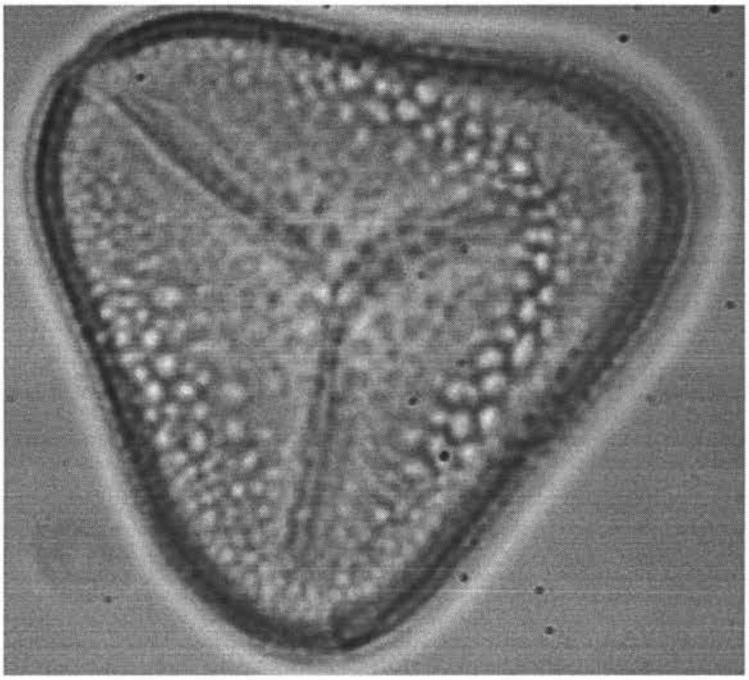


Figure Ap.1.37a *Phormium tenax* - Trichotomocolpate, oblate, sharply angled when un-expanded; tectate, faveolate to reticulate; holes in tectum very small at angles of grain and towards furrow margins

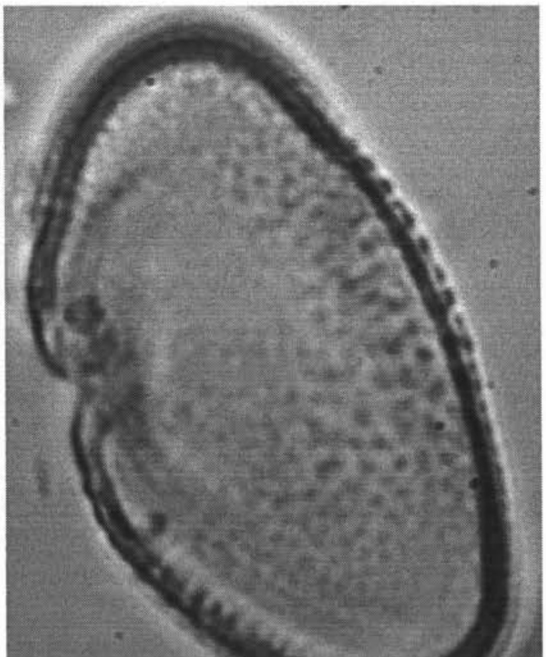


Figure Ap.1.37b *Phormium tenax* - Flattened, or rounded, often symmetrical in polar view, with very long triradiate furrow arms extending beyond angles of the grain margins; exine thinning at margins

Figure Ap.1.38a *Pittosporum crassifolium* - Tricolporate; ectoapertures very long, 2/3 of grain, tapering to a blunt end, costate; endoapertures lalongate, tapering; shape subprolate to spheroidal; amb circular

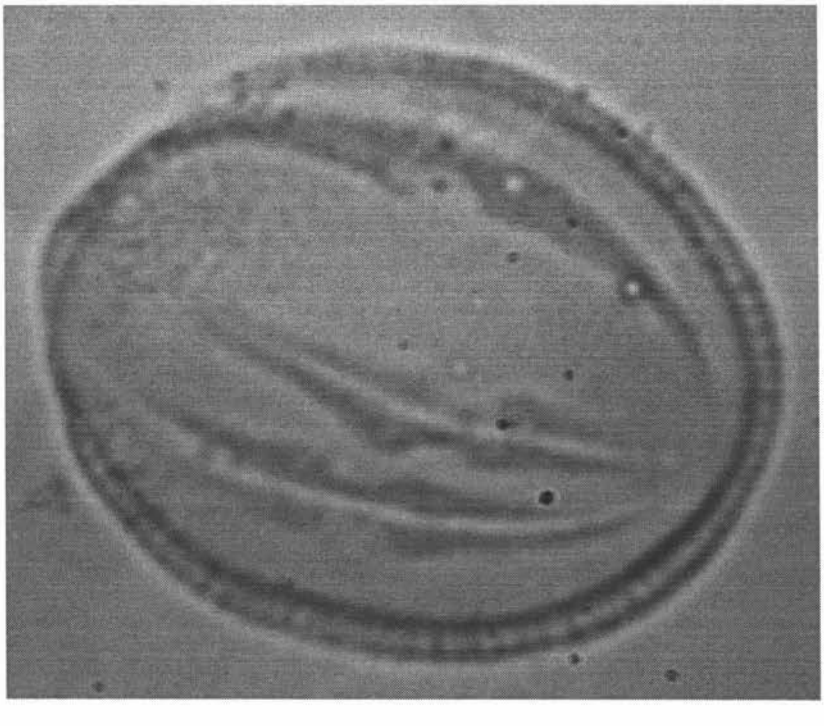


Figure Ap.1.38b *Pittosporum crassifolium* - Ectoapertures sometimes constricted at equator, narrowing slightly towards the poles, with fine ectexinous elements scattered over the membrane; amb subcircular

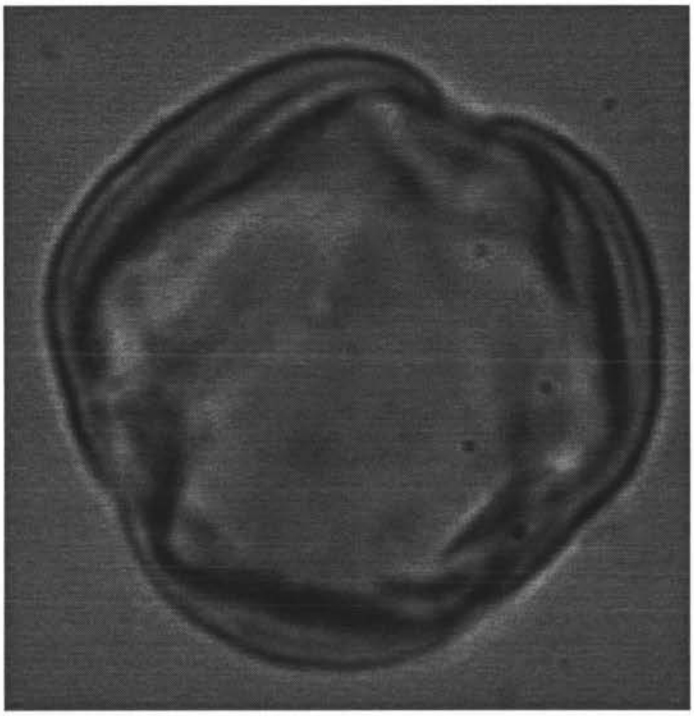


Figure Ap.1.39a *Pittosporum tenuifolium* - Tricolporate; tectate, baculate, bacula short, not easily resolved; tectum smooth, with few perforations; shape subcircular in polar view

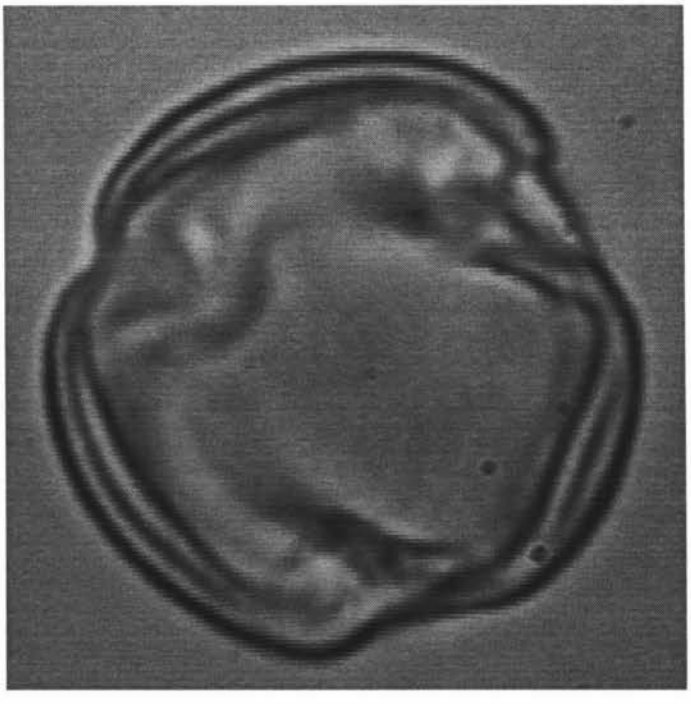


Figure Ap.1.39b *Pittosporum tenuifolium* - Exine thinning towards apertures; bacula short, not easily resolved; shape subprolate to spheroidal, amb subcircular to circular

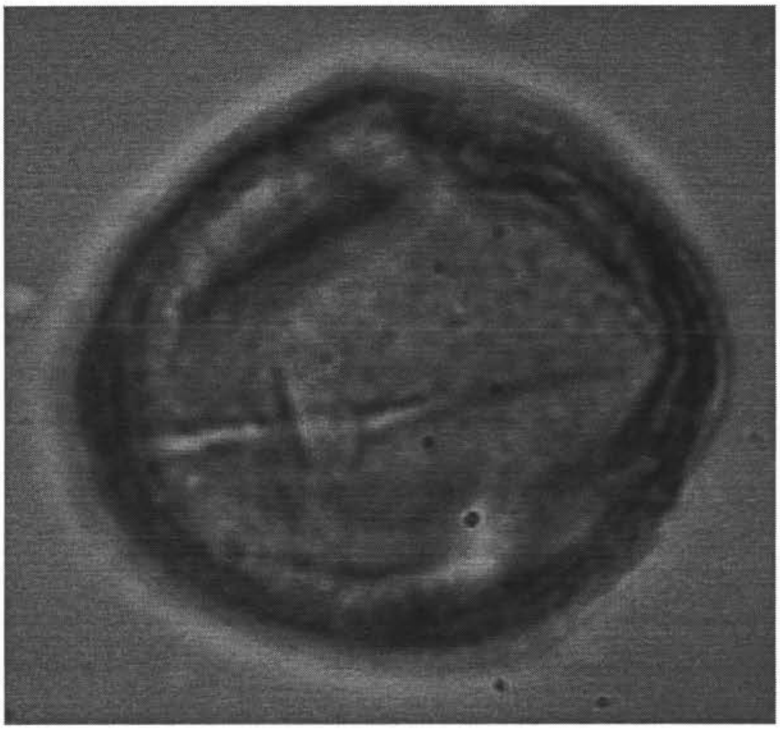


Figure Ap.1.40a *Pseudopanax arboreus* - Tricolporate; angulaperturate; ectoapertures very long reaching almost to poles; polar area small, endoapertures clearly defined, large rectangular, margins thickened.

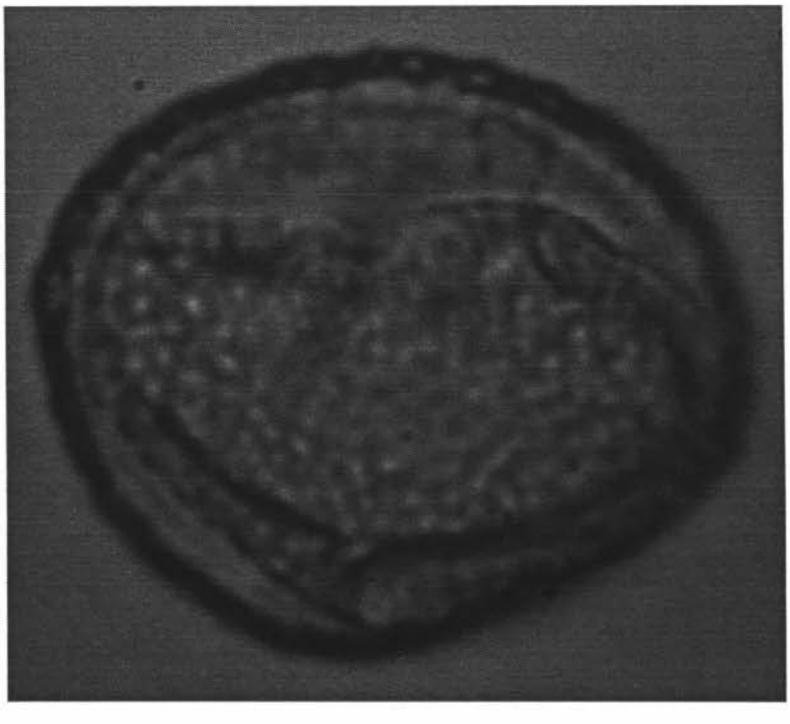


Figure Ap.1.40b *Pseudopanax arboreus* - Exine thinner towards equator; semitectate, baculate, reticulate, surface uneven, muri simpli- or duplibaculate, bold; bacula clearly visible; shape oblate to spheroidal

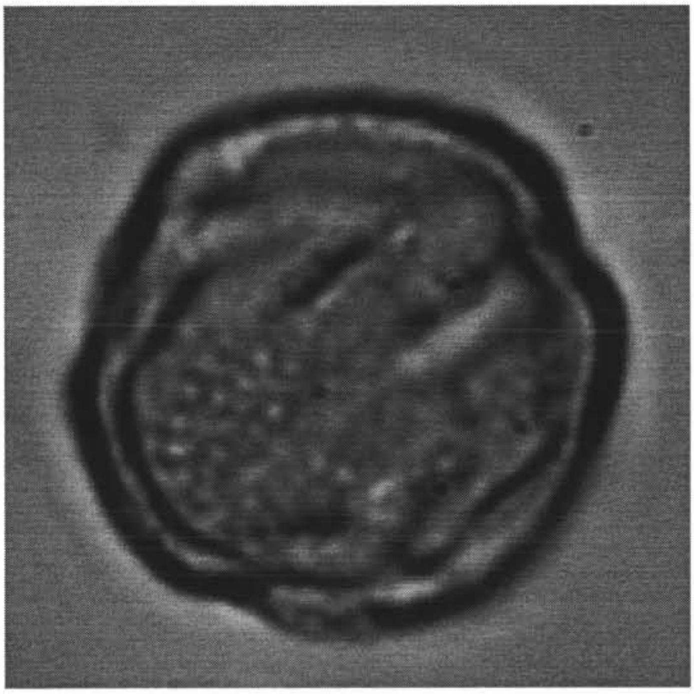


Figure Ap.1.41a *Pseudopanax crassifolium* - Tricolporate; angulaperturates; ectoapertures very long reaching almost to poles; endoapertures lalongate, rectangular, margins thickened; shape oblate

Figure Ap.1.41b *Pseudopanax crassifolium* - Lumina equant, smaller at apertures, exine thinner towards equator, semitectate, baculate; reticulum fine; muri simpli/duplibaculate, bold; shape spheroidal

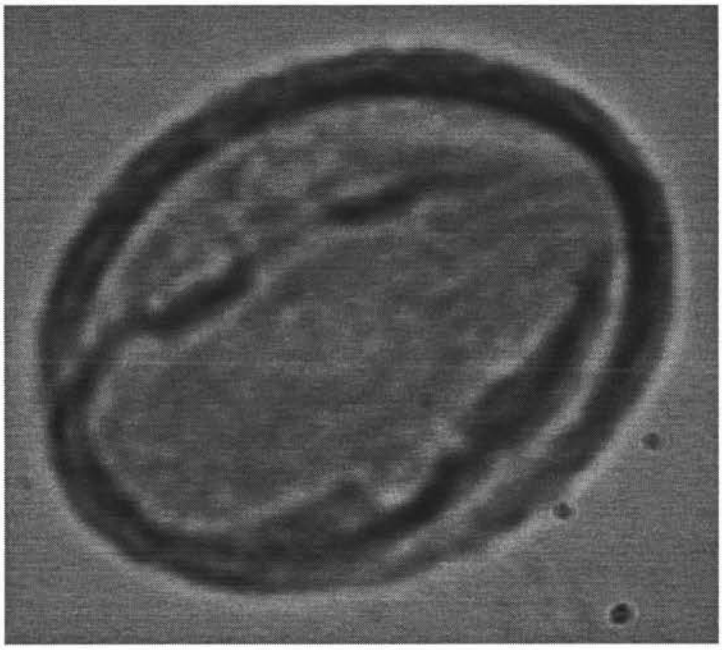


Figure Ap.1.42a *Rubus cissoides* - Tricolporate; angulaperturate, ectoapertures very long , almost to poles, often constricted at equator, tapering to rounded ends; polar area small; endoapertures rectangular; subprolate

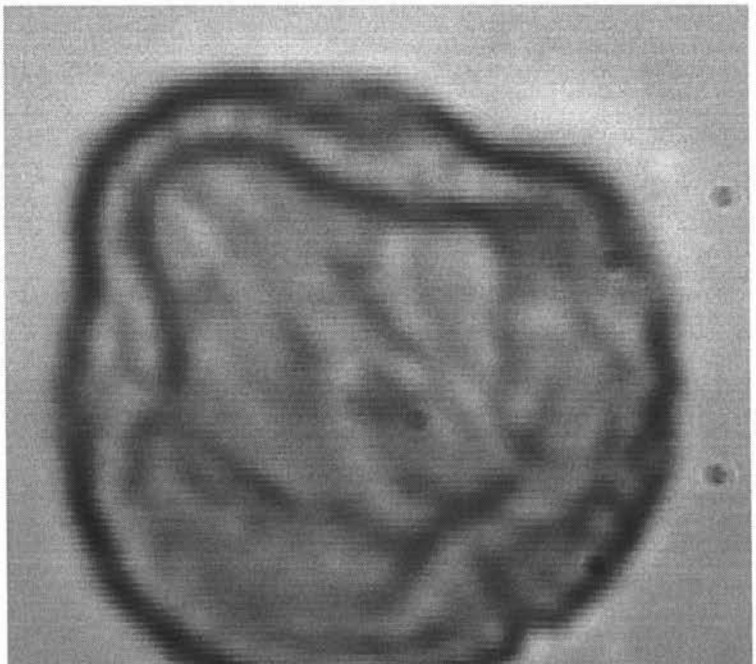


Figure Ap.1.42b *Rubus cissoides* - Tectate, baculate, striate, striae supratectal, bold, generally coarser at the poles; bacula fine; tectum perforate between ridges; shape subtriangular in polar view, amb convex

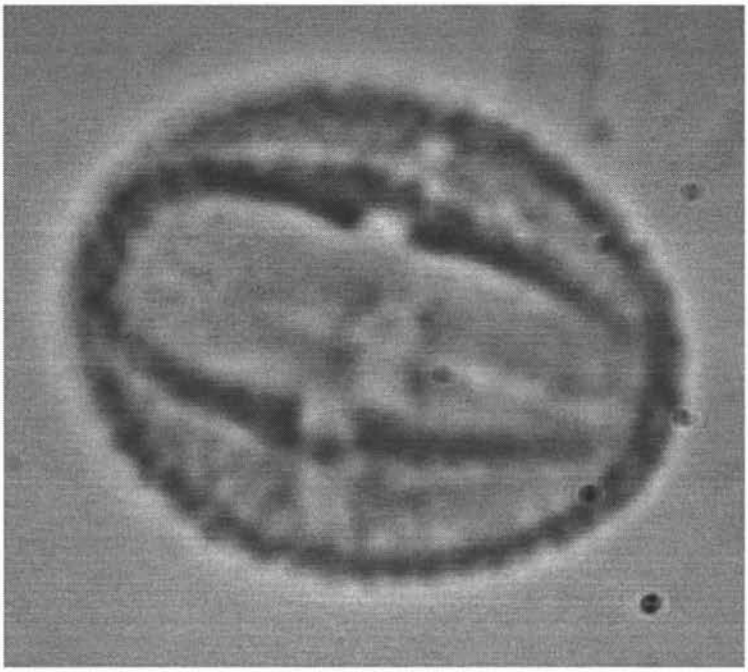


Figure Ap.1.43a *Schefflera digitata* - Tricolporate; angulaperturate; ectoapertures broad, >2/3 length of grain, costate; polar area medium; endoapertures clearly defined, lalongate, rectangular/H-shaped; prolate

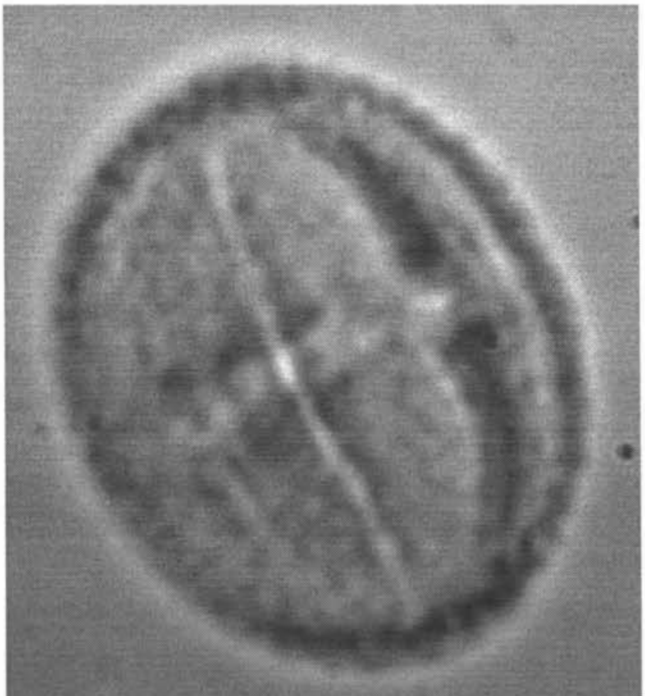


Figure Ap.1.43b - *Schefflera digitata* - Exine moderately thin, semitectate, baculate, reticulate; lumina at poles slightly smaller; muri simplibaculate, bacula just visible, shape prolate-spheroidal, flattened at poles

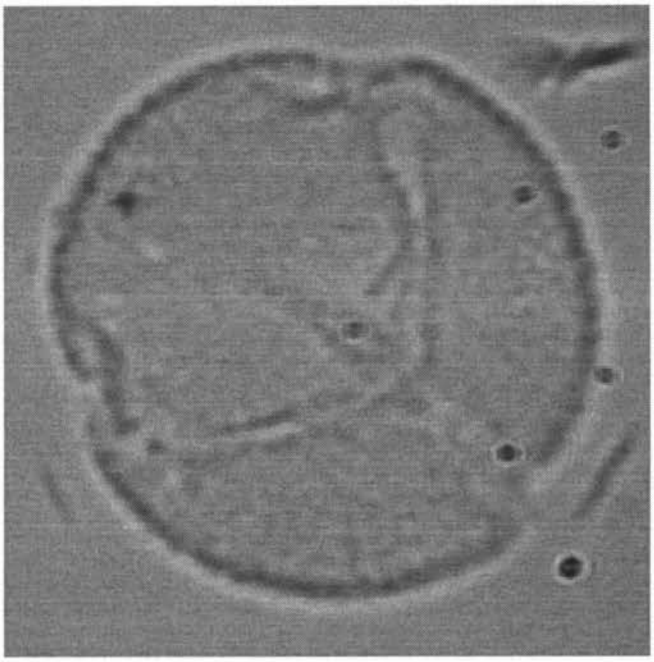


Figure Ap.1.44a *Melicytus ramiflorus* - Tricolporate; ectoapertures broad, very long, extending almost to poles, membrane granulate; exine very thin, semitectate, baculate, tectate; polar area small to medium

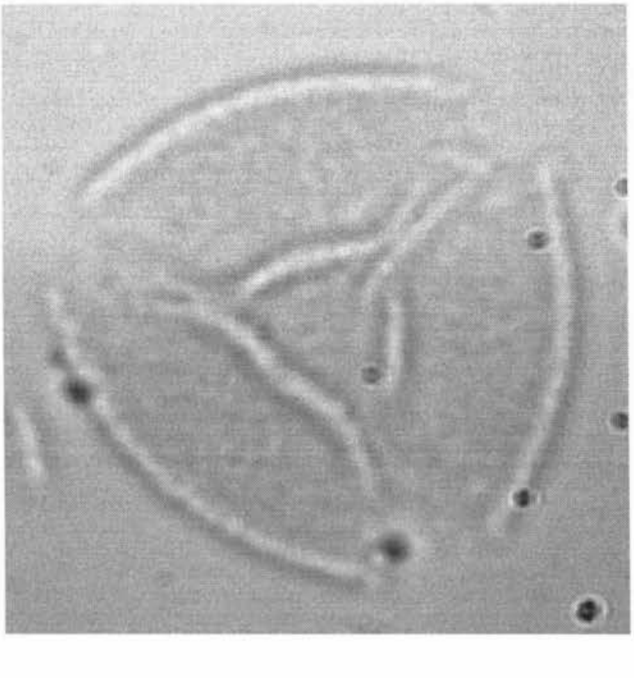


Figure Ap.1.44b *Melicytus ramiflorus* - Endoapertures indistinct, sometimes lolongate, tectum smooth, simplibaculate; reticulum slightly beaded; shape spheroidal, subtriangular in polar view, amb circular

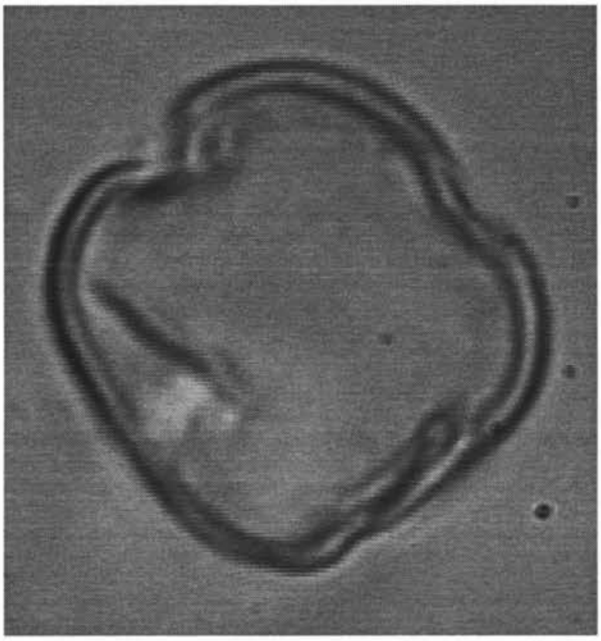


Figure Ap.1.45a *Myrsine australis* - Stephanocolpate; membrane faintly granular, exine appears smooth, but faintly verrucate in surface view; ectoapertures slightly sunken to produce a four-lobed appearance

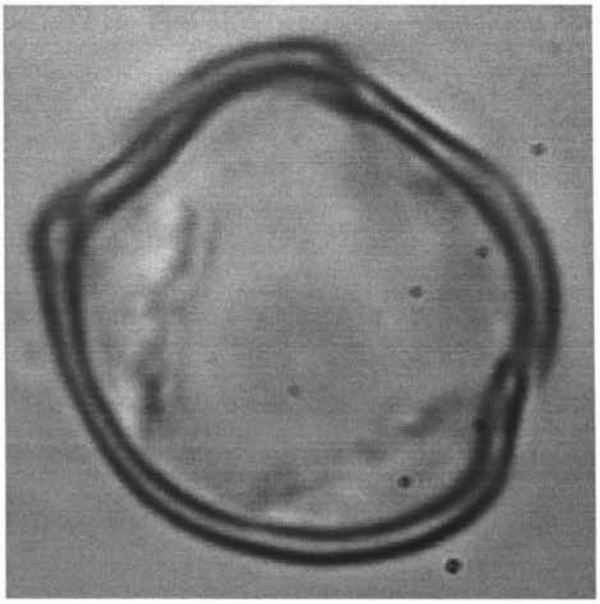


Figure Ap.1.45b - *Myrsine australis* - A second oblique view of the grain showing the generally subrectangular, but variable shape; poles flattened or spheroidal

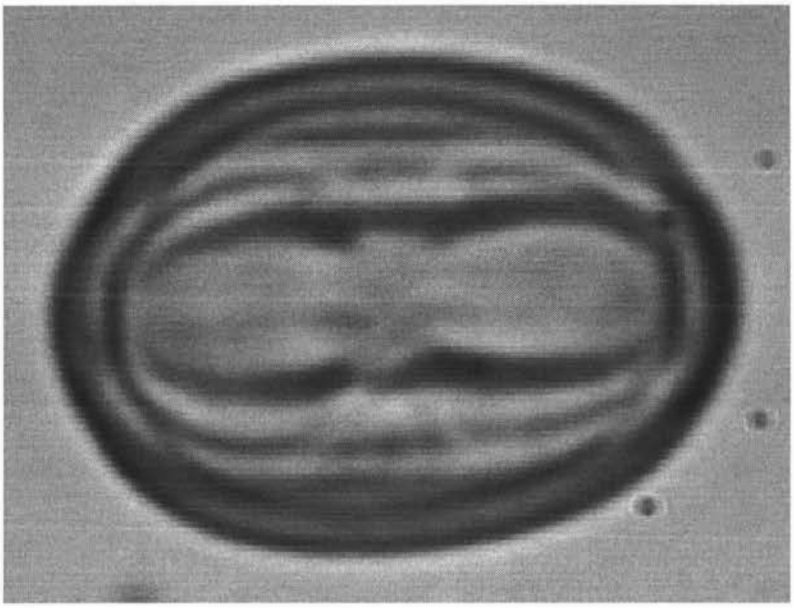


Figure Ap.1.46a - *Qunitinia serrata* - tetra-to pentacolporate, ectoapertures very long, somtimes almost syncolpate; shape subprolate to spheroidal, rounded at poles, amb convex

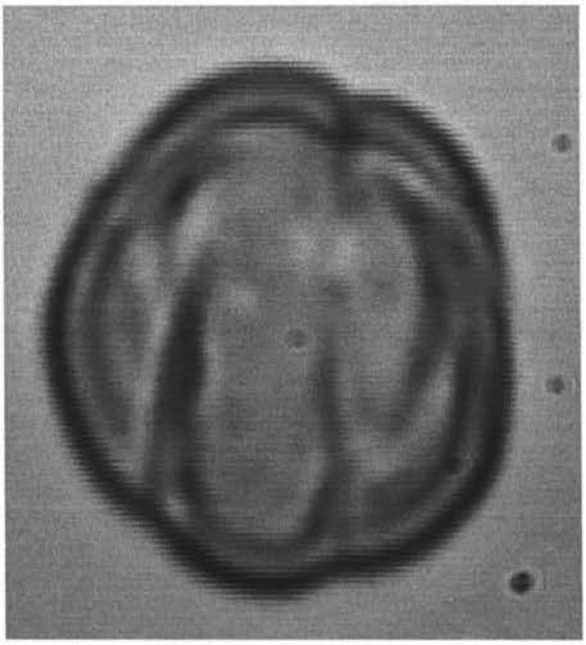


Figure Ap.1.46b - *Quintinia serrata* - Narrow slightly sunken endoapertures are small often more or less elliptical, often obscure; surface is psilate, faintly marked, sometimes visible; shape circular in polar view

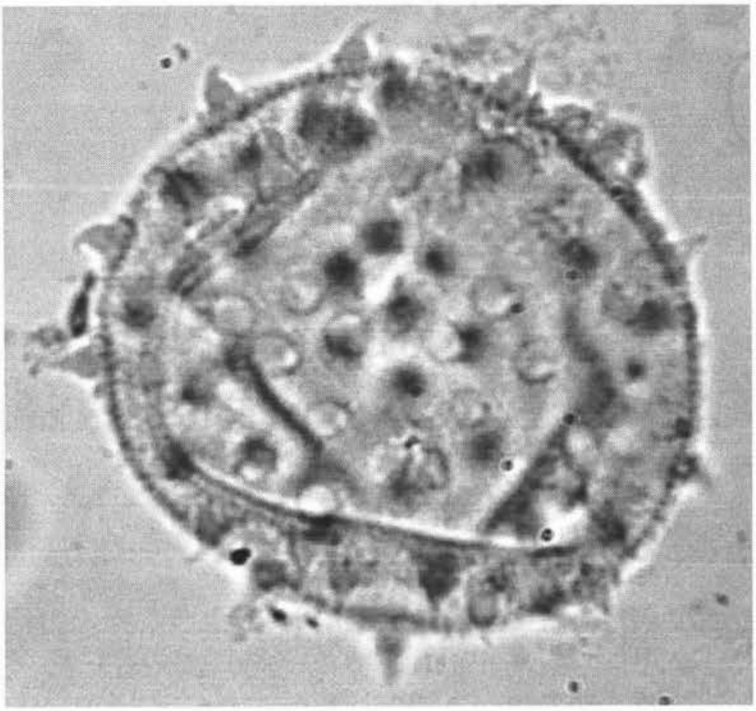


Figure Ap.1.47a - *Hoheria populnea* - Tri- to pentacolporate, mainly tetracolporate; ectoapertures narrow, very short, barely exceeding outside of endoapertures which are circular, with thickened rims

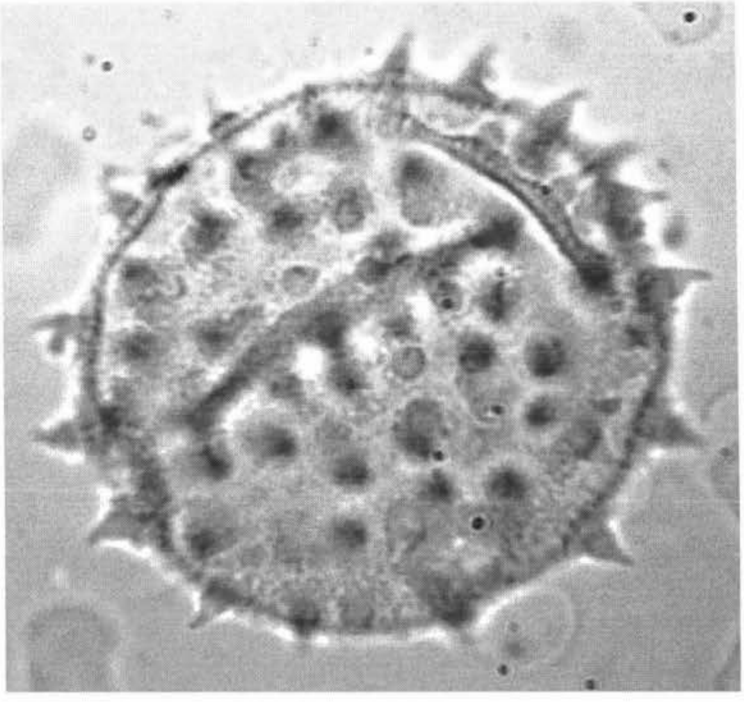


Figure Ap.1.47b - *Hoheria populnea* - Baculate, bacula coarser and longer under spines, tectum perforate, bearing supratectal spines; spines broad-based, tapering to a blunt apex, shape oval, circular in polar view

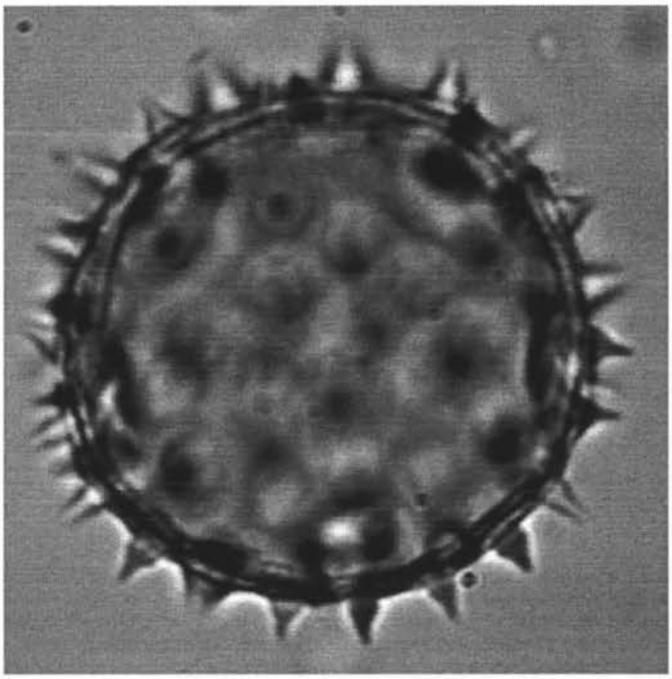


Figure Ap.1.48a - *Plagianthus divaricatus* - Tetra- to hexacolporate, mainly pentacolporate; ectoapertures very short, slit-like, barely exceeding diameter of endoapertures which are large

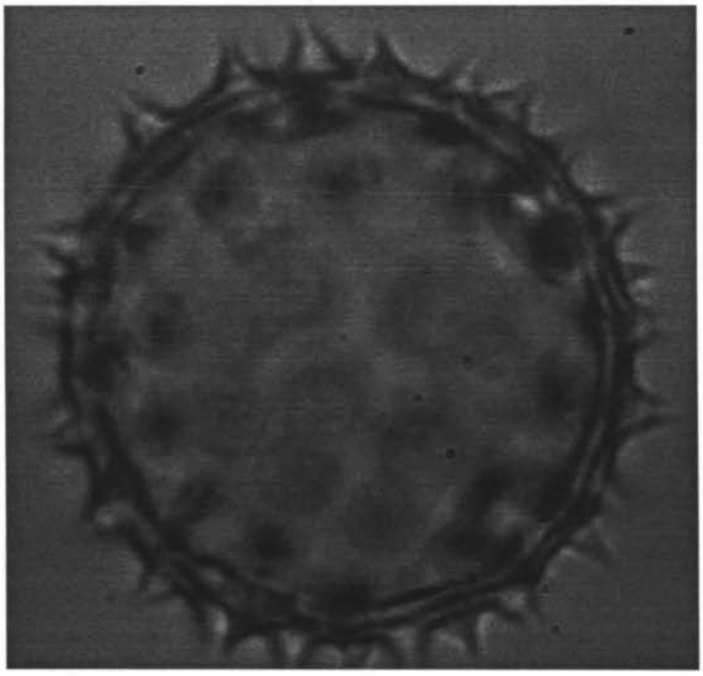


Figure Ap.1.48b - *Plagianthus divaricatus* - Tectum perforate or torn, smooth bearing well spaced short acute supratectal spines which resemble those of *Hoheria* pollen grains; minute spines occasionally seen

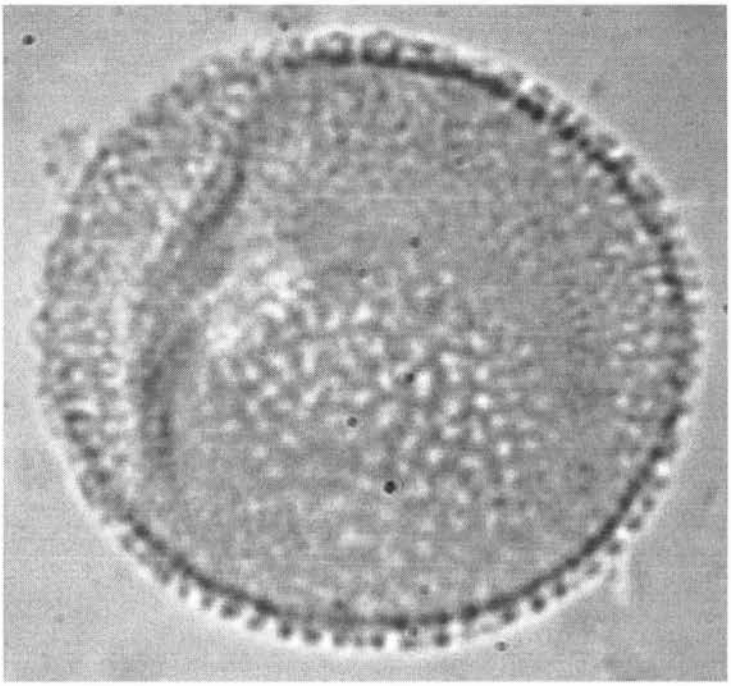


Figure Ap.1.49a *Typha muelleri* - Monoporate; spheroidal shape, exine thin, weak, finely reticulate-clavate; edged with open lacunae, lacunae small in proportion to width of rugulate ridges between them

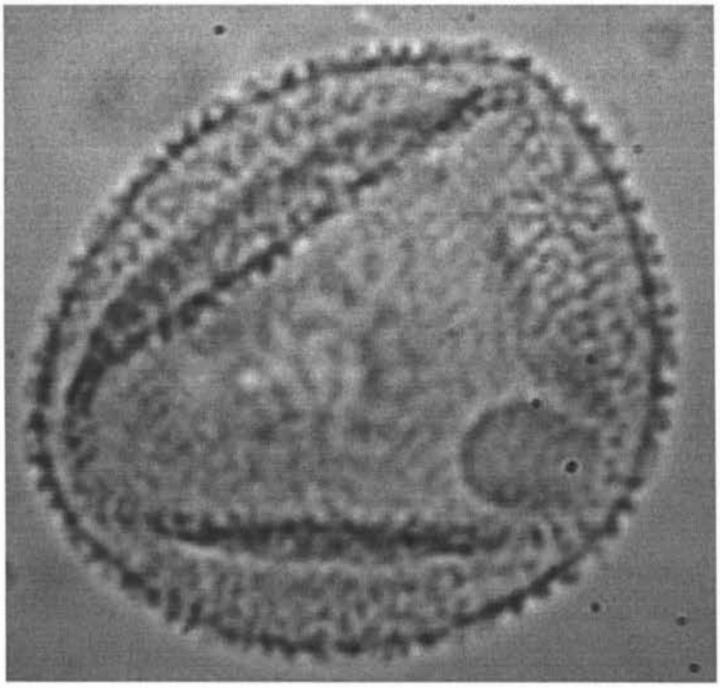


Figure Ap.1.49b - *Typha muelleri* - View showing compressed shape; pore irregular in outline c. 6 μm in diameter; membrane smooth; lacunae sometimes as small as .5 μm giving a beaded roughened appearance

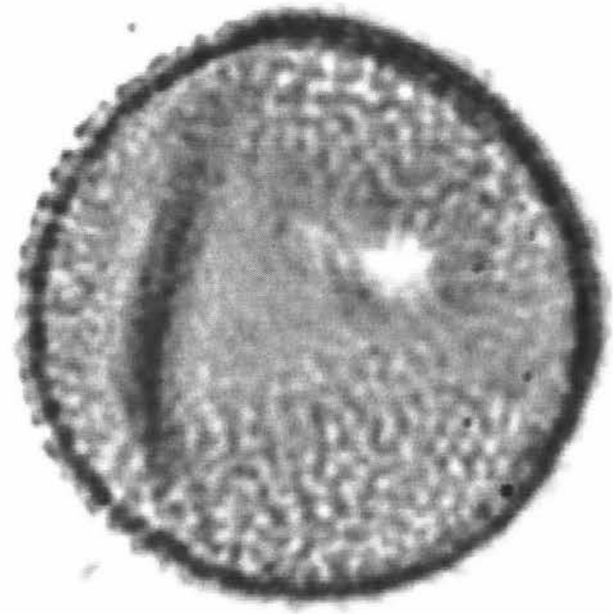


Figure Ap.1.50a *Typha orientalis* - Monoporate; shape spheroidal, slightly compressed; pore rounded edged with open lacunae; lacunae of different sizes; exine weak, reticulate-clavate

Figure Ap.1.50b *Typha orientalis* - Compressed spheroidal shape; exine very thin, finely reticulate, resulting in pore being ruptured; pore may also be irregular in outline; intine moderately thick

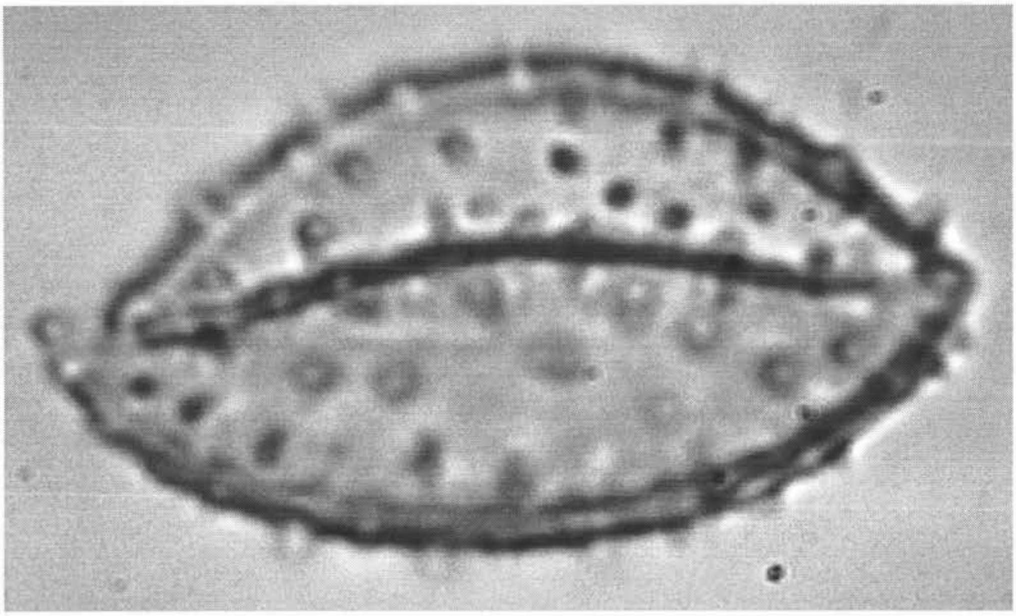


Figure Ap.1.51a *Astelia fragrans* - Monocolpate; spheroidal to oblate when expanded, furrow very long, tending to cause deep channelling of distal side of grain; membrane distension very great; exine spiny

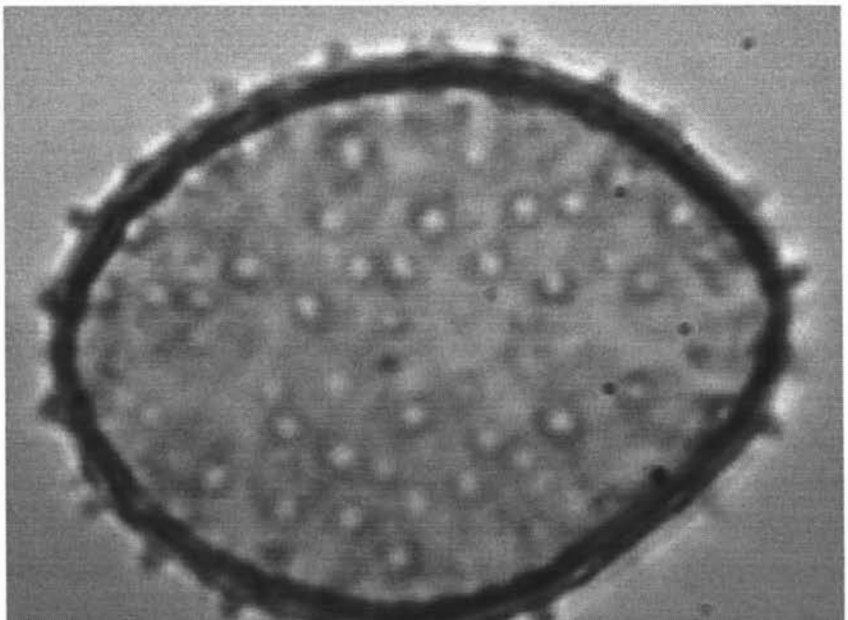


Figure Ap.1.51b *Astelia fragrans* - Unexpanded view showing ellipsoidal to spheroidal shape; tectum continuous, rods baculate, spines short, conical; exine thin to moderately thick (1-2 μm)

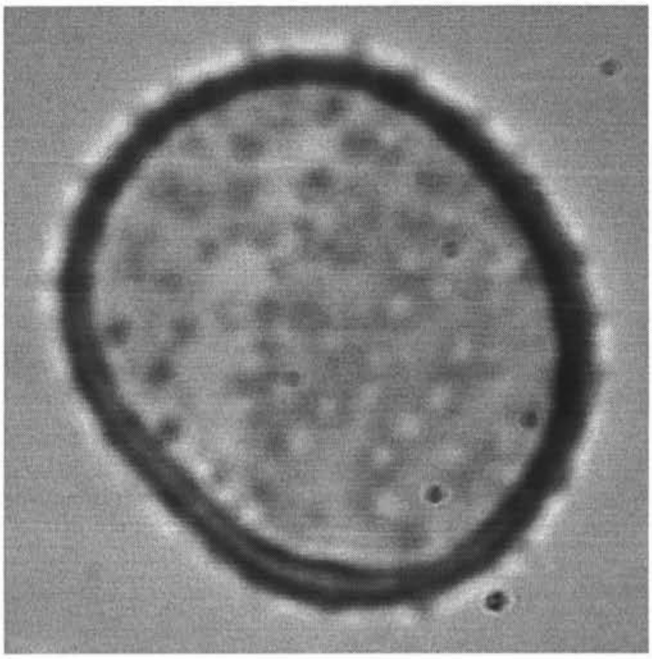


Figure Ap.1.52a *Astelia solandri* - Monocolpate; shape ellipsoidal to spheroidal, size 20-25 µ; exine thin to moderately thick; spiny, spines short, about 1 µm, conical, tips of spines rounded

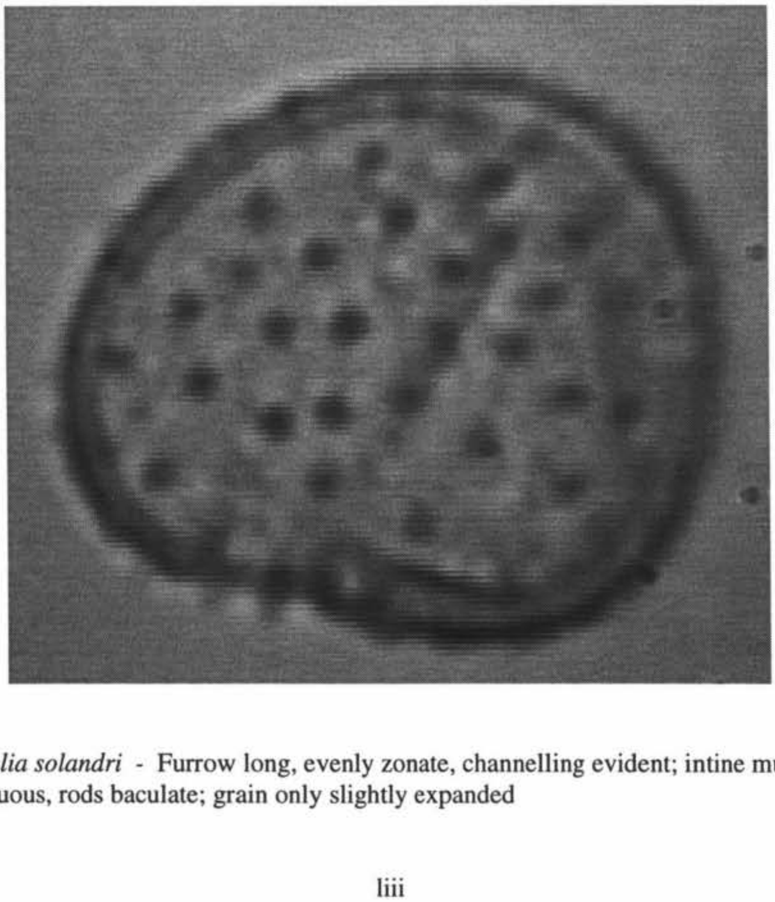


Figure Ap.1.52b *Astelia solandri* - Furrow long, evenly zonate, channelling evident; intine much thicker under furrow; tectum continuous, rods baculate; grain only slightly expanded

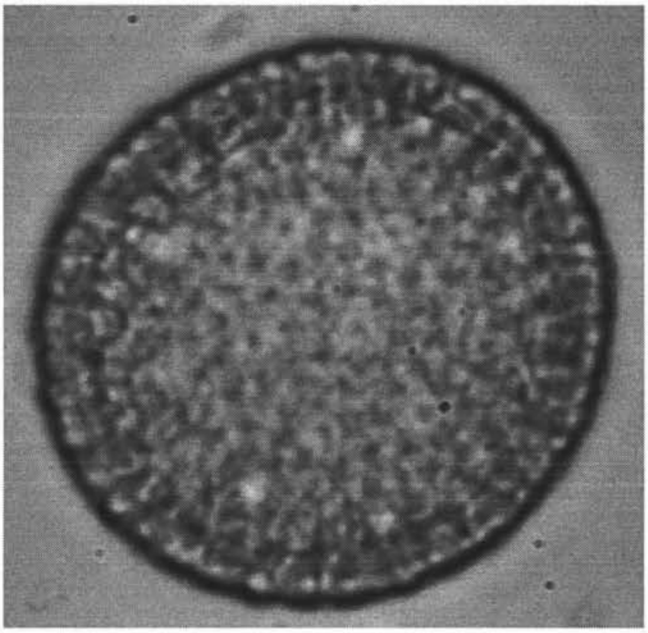


Figure Ap.1.53a *Pimelea longifolia* - Periporate; pores recessed, c. 3 µm in diameter, clearly defined annulus about the pore; exine very thick, . 3-4 µm; semitectate, baculate, shape irregularly spheroidal

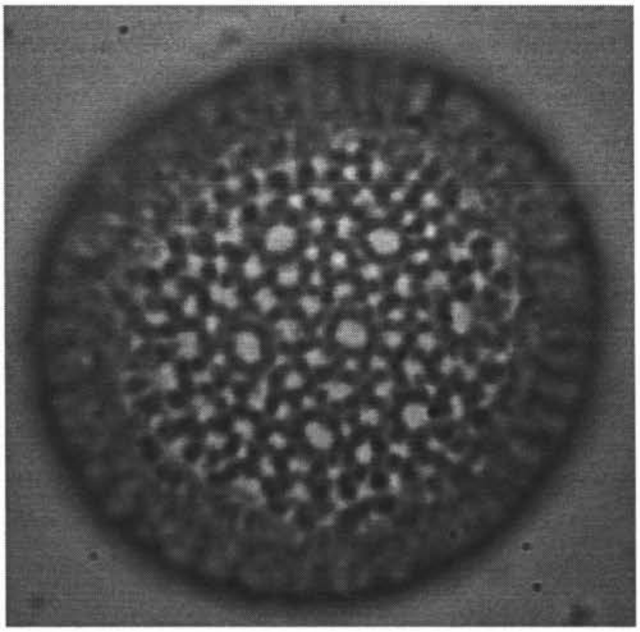


Figure Ap.1.53b *Pimelea longifolia* - muri coarse bearing triangular shaped supratectal processes with small spinules; surface corrugated; lumina often concealed by supratectal processes; bacula fine

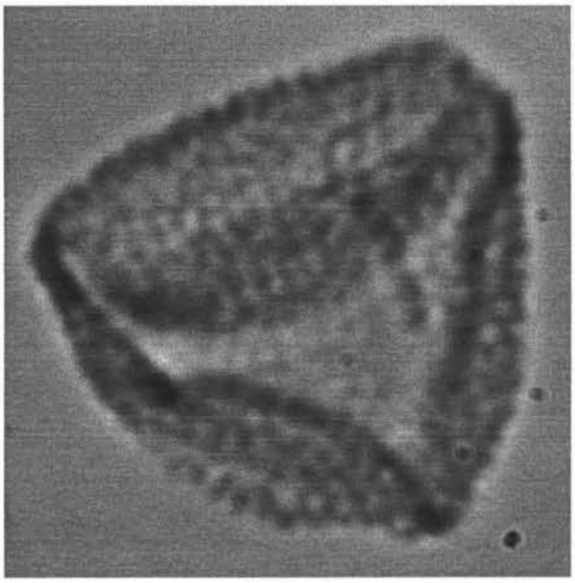


Figure Ap.1.54a *Potomageton cheesemani* - Shape more or less globular, with changes due to state of expansion; exine sculpture evenly reticulate-clavate; inaperturate; columellae baculate;

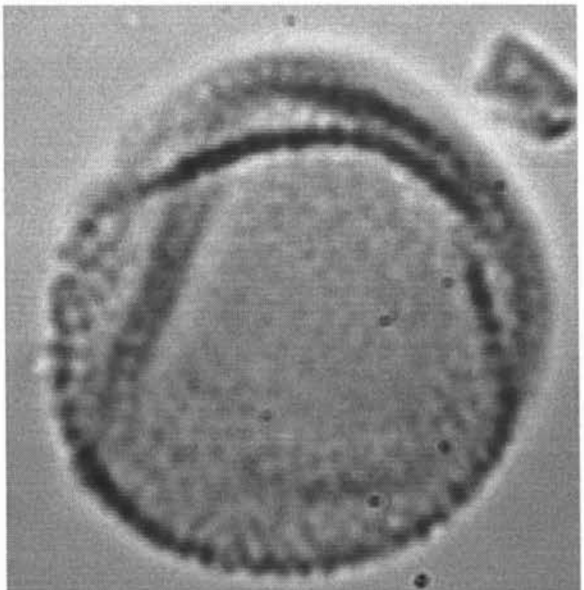


Figure Ap.1.54b *Potomageton cheesemani* - intine thin but greatly thickened in a longitudinal strip on one side of the grain, resembling a "temporal furrow"; reticulum indistinct but clearly spaced

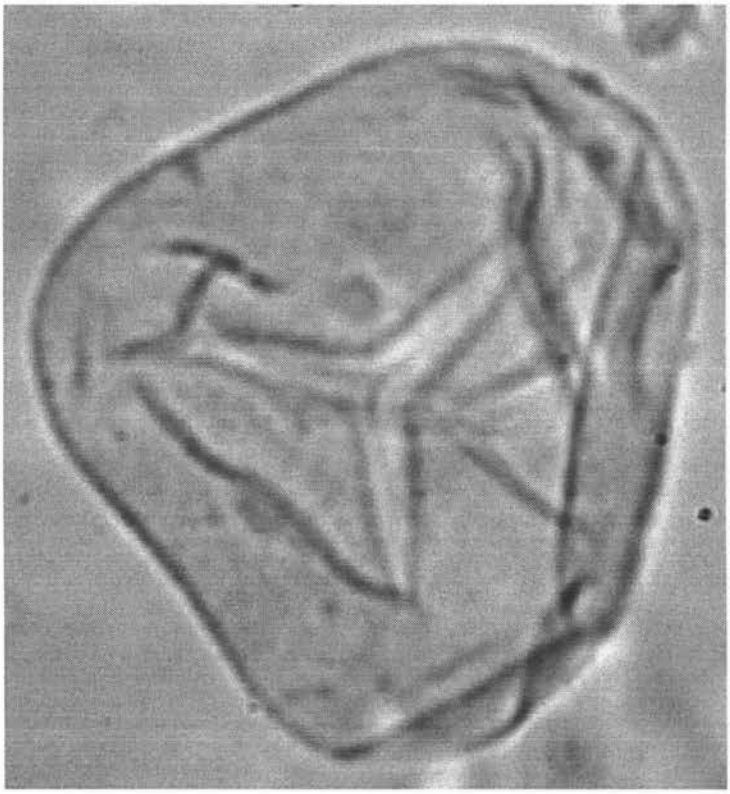


Figure Ap.1.55 *Pteridium aquilinum* - Trilete, radially symmetrical, heteropolar; polar outline triangular, to rounded triangular, angles rounded; laesurae, ridge extends one half of spore radius; perine thin, coarsely granulate, surface sometimes eroded; exine scabrate-granulate

Appendix 2

List of Earthquakes reported in the Waipawa Mail 1878 - 1910

compiled from copies of the Waipawa Mail held in the Berry Library, Hawkes Bay Cultural Trust, at the Hawkes Bay Museum, Napier.

Date Reported	Magnitude	Where	Time	Comments	Date of event
1878 25/9	Slight shock	in Waipawa	7.00 pm	Sunday evening	22/7
7/12	Severe shock	in Waipawa	8.15 pm	Wave Nth/Sth	6/12
1879 8/1	**Severest shock for many years**		10.45 pm	Felt in whole of H.Bay	6/1
25/1	Sharp shock	in Waipawa	7.45 am		23/1
23/7	Smart shock	in Waipawa	10.45 pm		21/7
1/11	**Very sharp shock**		2.25 am	Felt in southn half of N.I.	30/10
1881 5/3	Slight shock	in Waipawa	11.05 am		4/3
29/6	**Several smart shocks for past week**	in lower half of N.I.		(1° 1 am)	24/6+
2/7	Slight sharp shock	Waipawa	7.10 am		29/6
	(Further shock		same hour		30/6)
20/8	Sharp shock	in Waipawa	2.04 pm (?-)	No damage reported	17/8
28/12	Slight shock	in Waipawa	2.17 pm	Well defined	27/12
1882 8/4	Smart shock	in Waipawa	4.12 pm	Well defined	6/4
1883 27/3	Very sharp shock -	Woodville district		in morning	25/3
1884 9/1	Smart shock	in Waipawa	12.00 pm		7/1
1/2	Smart shock	in Waipawa	1.30 am		30/1
11/4	Two shocks	in Napier	10.45 am	& 11.45 am	11/4
6/6	Smart shock	in Blenheim	6.56 am		2/6
29/8	2 slight shocks	in Ormondville	5.00 am ca.	& 7.am ca.	24/8
26/9	Slight shock	in Waipawa	7.10 am		24/9
14/11	Slight shock	in Onga Onga	3.45 pm		9/11
1885 2/1	Shock	in Waipawa	11.20 pm		31/12
28/7	Slight shock	in Waipawa	7.45 pm	Felt in Wgtn & West Coast	26/7
8/12	Rather sharp shock	Waipawa	10.00 pm ca.	(ex H.B. Herald)	5/12
1886 10/6	Flames from **Mt Tarawera** last night were clearly visible from Waipawa. A rumbling noise was so audible the Woodville people thought the Russian ship the "Vestrich" was bombarding Napier.				
24/6	Distinct shocks	in Waipawa	am		23/6
28/12	Sharp shock	in Waipawa	2.25 am ca.		27/12

1887	27/1	Sharp shock in Waipawa 4.16 pm	27/1
	13/8	Short sharp shock Waipawa 6.43 pm	11/8
	20/12	Slight tremor in Waipawa just before 5 am	19/12
1888	13/3	Sharp shock in Waipawa 6.43 pm	10/3
	3/5	**Very violent shock** Waipawa 2.10 am Terrific roaring & shaking (Heavy shock in Fielding; Violent shock in Woodville; Slight shock in Marton, Wanganui, & Palmerston Nth. 2° slight shock at 6.40 am	3/5
	5/5	A brilliant **meteor** fell here (Waipawa) last night (May 4th). It formed a track across the sky; a blaze of light illuminating the whole heavens and lighting the insides of houses. After the light disappeared a shock as if an earthquake was felt and some say the meteor must have struck the earth close to Waipawa	
	10/5	At Hampton (Tikokino) about 4 o'clock on Tuesday morning (May 8th) a **very bright star** was seen in the western heavens with a ring as white as snow around it, to the human vision about 18 inches in circumference.	
	29/5	Slight shock in Waipawa 1.00 am	29/5
	7/8	Very severe shock in Waipawa 10.28 pm	4/8
	1/9	**Fearful shock** felt in Wellington, Westport, Greymouth, Christchurch, Invercargil, Dunedin, Timaru, Masterton, Fielding, New Plymouth & Hokitika.	1/9
	6/9	there have been 35 aftershocks since the main shock on Saturday (1/9) **Unusual tidal movements** in Hawke Bay and the Iron Pot (H.B. Herald)	
	4/10	gentle rocking shock in Waipawa 3.30 pm Also felt in Waipukurau	3/10
1889	28/5	**Prolonged shock** in Waipawa 7.13 am	27/5
		Slight shock in Waipawa 10.00 am	28/5
	17/12	Slight shock in Waipawa 2.40 pm	15/12
1890	8/3	Small shock in Waipawa 5.50 pm ca. Felt in Napier/Hstgs	7/3
	25/9	Slight shock in Waipawa in the morning	25/9
	30/9	Heavy shock in Waipawa 2.00 am Rumbling heard	30/9
	16/10	Noticeable shock in Waipawa During a lull in a gale	15/10
	11/11	**Short violent shock** in Waipawa 10.40 am ca. (A further lighter shock at 1.20 pm)	11/11
1891	1/8	Slight shock in Waipawa 6.00 am	1/8
	5/12	Severe shock in Waipawa 4.40 am More severe in Wgtn	5/12
	18/8	Sharp shock in Waipawa 10.00 pm c. also felt elsewhere	17/8

1892	9/12	Prolonged shock	in Waipawa	4.22 am c.	9/2
	14/5	**Heavy shock**	in Makaretu	2.10	13/3
	9/7	Sharp shock	in Waipawa	7.16 am	8/7
	29/9	Slight shock	in Waipawa	3.00 am c.	29/9
	11/10	Sharp shock	in Waipawa	2.00 pm c.	11/10
	1/12	Sharp shock	in Waipawa	7.12 am	30/11
	3/12	Slight shock	in Waipawa	3.20 pm	3/12
1893	26/1	Another shock	in Napier	12.57 pm (But only slight)	26/1
	14/2	Severe shock	in Waipawa	8.03 am	12/2
	22/4	**Heavy shock**	in Waipawa	10.25 am	23/4
		Heavy rumble at **Hampden** followed by a severe shock everyone rushed outside			
	18/5	Shock	in Waipawa	9.00 pm c.	17/5
	18/5	Smart shock in Wgtn & 3 shocks in Dannevirke at 3.20 am.			18/5 ?
	29/6	Shock	in Waipawa	12.10 pm	29/6
	3/10	Sharp shock	in Waipawa	9.35 pm	2/10
	24/10	Severe shock	in Waipawa	3.10 am	24/10
1894	20/11	Sharp shock	in Waipawa	7.58 pm	18/11
	22/12	Shock	in Waipawa	6.45 am	22/12
1895	23/5	Very severe shock	in Waipawa	6.42 am	23/5
	13/6	Smart shock	in Waipawa	9.55 am	13/6
	20/8	**Very sharp shock**	in Waipawa	6.30 am c.	17/8
	22/8	Earthquake of 17/8 did **considerable damage in the district**. At Pukehau hardly a chimney is left standing; at Te Aute several chimneys were shaken; at Kaikora (Otane) things were lifted out of place.			
	24/8	Smart shock	in Waipawa this morning		24/8
	17/10	Sharp shock	in Waipawa	5.45 am Felt in Napier & W/ville	17/10
	9/11	Slight shock	in Waipawa	3.00 am	9/11
1896	30/1	Sharp shock	in Waipawa	7.05 am c.	28/1
	25/4	Slight shock	in Waipawa	2.45 am c.	25/4
	2/5	Sharp shock	in Waipawa	11.25 am	2/5
	27/6	**Violent shock**	in Waipawa	12.45 am c.	27/6
	15/8	Sharp shock	in Waipawa	5.30 am c.	15/8
	29/8	Sharp shock	in Waipawa	5.30 am c.	29/8
	22/9	Sharp shock	in Waipawa	8.30 pm	20/9

1897	20/3	Sharp shock	in Waipawa	7.30 am c.		20/3
	10/6	**Very severe shock** (20 sec)	Waipawa	12.20 am	Preceded by a rumble	9/6
	8/7	Long shock	in Waipawa	1.15 am		8/7
	13/7	Smart shock	in Waipawa	9.35 am		13/7
	24/7	**Very severe shock**	in Waipawa	11.10 am	**Also felt in Napier**	14/7
	15/8	Shock	in Waipawa	10.30 pm c.		14/8
	16/10	Sharp shock	in Waipawa	5.55 am c.		16/10
	9/12	Shock	in Waipawa	2.45 am c.		8/12
	11/12	Shock	in Waipawa	8.00 pm c.		10/12
1898	1/2	Slight shock	in Waipawa	4.00 am c.		31/1
	31/3	Slight shock	in Waipawa	11.20 pm c.		30/3
	5/7	**Very sharp shock**	in Waipawa	4.20 am	**Felt in Napier/Hstgs**	5/7
1899	18/2	Slight shock	in Waipawa	10.10 pm c.		16/2
	2/3	Shock	in Waipawa	4.50 am		2/3
	21/11	Small shock	in Waipawa	8.35 am		19/11
1900	29/5	Sharp shock	in Waipawa	8.00 am c.		28/5
	28/8	Slight shock	in Waipawa	1.00 am c.		28/8
	18/10	Sharp shock	in Waipawa	10.48		16/10
	23/10	**Very prolonged shock**	in Waipawa	9.36		21/10
1901	7/2?	**Sharp shock**	in Porangahau	6.30 pm		2/1
		(Half the **chimneys** in the township [Porangahau] cracked; several chimneys **collapsed** at the Maori Pa; - Further milder shock in am of 3 /1)				
	7/2	Earthquakes frequent in Tikokino area in past few days				
	16/3	Shock	in Waipawa	11.20 pm c.		15/3
	18/7	Two shocks	in Waipawa	8.30 pm = 1°		17/7
		(The second severe and prolonged shock shook several buildings)				
	13/8	Prolonged shock	in Waipawa	1.53 am		12/8
	20/8	Smart shock	in Waipawa	4.54 pm		19/8
	24/10	**Severe prolonged shock**	in Waipawa	few minutes after 4 am		24/10
		(Followed by several minor ones)				
	14/11	Sharp shock	in Waipawa	3.10 pm		14/11
	21/12	Two sharp shocks	in Waipawa	6.33 pm		19/12

1902	27/2	Shock	in Waipawa	10.18 am		27/2
	5/4	Slight shock	in Waipawa	8.25 pm		4/4
	10/5	Severe shock	in Waipawa	12.57 am		9/5
	10/6	Two shocks	in Waipawa	3.56 pm	2° shock more severe	10/6
	26/8	Sharp shock	in Waipawa	12.49 am		25/8
	15/11	**Violent shock**	in Waipawa	2.15 pm		15/11
1903	6/1	Short severe shock	in Waipawa	10.00 pm		4/1
	2/5	Shock	in Waipawa	2.53 pm		1/5
	14/5	Short severe shock	in Waipawa	9.41 pm		12/5
	14/7	Sharp shock	in Ormondville	11.30 pm		11/7
	4/8	**Very severe shock**	in Waipawa	3.45 am		2/8
		(Caused walls to rock - preceded by a mild shock and a rather sharp shock followed. Another sudden shock at 5.20. **Chimneys knocked over** in **Hastings and Taradale**				
	10/9	Shock	in Waipawa	3.25 am		10/9
	8/10	Slight shock	in Waipawa	4.46 am		8/10
	15/12	Shock	in Waipawa	3.34 pm		15/12
1904	23/2	Sharp prolonged shock	in Waipukurau	5.07		22/2
	26/4	Two shocks	in Waipawa	11.20 pm	1° not severe	23/4
		(2° shock a few minutes later, violent and prolonged for several seconds)				
	26/5	Two slight shocks	in Waipawa	4.24		25/5
	23/7	Heavy shock	in Napier	6.24 am		23/7
	9/8	**Most severe shock ever**	in Waipawa	10.31 am		9/8
		(Of long duration resulted in a **gap** forming in the **road between Te Aute** and Te Hauke. The **railway bridge** at Kopua **collapsed**. **Damage reported** from **all over the district**.				
	4/10	Slight shock	in Waipawa	5.10 am		2/10
	8/11	Short severe shock	in Waipawa	7.55 am		6/11
	20/12	Short shock	in Waipawa	4.19 am		20/12
	24/12	Short sharp shock	in Waipawa	3.02 pm	Another c. 10.22 pm	23/12
1905	7/3	**Short severe shock**	in Waipawa	4.0 am c.		6/3
	30/5	Shock	in Waipawa	11.18 am		30/5
	11/7	Sharp shock	in Waipawa	2.58 pm		10/7
	11/7	Sharp shock	in Waipawa	5.23 am		11/7
	19/8	Sharp shock	in Waipawa	11.00 pm		18/8

1906	20/3	**Severe shock (20 sec)**	in Waipawa	3.05 pm	20/3
	27/3	Shock	in Waipawa	1.30 pm	26/3
	31/3	Sharp shock	in Hampden	1.30 pm (Tikokino)	26/3
		(Loud rumblings from the direction of Mt Ruapehu heard frequently)			
	23/10	Sharp shock	in Waipawa	8.10 pm	20/10
	8/12	Sharp shock	in Waipawa	11.20 am	8/12
1907	21/5	**Sharp shock**	in Waipawa	7.25 pm	18/5
	13/6	Shock	in Waipawa	7.40 am	13/6
	9/7	Shock	in Waipawa	1.10 am	9/7
	10/9	Shock	in Waipawa	6.11 am	10/9
	3/12	Shock	in Waipawa	5.00 am c.	3/12
1908	16/4	Shock	in Waipawa	6.40 pm c.	15/4
	2/6	**Long severe shock**	in Waipawa	9.48 am c.	31/5
		(Shock preceded by a short shake and a rushing noise - Houses shook)			
	8/8	**Prolonged shock**	in Waipawa	1.35 am	8/8
		(**Very heavy** shock **in Waipukurau** - precede by a rumble (20 sec.)			
	13/8	Shock	in Elsthorpe	1.35 am During school concert	8/8
	22/8	Prolonged shock	in Waipawa	2.45 am c.	22/8
		(Preceded by a rushing sound and 3 preliminary shakes)			
1909	27/3	**Sharp shock**	in Waipawa	8.35 pm c.	26/3
		(At Kaikora (**Otane**) **2 severe shocks** felt about 8.35 pm)			
	10/8	Sharp shock	in Waipawa	7.15 am c.	8/8
		(5-10/8 "UFO.s" reported; 19/8 Meteor reported; 21/8 Shooting star reported)			
1910	13/1	Sharp shock	in Waipawa	8.24 am	12/1
	18/1	Slight shock	in Waipawa	10.00 am	17/1
	15/2	Slight shock	in Waipawa	1.50 pm	15/2
	14/4	Shock	in Waipawa	1.39	14/4
	2/6	Slight shock	in Waipawa	7.00 pm c.	31/5
	25/6	Mild shock	in Waipawa	1.40 pm	24/6
	19/7	Sharp shock	in Waipawa	12.15 am c	19/7
	30/7	Sharp shock	in Waipawa	2.15 am	30/7
	20/9	Sharp shock	in Waipawa	5.45 am Lasted some time	19/9
	19/11	**Violent shock**	in Waipawa	7.45 pm	17/11
	26/11	Short sharp shock	in Waipawa	7.30 am	25/11
	22/12	Short sharp shock	in Waipukurau	9.03 pm c.	21/12

Appendix 3.

The cultivation, storage and uses of :

Pteridium (bracken) by the early Maori in New Zealand.

Extracts from the writings and unpublished journals of some nineteenth century travellers in New Zealand, and selected more recent published works on the importance of *aruhe* (the bracken root) for the pre-European Maori. The extracts may be quoted verbatim, or paraphrased for brevity. In all cases the page number is quoted in brackets.

(1) Colenso W. (1880) *On the Vegetation food of the Ancient New Zealanders before Cook's Visit*, Transactions of the New Zealand Institute, Miscellaneous papers # 1

The [bracken] fern root (*aruhe*) :

Good edible fern-root, that which produced a large amount of *fecula*, was not to be found everywhere, In some districts, particularly at the north, it was comparatively scarce, and had to be dug and brought many a weary mile of the backs of the people to their homes, especially to their sea-side or fishing villages. In Hawkes Bay (south side), in many patches of low-lying rich alluvial grounds, on the banks of the rivers, it was more readily obtained. The best roots were produced in loose rich soils, where the plant had been undisturbed for several years (p 20).

Footnote: At the reading of the paper on the vegetable food of the ancient New Zealanders in 1880 Colenso displayed some fern root presented to him by the late chief Karaitiana's tribe at Pakowhai. "They had had three baskets of it sent to them as a present, some six months ago, from a place about 20 miles [32km] inland from Te Wairoa (Hawke's Bay), it had grown in volcanic soil, the roots being much pitted and still having many bits of pumice adhering to them. They contained a very large amount of *fecula*, and commonly measured 12 to 15 inches in length and 3 inches in circumference [sic diameter".

One striking peculiarity ... their national non-usage of all and every kind of manure. [they] choose rather to prepare fresh ground every year, generally by felling and burning on the outskirts of forests. They never watered their plants, not even in times of great drought, with their plantations close to a river (p 11).

Colenso remembers, many years previous to 1880, travelling over an isolated hill of loose rich earth in the interior, which had been long farmed for its fire fern-root; and for the occupancy and use of that hill for digging the root, several battles had been fought. ...All diggings and places of good fern-root, were rigidly preserved; no trespassing was ever allowed (p 20-21).

The old Maoris had their set fixed times of digging the root, in the spring and early summer months, they knew will when the roots were abounding in nutriment, and would no more have dug them up in the wrong season than we should our potatoes. They were also careful not to burn off the fern plants from their digging grounds, save at the proper time of the year, as such careless burning injured the roots; but burning off the fern in the proper season, in August, improved them. In doing so they were ceremonially carefull (at the north) to use the wood of two plants, *Kareao* (*Ripogonum scandens*) and *mahoe* (*Melicytus ramiflorus*). In digging, it, which was always done with the long wooden sharp spade (a *koo*) they took care not to bruise or break it into pieces; at the same time they examined it by breaking, etc., - if it were dry internally, then it was good, and they went on with their digging,; if wet, inferior. They carefully put it in stage-like piles, on wood, to dry in the wind, shading it from the sun. When it was quite dry, at the end of a fortnight, they went over it, selecting and separating it into several kinds or qualities, of which they had many, some being for the chiefs, some for warriors, some for visitors, some for common daily use, and some for the slaves. Each quality was put up separately, and carefully stored away in large quantities from both sun and rain for future use - properly harvested, dried, and stored, it would keep good for years (p 21).

The best kinds of *aruhe* or fern root, in the north, were known by the general names of *maahunga* (mealy) and *motuhanga* (brittle, easily snapped). On the East Coast, the best kinds were called *kaitaa* (gentlemen's food) and *renga* (mealy). The *motuhanga* was really a splendid sort. Colenso has seen it, a fine looking, black-skinned smooth root, eight to ten lines [?] in diameter, with scarcely any woody fibres, and these were small, like a very fine rush, lustrous, hollow, and white. It would snap readily, like a good biscuit, before being prepared or beaten (p 37).

Then the best was again separated thus:-

Kowhiti - best selected for chiefs

Huirau- a hundred together in company; for warriors - this type was stored up in the hill forts for sieges and fighting times. This is the kind that Cook, Crozet and others saw stored up largely in their forts and fighting places. Moreover, the Maoris would not sell them any of it.

Paka- dried, for general feasts; or *Pakakohi* - dried and gathered scraps.

Ngapehapeha - rinds, skins, for common daily use.

Pitopito - ends, *pakupaku* - small in size, (broken parts of choicer kinds) other names were *tuakau*, and *pararaa* (p 38).

In preparing the fern-root for daily food, it was never used green. the dried root was slightly soaked in water, roasted a little on the embers, and beaten soft with a stone pestle, or short, hard-wood club, or one made from the bone of a whale, on another large smooth water-worn stone; this beating of the root was constant and hard work. In the roasting and beating the black outer bark, or skin, peeled off. the better quality root so prepared was as soft as a bit of tough dough; it soon, however, became stiff and hard, when it snapped like glass or a good biscuit. When it was prepared in large quantities for taking with them to the sea in their coasting voyages, and also for going into fight, then it was made into a kind of pounded mass. In the spring of the year the succulent young shoots (*monehu*), which rose out of the ground like young asparagus, were also eaten fresh, they were very mucilaginous. (produced a musty juice when chewed).

The old Maori thought very highly of the fern-root, and always liked it, even preferring it in summer as an adjunct to the choicest of fresh fish caught from the large shoals that approached the coast, as well as to the cockles and other shell fish that were in season. They also used it in the summer soaked, after pounding, in the sweet luscious juice of the berry-like petals of the *tutu* (*Coriaria ruscifolia*). Summer was also a time when the kumara was out of season. Pigs also fed off it in their wild state.

(2) Best, E., (1976b) *Maori Agriculture*, Government Printer, Wellington.

Quoting Nicholas who visited the Bay of Islands district with Bishop Marsden in 1814-15: "The plantations, though they frequently surround the village, are generally at some distance from them and the latter are always constructed either upon the summit or at the foot of some high and almost inaccessible hill, that is, commonly in detached places where soil is favourable. This is most certainly occasioned by that state of disunited barbarism and feudal emnity, whereby they are obliged to choose those places for their defence which are best suited for that purpose" (p 33).

Again quoting Nicholas: "This root is to the New Zealanders an invaluable production, as it forms the chief article of their diet, having no idea of subsisting on potatoes or coomeras (Kumara) exclusively, which are considered rather as luxuries food." Later the potato did in fact, become the main food supply (p 237).

Quoting Crozet, in his account of his sojourn at the Bay of Islands in 1772, he remarks that the "basis of the food of these people is the root of the fern" (p 33). When the Polynesians settled in New Zealand they either lost many of their food plants, or they did not flourish, thus considerable reliance on wild products became necessary and *aruhe* became the principal vegetable food of the Maori in many districts.

The sudden change from a tropical clime with its easily obtained food supplies, which demanded no trouble in cultivation compelled Maori immigrants to devote more time to the task of collecting food supplies. They were urged by necessity to spend much of their time in fishing and the collection of shellfish, berries roots and the birds of stream and forest. It was probably during this period that the Maori began to utilise the *aruhe* as a food supply (p 21-22).

Good fern root is not the product of a particular variety of *Pteris* but of suitable soil-conditions. Each community had its own *tawaha aruke*, or places where fern-root was dug, and these places were prized and attended to in proper manner. Any attempt made by unauthorised persons to obtain the root from such places would lead to hostilities and ejection. A Ngati Porou member told Best that a place where fern-root was procured was termed a *maunga aruhe*, which seems to demand a hill preserve. Other names were keringa aruhe (fern-root digging places) *kohiti* and *pakihi* (p 78).

In pre-European days every kind of work was organised and regulated. Whether it was the breaking up of land, or the planting or taking-up of crop the people worked in gangs under the direction of a leader. each class of work had its appointed season, determined by recognised signs, such as the blooming of a certain tree or flower. Growing crops were under strict tapu, and it was believed that any breach or neglect of the tapu would involve serious disaster. Places where edible fern-roots grew were prized and carefully preserved, if considered necessary would be protected by a *rahui* ordinance (p 36).

A number of persons working together in a digging-bee was termed an *ohu* (p 78). Eight or ten men with their spades (*ko*) form a row at a convenient distance from one another. They cut a line in the ground 9 or 10 inches deep by means of a punching process with their spades, and then with one united effort, throw over a furrow or piece of ground about 18 to 20 ft. in length and 8 to 10 inches in breadth. The compact mass overthrown was then separated by using the tools in a similar manner, after which the smaller pieces were broken with lighter implements and pulverised with wooden clubs, while the roots were picked out and put aside (p 71). In favourable soils good roots were found quite deep down. It was not unusual for a root digger to reset any small broken pieces of root in the earth if it carried a young shoot (p 80).

Re : Firing of the bracken:

Tawha were occasionally burned off, such a fire destroying all the fronds, which were soon replaced by others springing from the younger roots. This is said to have caused the bracken to produce finer roots, it also destroyed all foreign growth, such as shrubs, that had sprung up since last burning; hence such a burning every three, four, or five years. If man and fire leave fern-land alone long enough it becomes scrub-land. Fire prevents the condition known as *kaikai rakau* . Such burning was done when the *Hinau* was in bloom (November/December), after such a fire *aruhe* is produced (p 78-79).

Quoting Nichols: The prepared fern roots were thrown in handfuls to each waiting diner by the person preparing it, and 'the fern-root when hot has a pleasant sweetish taste; three-year old plants furnish the best fern-root and is an inch in diameter " (p 77).

The roots are dug about November, cut into lengths, and stacked to dry; fresh roots are very poor eating. The dried roots are steeped in water before being roasted, pounded and eaten. The pounding process softens the fecula and tends to free it from the harsh fibres. such is the procedure when the fecula is to be formed into cakes known variously as *Kohere, Komeke, Meke, or Parehe* (p 77).

Fern root was viewed as a strong, sustaining food, hence it was deemed excellent rations for workers, travellers and fighting-men when at war. Bracken was said to be the food of war, Kumara that of peace (Riley, 1994.) A cake of *aruhe* that has been steeped in juice of *tutu* berries was looked upon as a superior meal (p 81).

Brunner when exploring Westland, remarked on the native dish of fern-root steeped in a form of gruel made with the sage-like farina obtained from the young cabbage-tree (*Cordyline*) (pp 82-83). The better kind of fern-root was not found in places where young *Cordyline* were obtained. The two did not grow together (p 83).

The account of Sir George Grey's journey to Taranaki in 1849- 50 gives a description of "A number of female slaves seated near the fires in which the root was roasting, each of whom had a large smooth stone on the ground before her and a wooden mallet in her hand. The guests sat in a semi-circle in front of the slaves, and as fast as the latter could beat the root and throw it to the former, so fast did they demolish it" (p 82).

Referring to a South Island Addenda re the procuring & treatment of fern-roots:
It took 4 days to dry immature fern-root, but matured roots are dried in one day and are then thrust into baskets, conveyed to the village and placed on elevated platforms. Strong persons were selected for the task of carrying the loads of roots to the village. In some cases they were carried to a river, if the digging ground was near such, and there placed in canoes. They would not all be conveyed in one trip, but the conoes would return, perhaps four or five times in a month (p 84).

(3) Brooker, S.G., Cambrie, R.C. & Cooper, R.C., (1987) *New Zealand Medicinal Plants,* Reed Books, Auckland, Revised 2nd Edition, 268 pp.

Medical uses of bracken

The root of the bracken was used as food for invalids and was eaten before a sea voyage to prevent sea sickness. Ashes and charcoal dust of burnt fronts were applied to severe burns. The frond was used by the Maori priest to expel a demon from a sick person and the tender shoot was eaten to cure dysentery. Fern root was also masticated for dysentery. It has been reported that a decoction of fern root was effective in the influenza epidemic of 1918-19.

It is reported that young actively growing bracken is carcinogenic. Fresh young shoots of bracken were eaten by the Maori but there is no record of stomach cancer in pre-European times, although it has been suggested that the low expectation of life of the Maori could have been due to the consumption of bracken. Bracken does not appear to be cacinogenic to rats.

(4) Riley, M., (1994) *Maori Healing and Herbal,* Viking Sevenseas, Paraparaumu, 528 pp.

- Bracken fern was used for protection, healing and fertility. The Maori put great store on its use as a medium to contact the *atua*.
- When travelling on foot, if ones feet got filled with fern between the toes this was taken as a sign that food in abundance would be waiting at the next village.
- *Rahurahu* was used in the ritual healing of headaches - two stalks which had had the outer fibres removed were beaten together above the head.
- At a funeral, the fern tips were given to the people by the *tohunga* to take to the chief mourners to appease the god so that he would not devour them and the feast on the *marae* could proceed.

Appendix 4.

The cultivation, storage and uses of :
Typha angustifolia (*Raupo/Pungapunga* - bulrush) by the early Maori in New Zealand

Extracts from the writings and unpublished journals of some nineteenth century travellers in New Zealand, and selected more recent published works on the importance of *Raupo* (bulrush) for the pre-European Maori. The extracts may be quoted verbatim, or paraphrased for brevity. Where appropriate the page number is quoted in brackets.

(1) Colenso, W., (1880) - *On the Vegetable food of the ancient New Zealanders before Cook's visit.* Transactions of the New Zealand Institute, 3-38.

Another highly curious article of vegetable food was the *pungapunga* the yellow pollen of the *raupo* flowers - the common bulrush, or cat's-reed mace (*Typha angustifolia*). This was collected in the summer season, when the plant is in full flower, in the wet swamps and sides of lagoons, streams, and lakes. I have been astonished at the large quantities of pollen then obtained. On one occasion, more than thirty years ago, I had several buckets full brought me by the present chief, Tareha, in his canoe, some of which I sent both raw and cooked to the Kew Museum. In appearance in its raw state it exactly resembles the ground yellow mustard of commeree [?commere], and when put into bottles would be mistaken for it. It is obtained by gently beating it out of the dense flowering spikes. To use it as food it is mixed up with water into cakes and baked. It is sweetish and light and reminds one strongly of London gingerbread (p 28).

(2) Best, E., (1977) - *Forest lore of the Maori*, Government Printer, Wellington

Raupo was known by several names, depending on what was being referred to:
Hune, tahune, tahuna tahunga = pappus of seed of *raupo*
Karito, rito = young shoots of *raupo*
Koareare, aka koareare, koreirei, kouka, piaka = edible rhizome (root) of *raupo*
Konehu, nehu raupo, pungapunga = pollen of *raupo*
Ngai = dried leaves of *raupo*
Ngatu = Lower part of stem of *raupo*
Pua = bread made from *raupo* pollen
Pungapunga or tahuna= A sweet bread made from the *raupo* flower heads (see Riley)
Rerepe = a porrige made from pollen of *raupo* (see Riley)

Cheeseman's (1906) *Flora* says "the *raupo* pollen was formerly collected by the Maoris, made into cakes with water, and then baked and eaten; the starchy rhizome was also used for food in times of scarcity". An East Coast note states that the *rito*, or young undeveloped leaves, were sometimes cooked in a steaming pit and eaten as greens. In some districts a considerable amount of *pua* or pollen bread was made, in others little, while some forest-dwelling folk rarely saw it, the quantity being based on the amount available, the plenty or otherwise of food supplies, and local conditions generally. Where extensive *raupo* swamps existed many people might join in collecting the *pungapunga*, and if the swamps were anyway distant from the village, then the people would probably camp near it while engaged at their task, in which case whole families would move. Experts would decide when the work should commence, and care had to be taken to prevent loss of the coveted pollen, hence the work of procuring it was performed early in the morning, before the sun rendered the pappus light, and easily blown away. The spikes were broken off and tapped on a close-woven mat, or the *hune* (seed pappus) was stripped off and the pollen was exposed to the sun in order to dry it thoroughly. It was then sifted in close-plait baskets, and the pollen fell into a bark vessel, from which it was removed later and put into baskets lined with large leaves. The meal-cakes made of this material were cooked in a steam oven, and formed a much appreciated food. Taylor, writing in 1848, says the pollen was cooked in the leaf-lined baskets. There were a number of restrictions and superstitions pertaining to the procuring and cooking of this comestible. Best was also told the meal was cooked in small baskets (*tapora*).

The Tuhoe people were wont to collect large quantities of the small green beetle *tutaeruru* or *kekerewai*, that were formerly seen in large numbers on manuka (*Leptospermum*) in summer. These were pounded in a wooden vessel then mixed with the *raupo* pollen and the compound was then put into small baskets and cooked in a steam oven, which is the *tapora* mode of cooking.

The roots or rhizomes of *raupo* also furnished a small food supply in the form of a kind of fecula or farina; this is found in the inner part of the rootstock, of which the outer part is pealed off to expose the soft, white and edible inner part, which, in a large root, contains a considerable amount of mealy matter. As in the case of the fern-root a place must be selected where conditions favour the growth of *raupo* in order to obtain fine, large roots. Under poor conditions both bulrush and bracken produce small hard fibre-packed roots quite useless to the food-seeker. These soft interior parts of the roots were sometimes eaten raw, the fibrous matter being spat out by the eater as in the case of the fern or bracken-roots (*aruhe*). The taste of *raupo* fecula (farina) is rather pleasant and if made into a cake and cooked, it might be a desirable comestible. The edible part was sometimes cooked by the common steaming process, after which the fecula is more easily detached from the fibrous matter. One informant stated that the peeled root was cut into short pieces, and these were put into a gourd vessel and so deposited in the steaming pits; when cooked they were rubbed in the hands so as to disengage the fecula. Possibly this meal may have been formed into cakes and re-cooked, as in the case of the fernroot meal, but I (Best) have never gathered any proof that the Maori so treated it.

(3) Riley, M., (1994) *Maori Healing and Herbal*, Viking Sevenseas, Paraparaumu, N.Z.

The Maori waded into the swamps for the longest and largest *raupo* roots which can be 5 or 6 feet below the surface. These *koreirei* or *koareare* as the roots are called, were pounded and eaten raw, or dried and put in storage for use. The taste is described by White in his *Maori Pharmacopia* (1883) as "not unlike flour mixed with cream, being also a little sweet". A sweet bread named *pungapunga* or *tahuna* was made in the days when *raupo* was plentiful and a large labour force available to collect the flower heads. Reily also refers to the mixing of the green beetle (*kerewai*) with *raupo* pollen and the cooking of the mixture in flax baskets in a steam oven (412-413).

<u>Medicinal and social uses of raupo</u> - Sources quoted by Riley (1994)

- It has been suggested that the poi balls twirled during action songs in the old days to invite warriors to join a fighting party were made from *raupo* leaves.
- *Raupo* stems were used to make an effigy both in a ceremony nullifying a curse; and

in a ceremony to see anyone was attempting to harm another person (White, 1861).

- For wounds or old ulcerated sores, they used ... the hune of pappus down of the large bulrush (*raupo*) as a protection against dust, etc., (Colenso, 1869).

- Hune, the fluff or seed-like down on the *raupo* is beaten out of the stem, not scraped off, and is sprinkled on sores or wounds as a light covering to keep flies from them (White, 1883).

- The the outer skin of the *raupo* root is peeled off when it is about half an inch in diameter to reveal a white dry substance, This was called *koreirei* and was eaten raw by invalids recovering from long illnesses (White, 1883).

- For cuts on the head or leg a bandage of *raupo* may be used. For a broken leg or bruise, bathe with warm water (a decoction from tutu leaves). Apply the *kaikai* plaster. Tie with a bandage - *raupo* or flax or bark - hammered with a stone to make it soft (Smith, 1940).

- Costiveness was relieved by swallowing flax root or *koareare*, the edible lower part of the *raupo*, it had a very sweet taste and was not as powerful in its effects as the flax root. (Beattie, n.d.).

(4) Brooker, S.G., Cambie, R.C. & Cooper, R.C., (1987) *New Zealand Medicinal Plants*, Reed Books, Auckland

<u>Medical use of raupo</u> (Sources quoted by Brooker, Cambrie & Cooper).

The Hune or pappus of the [*raupo*] seeds was applied to wounds and old ulcerated sores as protection against dust (Colenso, 1969). The rhizomes are slightly astringent, diuretic and antidysenteric. The rhizome was boiled with flax root (*Phormium*) and *Tataramoa* root (*Rubus*) and the liquid was drunk to assist the removal of the afterbirth (Garg & Mather, 1972) (p 229).

(5) Best, E., (1976) *The Maori Canoe*, Shearer, Government Printer, Wellington

Quoting Colenso: "Besides their canoes, they sometimes made use of rafts for crossing streams and inlets when the water was deep; such, however, were only made for the occasion, of dry bulrushes, or the dry flowering-stems of the flax (*Phormium*) plant, tied together in bundles with green flax"(p 195).

Another type of raft mentioned by Colenso may be described at a float, though timber raft and reed or bulrush floats were called by the same names - *mokihi* or *moki*. There were two forms of these floats : one was a small affair, a bundle of dry bulrushes or flower-stalks of *Phormium*, which a person bestrode, paddling with his hands or a piece of wood; the other was a more elaborate and a larger float, composed of several or many such bundles lashed together so as to resemble a boat in form (p 198).

Tua Nihoniho contributed the following note; Rude rafts, termed *mokihi* , were sometimes made whereon to cross rivers, of dry *raupo* or timber. If the former, the *raupo* leaves were tied in bundles about 8 in in diameter, several of such bundles were lashed together to form a large one, three of these large bundles were lashed together side by side, and two more tied on top of them, so as to break joins. Upon these two upper bundles travellers placed themselves, propelling their rude craft with poles (p 198-9).

Extract quoted from Shortland's *Southern Districts of New Zealand* (1851) "Our *mokihi* was made in the form of a conoe. Three bundles of *raupo* about eighteen feet long and two feet in diameter at the centre, but tapering towards the extremities, were first constructed separately, each being tightly bound and secured with flax; and were then fastened together so as to form a flat raft. Another bundle similarly made was next laid along the middle of this, and secured in that position, forming a sort of keel; the hollowintervals left between the keel and sides were filled up with *raupo* packed carefully and tightly in layers, and secured with bands of flax. The bottom of the mohiki being then finished, it was turned over, and two smaller bundles were laid along its outer rim, from stem to stern, for topsides, and all the vacancies within were filled up with layers of *raupo* tied down with flax. The leaf of the *raupo* is remarkably light and buoyant when dry, but gradually becomes water-logged when immersed in water (p. 200).

Polack, an early trader in the Bay of Island wrote of maori vessels of olden times nearly 60 feet in length and capable of holding as many persons made entirely of *raupo* (p 201).

Wakefield (1845) when descending the Pelorus river tells of a boy ages 12 made himself a canoe of two bundles of soft bulrushes (*raupo*) which he bound together with flax, and guided with great dexterity from his perch in the middle (p 202).

Quoting Bishop Selwyn: Selwyn records in his diary of crossing the Waitangi River in the South Island on a *Mokihi* To cross it is necessary to start at some point where the main stream touches the bank and to keep the same channel till it winds its way to the opposite bank (p 198).

(6) Nelson, Anne, (1991) *Nga Waka Maori* : *Maori canoes* Macmillan, Auckland.

Even quite small waka had sails and large waka had as many as three. The art of sailmaking was a specialised one *Harakeke, kieke* [*Freycinetia banksii*] or *raupo* being used. When raupo, a particularly light material was used, the leaves were laced together with strips of *harakeke* [flax] (p 40).

Quoting Augustus Hamilton, *Maori Art* (1896) : When the triangular *raupo* sails were set the canoes sailed well in a good breeze, sailing very close to the wind, but not having any hold on the water they made great leeway (p 41).

On the use of *Mokihi* (p.47)

Mokihi were used in both the North and South Islands. They were usually made from bundles of *raupo* which grew abundantly near many waterways. *Mokihi* were very strong and because of their weight when saturated, very stable. In addition they were easily manipulated, making them ideal vessels for travelling down rough rivers in. Because of their drag *mokihi* could be poled upstream. They were often constructed as temporary vessels - for example, parties on an overland expedition could make them relatively quickly for crossing rivers. People on inland hunting and food gathering expeditions used them to transport their produce down rivers. *Ngati Kura Mokihi* are a *hapu* of *Ngati Kahungunu* who live on the shore of Lake Tutira. They take their name from the *mokihi* and floating islands which they used on the lake in traditional times.

(7) Best, E., (1974) *Maori storehouses and kindred structures*, Government Printer, Wellington.

The *whata a rangi* was a small storehouse like a diminutive hut elevated on the top of a single high post. They were used to keep miscellaneous items in - such as weapons, garments etc but not food- supplies (*Te Whatahoro*) . The foundation of the little storehouse was in the form of a cross, and on this was erected a hut of light materials often of thatch - such as *raupo* (bulrush) or leaves of the *Cordyline*, this latter being a very durable thatch (p 28-9). However, for the Tuhoe people the *whata-a-rangi* is a platform erected in a tree and used for storing food-supplies (p.31).

For the Nga-Puhi the generic name for storehouses was *whata* which means to elevate on supports. *Whata* were of various kinds, having various [storage] uses - fresh and preserved foods, garments digging and gardening tools, fighting spears, armour, goods in general; and *whata-moenga* were for sleeping. When all the posts and rafters had been served with kahikatea laths to carry the thatching, the hut was ready for thatching. This was usually *raupo* reed, a reed which was readily procurable, durable, easily handled, which gave coolness in summer and warmth in winter. The side and end walls were thatched first, then the roof. This sometimes got a first coat of nikau palm, then one of *raupo* and finally one of *toetoe* grass or *wiwi* (the common rush). More laths were then fastened on to bind the whole down ... and the thatching was secured with prepared and toughened flax (p 33).

Quoting Polock: The house appropriated to the kumara or sweet-potato, is built expressly of *raupo*, with exceeding neatness. Colenso says the kumara barn or store was almost universally the well-made handsome house of the village. ... Its walls were made of reeds ... and its thatched roof was well secured with loosely twisted ropes of the durable mangemange (*Lygodium*) fern (p 55).

After the trade in flax was inaugurated large shed were constructed in which to store the prepared fibre. Polock states some were more that 100 ft in length , 30 ft in width and 40 ft heigh. These flax houses were constructed of poles and *raupo*, and the lower parts were open. Great care was taken that the roof was watertight (p 55-6).

Quoting Colenso in *Tarnsactions of the N.Z. Institute* : the Maori wisely preferred cultivating in patches far apart, so as perchance to save one or more in case of a sudden inroad from a *taua* (war party).

Best, E., (1976) *Maori Agriculture*, Government Printer, Wellington.

Maori war parties never destroyed unripe crops, always waiting till the crop was ripe before attacking so they had something to eat.

Appendix 5

List of radiocarbon dates pertinent to Maori Occupation in Hawkes Bay
used in the compilation of Figure 5. 2

adapted from : Higham, T. F. G., & Hogg, A. G., (1997)
Evidence for late Polynesian colonization of New Zealand:
University of Waikato Radiocarbon measurements.
Radiocarbon. **39** : 149-192.

14C Yrs BP	Reference	Site	Material	Deposit/activity dated
1040 ± 60	Wk-2515	Parangatau Pa (Cape Turnagain)	- shell	midden
880 ± 50	Wk-3048	Heipipi Pa (above Petane)	- shell	
730 ± 45	Wk-1956		- shell	midden
700 ± 45	Wk-1958		- shell	midden
680 ± 45	Wk-1957		- shell	midden
840 ± 45	Wk-2133	Koutouroa Pa (Wharerangi)	- shell	midden on a pa
750 ± 50	Wk-2132		- shell	midden on a pa
710 ± 45	Wk-2134		- shell	midden on a pa
810 ± 45	Wk-2273	Otatara Pa (Taradale)	- shell	date of occupation
750 ± 45	Wk-2274		- shell	date of occupation
790 ± 50	Wk-2131	Poto Pa (Ahuriri)	- shell	defensive bank
660 ± 55	Wk-2130		- shell	defensive bank
720 ± 45	Wk-2307	Te Ihu O Te Rei (Inner Harbour)	- shell	
660 ± 45	Wk-2306		- shell	
710 ± 40	Wk-2135	Te Mingi Pa (Tutaekuri River)	- shell	midden on a pa
710 ± 50	Wk-2137	Mangawharau Pa (Waimarama)	- shell	paua cache outside a defensive [bank.
640 ± 50	Wk-2136		- shell	midden on a pa
570 ± 45	Wk-2138		- shell	midden on a pa
680 ± 40	Wk-1967	Manawarakau Pa (Kairakau Beach)	- shell	midden below house terrace
590 ± 40	Wk-1966		- shell	midden postdating defences
560 ± 50	Wk-1965		- shell	midden below a terrace
520 ± 40	Wk-1960	Matanginui Pa (Waimarama)	- shell	date of occupation
500 ± 40	Wk-1959		- shell	date of occupation
480 ± 40	Wk-1961		- shell	date of occupation
220 ± 50	Wk-1962	Motukumara Pa (Lake Oingo)	- charcoal	midden on pa/defenses
Modern	Wk-1964		- charcoal	burning bracken, before construction
Modern	Wk-1963		- charcoal	hangi site on a terrace