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LATE HOLOCENE CHANGES IN THE VEGETATION OF WESTERN TARANAKI
INVESTIGATED BY SOIL PALYNOLOGY

VOLUME I

A thesis presented in partial fulfilment of
the requirements for the
Degree of Doctor of Philosophy
at Massey University

Cynthia M Lees

1987



FIG. 44.—New vegetation as it was in 1905 on the deep volcanic ash ejected during the eruption of Mount Tarawera in 1886. The tussocks are those of the toetoe (*Arundo conspicua*); they are at least 5 feet high.
(Photo, L. Cockayne.)

From "New Zealand Plants and Their Story"
L. Cockayne (2nd Ed.) 1919.

ABSTRACT

The study area in western Taranaki is dominated by the andesitic volcano, Mount Egmont. Palynological study of 22 fossil pollen sites from a wide range of sediments has produced evidence of change in vegetation over last 4000 years. The resilience of the indigenous vegetation ensured survival of temperate lowland forests until the arrival of European settlers about 150 years ago. Within this period, deforestation of the lowlands has been almost complete. Surviving forest is protected within Egmont National Park. There is little evidence of pre-European deforestation, but indications of earlier fires are thought to be due to an increase in the Maori diet of Pteridium rhizomes, dictated by a change of climate about 400yr B.P.

Information has been gained in general terms about the effects of older tephras and in detail about damage and recovery after tephras *were* deposited within the last 400 years. A revised tephrochronology for the last 400 years is offered. Palynological evidence suggests that an equable climate existed between 4000-1400yr B.P. A decline of Ascarina from very high values at this time to low values at 400yr B.P. has been interpreted as due to a prevalence of droughts. Since 400yr B.P. the climate has been wetter and cooler. This, together with the availability of newly exposed sites due to volcanic activity, has resulted in a dominance of Weinmannia in the Mount Egmont forests. Such dominance is not seen in pollen profiles of older sites over the last 4000 years.

PREFACE

This research was undertaken to elucidate the effect of volcanism on the vegetation of western Taranaki, particularly on the forests of Mount Egmont. The tephrochronology and botany were well known and formed a sound basis on which to commence palynological studies. In addition information was sought and gained about recent climatic change and changes brought about by man in his use of the Taranaki environment.

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my supervisors, Dr. V. E. Neall, Department of Soil Science, Dr. J. P. Skipworth, Botany Department, both of Massey University and Dr. M. S. McGlone, Botany Division, D. S. I. R. Lincoln, for their enthusiasm, valued advice and encouragement during the period of this research. To my two computer programmers, Mr. M. R. Lewis (recently of the Department of Soil Science) and Mr. B. S. Solomon, Geography Department, Massey University, I offer my grateful thanks for their patience and their innovative responses to my requests. Many helpful conversations have assisted with problems. I would like to mention particularly Dr. A. N. Macgregor, Dr. J. H. Kirkman and Mr. M. A. Turner, all of the Department of Soil Science and Dr. J. L. MacArthur, Geography Department, Massey University. Professor D. A. Livingstone of Duke University, North Carolina, U. S. A. sent helpful advice about the problem of clumping in pollen and Professor G. W. Dimbleby (Emeritus Professor of London University) generously made himself available to discuss soil palynology during my visit to London.

Members of the ^{*}Royal Society for the Protection of Forest and Bird, shared their knowledge of the indigenous vegetation and generously answered many questions, I would particularly like to record my thanks to Mr. R. M. Greenwood and Mr. R. A. Creswell in this respect. Last, but certainly not least, I acknowledge the debt I owe to the extensive knowledge of the Mount Egmont forests acquired by Mr. A. P. Druce and for useful discussion of some of my results. My tribute is paid in the many quotations of his work in this research.

Dr. R. N. Patel of the Botany Division, D. S. I. R., Lincoln, kindly identified wood samples for dating. The Radiocarbon Dating Laboratory, Institute of Nuclear Sciences, Lower Hutt, provided four new dates.

* Royal Forest & Bird Protection Society

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* = Figures presented in Volume 1.

CHAPTER 1

INTRODUCTORY LITERATURE REVIEW

1.1 INTRODUCTION

Prior to the arrival of Maori and European settlers, the Taranaki lowlands and lower slopes of Mount Egmont supported temperate rain forest. Indigenous forest is now largely restricted to Egmont National Park, a circular reserve of 9.6km radius centred on the 2518m high volcanic peak of Mount Egmont, plus two extinct volcanoes to the north which form the Kaitake and Pouakai Ranges. A broad Late Quaternary vegetational history has been elucidated by McGlone et al (1984) in south Taranaki and more detailed studies for the past 30ka years have been made by McGlone and Neall (in litt.) and McGlone et al (in litt.). Modern pollen rain within the Egmont National Park has been examined by McGlone (1982).

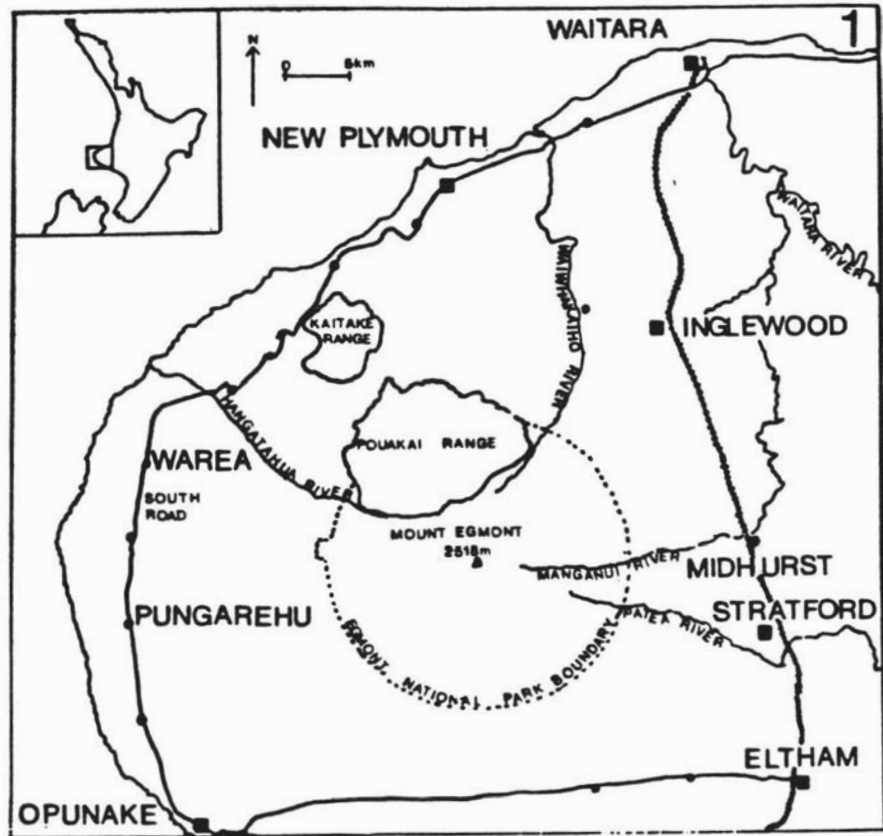
The present botanical knowledge of the region, including species distribution and zonation within Egmont National Park, stems from the work of Druce (1966, 1974, 1976a and b). More detailed studies on altitudinal changes in vegetation and factors which influence zonal boundaries have been made by Clarkson (1977, 1981, 1985). Nevertheless the impact of Late Holocene volcanic eruptions and anthropogenic effects on the vegetation have remained largely unknown. This study aims to ascertain finer details of changes in forests due to volcanic activity, Maori occupation, European settlement and climatic change. Tephrochronology forms a basis for dating the polleniferous

deposits investigated. The study area (Fig. 1) is therefore delimited by the distribution of dated lahars and tephras below the present treeline. Isopach maps of Late Holocene tephras which are available are presented in Figs.2A-G.

1.2 GEOLOGY

1.2.1 Reconstruction of Past Events: Taranaki district is dominated by New Zealand's largest andesitic stratovolcano, named Mount Egmont by Captain Cook but known to the Maori as Taranaki. The volcano is the most recent of a chain of volcanic vents originating in the north near the present city of New Plymouth. Here, the Sugar Loaf Islands and Paritutu are volcanic necks of a 1.75m yr old structure. Further south the Kaitake and Pouakai Ranges are eroded remnants of volcanoes dated at c.0.57m yr and 0.25m yr. The present upper cone of Mount Egmont is only 10ka old and has been built up on the site of at least two previous cones which collapsed about 100ka and 23ka ago. The vent of the small parasitic cone, known as Fantham's Peak 1962m, on the southern flank of Mount Egmont was particularly active about 3.3ka B.P. (Neall and Alloway 1986) when lava flows constructed much of the southern flanks of the cone. The geology of the region has been extensively studied by Neall (1972, 1974, 1976, 1979), Wellman (1962), Grant-Taylor (1964) and Hay (1967). The definitive work for Western Taranaki is a series of geological maps and accompanying booklet (Neall 1979). The most recent work is by Neall et al (1986) which examines the history and petrology of the Taranaki volcanoes. From all the above the following geological information can be summarised.

FIG 1 THE STUDY AREA TARANAKI, NORTH ISLAND, NEW ZEALAND.



SOURCE NZMS 1 N119 Taranaki (1st. Ed.) 1970

1.2.2 Composition of Mount Egmont: The upper portion of Mount Egmont is comprised principally of lava flows that have been extruded in Holocene time to form a prominent cone with a summit crater and a basal area of 25km². The lava is composed of augite-hornblende andesite, augite being in a greater proportion than hornblende. The lower portion of the volcano includes laharc, pyroclastic and alluvial volcaniclastics which cover a basal area of 1000km². Only the southern ridges of the Pouakai Range distort the near perfect circular base. There has been some marine erosion on the western side. Fantham's Peak also has a summit crater. Basaltic lava and the scoriaceous Manganui tephra were erupted from this vent about 3.3ka B.P. (Franks 1984). Both vents have been active during the Holocene, lava flows during this time have been restricted to within the Egmont National Park area. Between these lava effusion phases, pyroclastic flows and tephra have also been erupted. Lahars or debris flows, due to heavy rainfall have been frequent (Neall 1974, Neall and Alloway 1986).

1.2.3 Surface Deposits: Surface deposits of the ring plain include the Pungarehu Formation (23ka B.P.) to the west (Neall 1979). This Formation is distinguished by about 3000 flattened, hemispherical hills varying in height from 5-30m. These debris avalanche mounds formed convenient sites for small fortified Maori pa containing kumara storage pits (Day 1984). Debris flows have occurred frequently over the last 500 years on the northwestern slopes. Fourteen flows mapped by Hay (1967) within the Opunake Lahars have been re-named by Neall (1979), Maero Debris Flows, although 5 of these have since been proven to be of hot pyroclastic origin (Neall and Alloway 1986). Such flows have effectively destroyed all possible fossil pollen sites in the

northwest quadrant. Flows channelled down major streams devastated vegetation. The most recent flow, triggered by heavy rain, has been down the Oaonui Stream in 1922 A.D. (Druce 1976a).

1.2.4 Drainage: The radial drainage pattern on the upper cone is deeply incised to form steep-sided ravines. During periods of heavy rain, a feature of mountain climates (Coulter 1967), these ravines are filled with raging torrents. Streams on the western side run directly to the sea. Three major rivers, the Stony (Hangatahua), Waiwhakaiho and Manganui drain the northern quadrant. In the eastern quadrant the Patea River flows eastwards until it is deflected sharply south by the Eastern Taranaki uplands.

Between the volcano and Taranaki uplands, impeded drainage has created a chain of swamps. North to south these are named the Ratapiko, Midhurst, Ngaere and Eltham swamps. The latter has been previously investigated for palynological stratigraphic purposes (McGlone and Neall in litt.), but the other three have been researched in this study. The genesis and historical development of the Ngaere and Eltham swamps has been described by Franks (1984). A string of spring-fed bogs on the upper ring plain within the Egmont National Park includes Potaema, Norfolk Road and York Road bogs which are also investigated in this study.

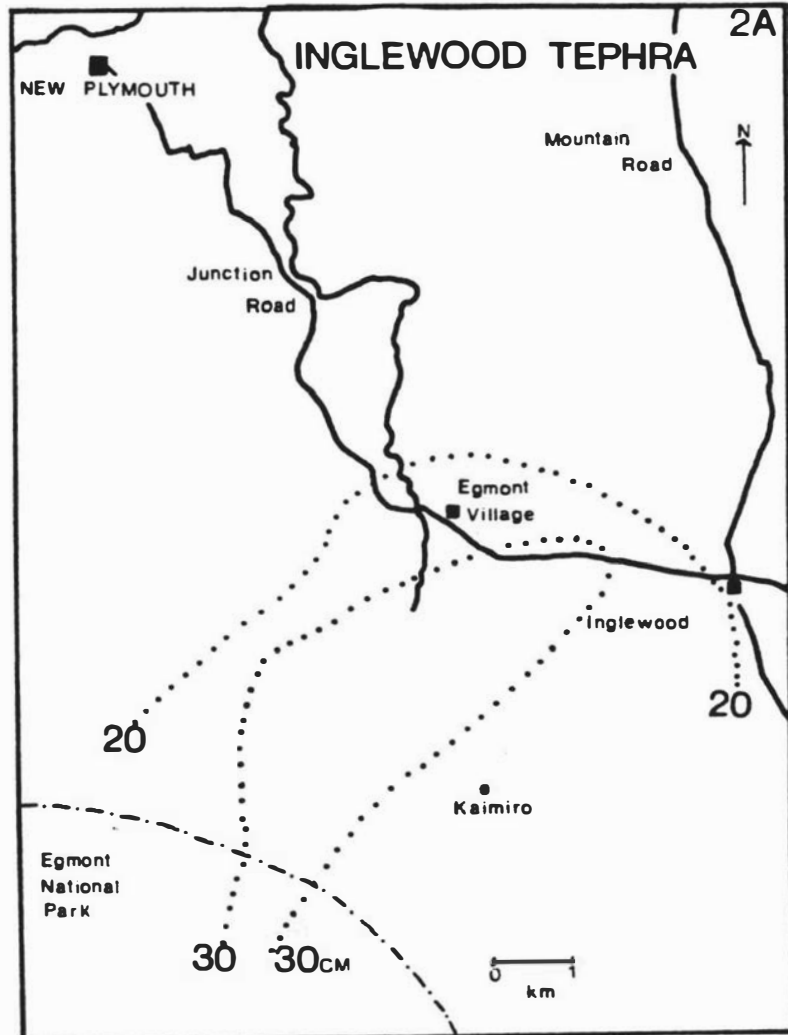
1.3 TEPHROCHRONOLOGY

1.3.1 Historical Accounts: Oliver (1931) records a Maori oven overlain by tephra near the Stratford Mountain House on Mount Egmont. A.H. Burrell discovered the same tephra in the fork of a recently felled matai (Prumnopitys taxifolia) * tree in 1883. The tree had 600 annual rings at breast height. Allowing for 150 years of growth to the fork, Burrell concluded that an eruption probably occurred 450 years ago or about 1433 A.D. (Oliver 1931). Charcoal from this oven yielded dates of 436 ± 60 yr (NZ63b) and 440 ± 60 yr B.P. (NZ64b) (Grant-Taylor and Rafter 1963). This white pumiceous lapilli layer has since been named the Burrell Lapilli.

1.3.2 Late Holocene 5000 to 450 yr B.P.: Tephras deposited within the last 5000 years include two distinctive pumiceous deposits named the Korito and the Inglewood Tephras erupted between 5ka and 3ka. These were carried by southwesterly winds to the present district of Inglewood lying between the northeastern flank of the volcano and the northern Taranaki coastline. Stratigraphically above them, the next distinctive marker bed is the Manganui tephra, a basaltic scoriaceous bed. Two periods of quiescence interrupted by activity were followed by the deposition of the pumiceous Kaupokonui tephra about 1.4ka which was deposited over the eastern portion of the Egmont National Park. The most recent active episode began about 450 yr B.P. ending a dormant spell lasting about 1000 years (Neall et al 1986).

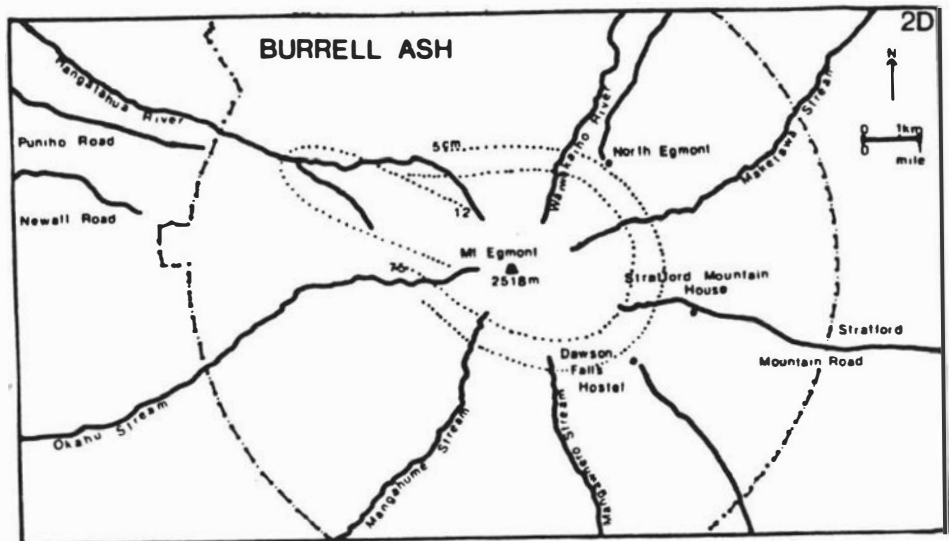
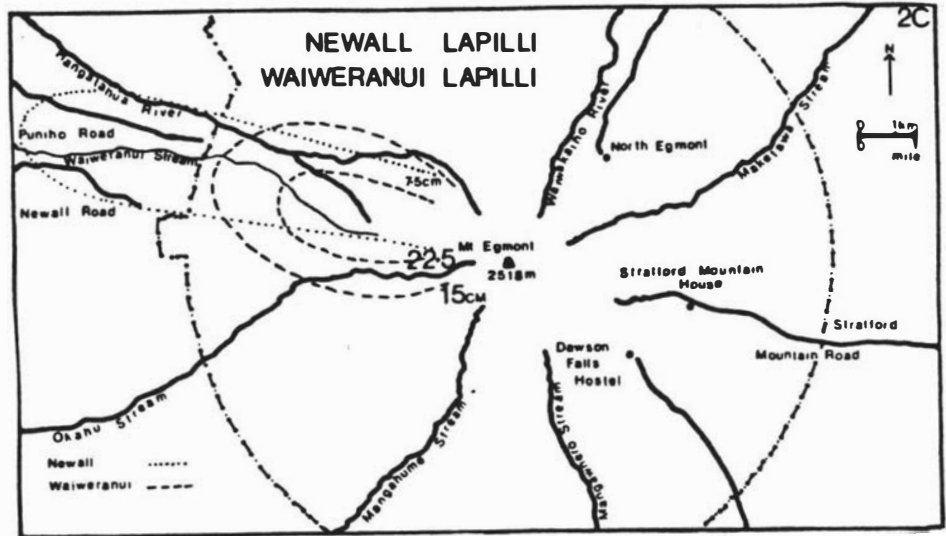
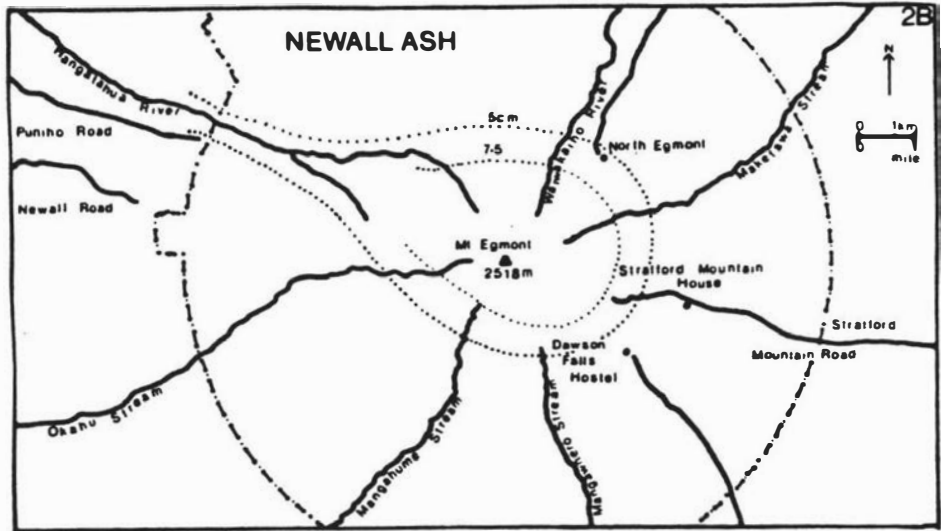
* See Appendix I Botanical Notes, for all botanical information.

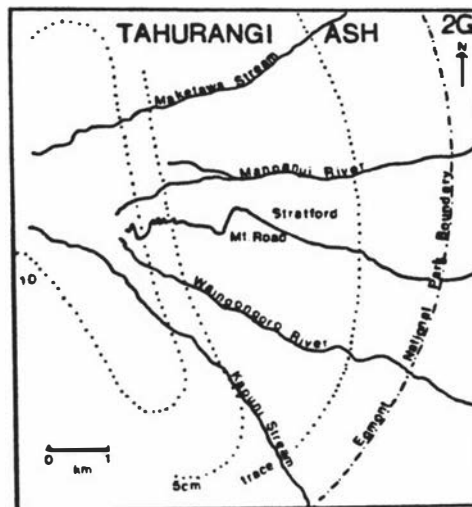
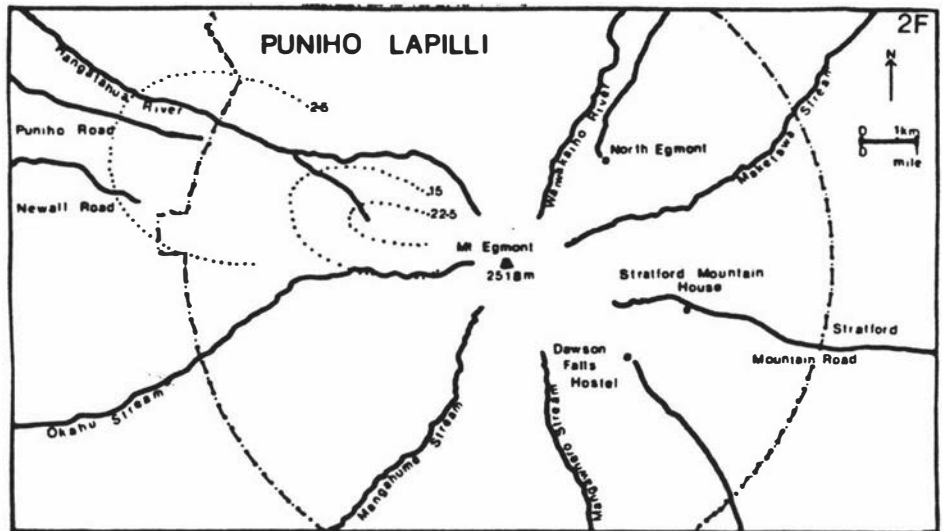
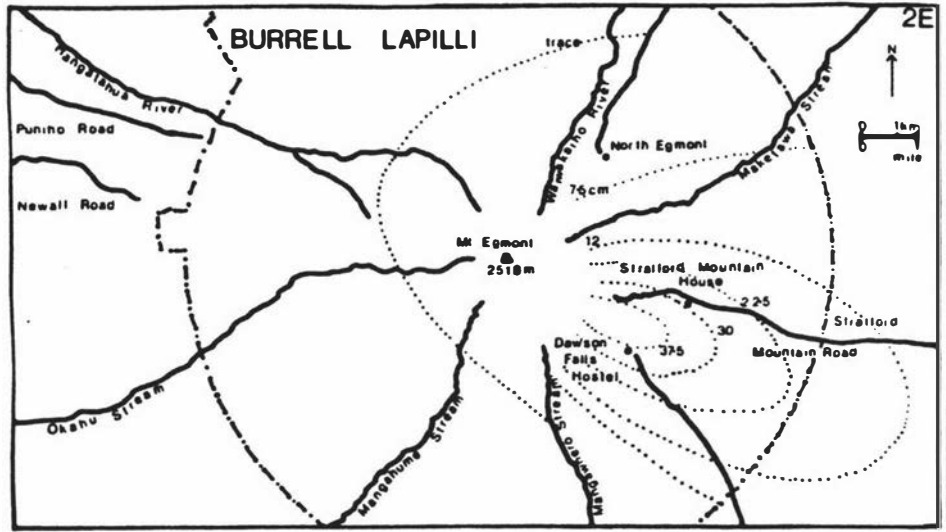
FIG 2 ISOPACH MAPS OF TEPHRA DISTRIBUTIONS



SOURCES

- 2A Inglewood (Neall 1972)
 2B-F Newall, Waiweranui, Burrell Druce (1972)
 2C Tahurangi Tonkin (1970)





The stratigraphy and chronology of these comparatively modern events has been researched by Druce (1966) based on an extensive field study of soil pits and sections within Egmont National Park. Descriptions of the likely manner of actual events, possible distributions and effects have been recorded by Neall and Alloway (1986) with isopach maps drawn by Druce (1966).

1.3.3 450 yr B.P. to Present: A date of 1604 A.D. was given by Druce (1966) for the Newall eruptions, the earliest event of the latest active episode but when a new radiocarbon date became available this was revised to 1500-1550 A.D. (Neall 1972). Charcoal from a second oven found on Mount Egmont which was overlain by Newall tephra has been dated (NZ1561B) at 470 ± 55 yr B.P. (Topping 1974).

The technique of tree-ring dating can be used when the material to be dated is outside the range of the radiocarbon method. For accurate dating, cores must be taken from a large number of trees established both before and after the eruption. Any decrease in ring width must be checked against the several possibilities that can retard annual growth. Druce, who used this technique was restricted by lack of suitable trees and his results must be treated with caution, a fact he himself acknowledged. Libocedrus bidwillii the species used by Druce (1966) for dating the Burrell Lapilli is stated (Dunwiddie 1979) to suffer from heart rot. Despite attempts to correlate growth rate, ring orientation and other information from four cores from each tree Dunwiddie found that age determinations were only poor to fair in most cores. Successful dating of eruptions on Mount St. Helens has been carried out by Yamaguchi (1985) who used a standard dendrochronological

method (Stokes and Smiley 1968) which requires cross referencing of each annual ring to those of a large number of trees in control sites having a similar elevation, aspect, slope and soil but not exposed to deposition of volcanoclastics in the eruption under investigation (Yamaguchi 1983, 1985).

Details of the mode of deposition of the Burrell Lapilli have been researched by Topping (1972). Three eruption phases are identified. Initially small-sized lapilli were carried by high level winds from the south or southwesterly direction. In the larger and longer second phase, larger lapilli were borne by a low level wind to the eastsoutheast while a final very small phase produced a lobe to the northeast. After this eruption a tholoid is thought to have been emplaced in the Egmont crater, and was partially destroyed in explosive eruptions which fractured the western rim of the crater. The Puniho 1 and 2 lapilli were deposited by these eruptions (Grant-Taylor 1964). The distribution of the tephras, their variation in thickness, and the carbonised wood and litter fragments contained within indicate that the event represented a nuée ardente type eruption (Grant-Taylor 1964; Topping 1972). All these beds were deposited within a short time and the 1655 A.D. date given is on the basis of limited tree-ring dating (Druce 1966).

In Table 3 of this same paper Druce lists the ages of nine Libocedrus trees identified by him as post-Burrell and all growing between 945-1036m. The ages ranged from 181-226 years in 1963 when the ring counts were made. This means that the oldest tree must have become established about 1737 A.D. or shortly before. A possible date of

1725-1750 A.D. has been accepted in this research. The information was apparently ignored by Druce (1966).

The most recent eruption, Tahurangi Ash, has a tentative date of 1755 A.D. based on the rate of peat accumulation in bogs between the Burrell tephras and the present ground surface (Druce 1966). Druce associated this last tephra with the deposition of "supposed post-Tahurangi alluvium" in the Okahu and other western streams which he had previously dated from tree-ring counts of kanuka (Leptospermum ericoides) at about 1755 A.D. A soil study of the southeastern sector of the Egmont National Park has increased knowledge of this tephra (Tonkin 1970). The axis of deposition is aligned southeast to northwest from Dawson Falls to North Egmont (Tonkin 1970). Tonkin agreed with Druce that the youthfulness of the soils would support a very recent date for the volcanoclastic parent materials. He suggested an alternative explanation for the humic layer described by Druce as "buried litter" between the Burrell Lapilli and Burrell Ash. An "in built B horizon" in the top layer of Burrell Ash he suggested was due to "melanisation downwards by illuviation". Druce (1966) reported traces of a buried soil between Burrell Lapilli and Burrell Ash at low altitude sites but as he did not find it in a sub-alpine bog, he interpreted the humic layer as litter.

1.4 CLIMATE

1.4.1 Holocene Climatic Changes: There have been changes in climate over the last 14,000 years. In a review of the literature of many disciplines Moar (1982) listed four climate related events which have widespread significance for the forests of New Zealand.

1. The retreat of South Island glaciers at 14,000 yr B.P. and development of scattered forest in the North at the same time.
2. The spread of scrubland in eastern central South Island and development of forest without a scrubland phase in Westport and Hokitika district.
3. In the South Island at 10,000 yr B.P. a change to mainly podocarp forest while in the North Island Dacrydium cupressinum established dominance in the podocarp forests.
4. Widespread decline of Ascarina pollen between 5000-2000 yr B.P.

Earlier climatic changes are responsible for the present distribution of some tree species. There is a striking absence of all species of southern beech (Nothofagus), pink pine (Halocarpus biformis) and mountain toatoa (Phyllocladus asplenifolius var. alpinus) on Mount Egmont (Druce 1974). Beech evidently survived the last glaciation in refugia in the Eastern Taranaki uplands, then climatic amelioration between 14-10ka yr B.P. permitted the spread of podocarp-hardwood forest. Beech however, a slow migrant, was unable to compete and could not penetrate the lowland forest to reach cooler slopes of Egmont (McGlone and Neall in litt.).

The only published palynological study on climatic change in

Taranaki is of Late Quaternary deposits at Inaha, South Taranaki (McGlone et al 1984). It is necessary therefore to refer to other regions of the North Island for information on Holocene changes. Several sites in the Tongariro region on the volcanic plateau ranging in altitude from 600-823m have been studied (McGlone and Topping 1973, 1977, 1983). Their conclusions (Table 2 p73 1983) are that from 10,000 -5000 yr B.P. podocarp-hardwood forest dominated by D.cupressinum, with abundant Ascarina lucida and trees ferns, covered the area in a climate that was wetter and milder than at present. This changed around 5000 years ago to forest dominated by Prumnopitys taxifolia and D.cupressinum. The climate then was similar to that to-day but with cooler intervals. The last 10,000 years is regarded as an interglaciation.

Within the last 5000 years two periods of climatic variation are indicated by fluctuations in the representation of Ascarina in pollen spectra from many sites. At the North Island sites of Ruapehu (also on the volcanic plateau) and the Ruahine Ranges two periods of decline are noted. One occurred before 3400 yr B.P. followed by a recovery between 3400 and 1800 yr B.P. After 1700 yr B.P. the levels of Ascarina fell to those of to-day. The species has a limited distribution, being mostly confined to the West Coast of the South Island and to favourable districts and sites between 300-600m in the North Island (McGlone and Moar 1977).

Palynological studies at Ahukawakawa Swamp, lying between Mount Egmont and the Pouakai Range at 920m, have indicated some fluctuation in Ascarina which to a certain extent is supported by other studies at

Potaema Bog (McGlone et al in litt). They concluded that there was a real increase in Ascarina between 2300-1300 yr B.P. and attributed this to a period with less severe frosts. They quoted a decrease in Libocedrus and a greater abundance of Weinmannia in support of their conclusions.

During the last three decades considerable evidence has accumulated for climatic changes within the last 500 years. The literature is extensive but the conclusions as diverse as the regional climates and topography on which they are based. A wide ranging and thorough analysis of this literature including meteorological data and other phenomena (dated glacial episodes, lake level and treeline changes, periods of accelerated erosion) was made by Burrows and Grennland (1979). They concluded that variation in climate in the last few hundred years could be attributed to latitudinal alteration in the positions of pressure systems and changes in the rate of circulation. Short term variation in weather patterns has been recorded by the early settlers in the region (Scanlan 1961). In 1878-1902 winters were long and snowfalls heavy enough on one occasion to cause severe damage to the forests at North Egmont and at Midhurst in the eastern lowlands. In 1916-1918 and again in 1955-56 little snow fell and the ice level in the crater of Mount Egmont was much below normal.

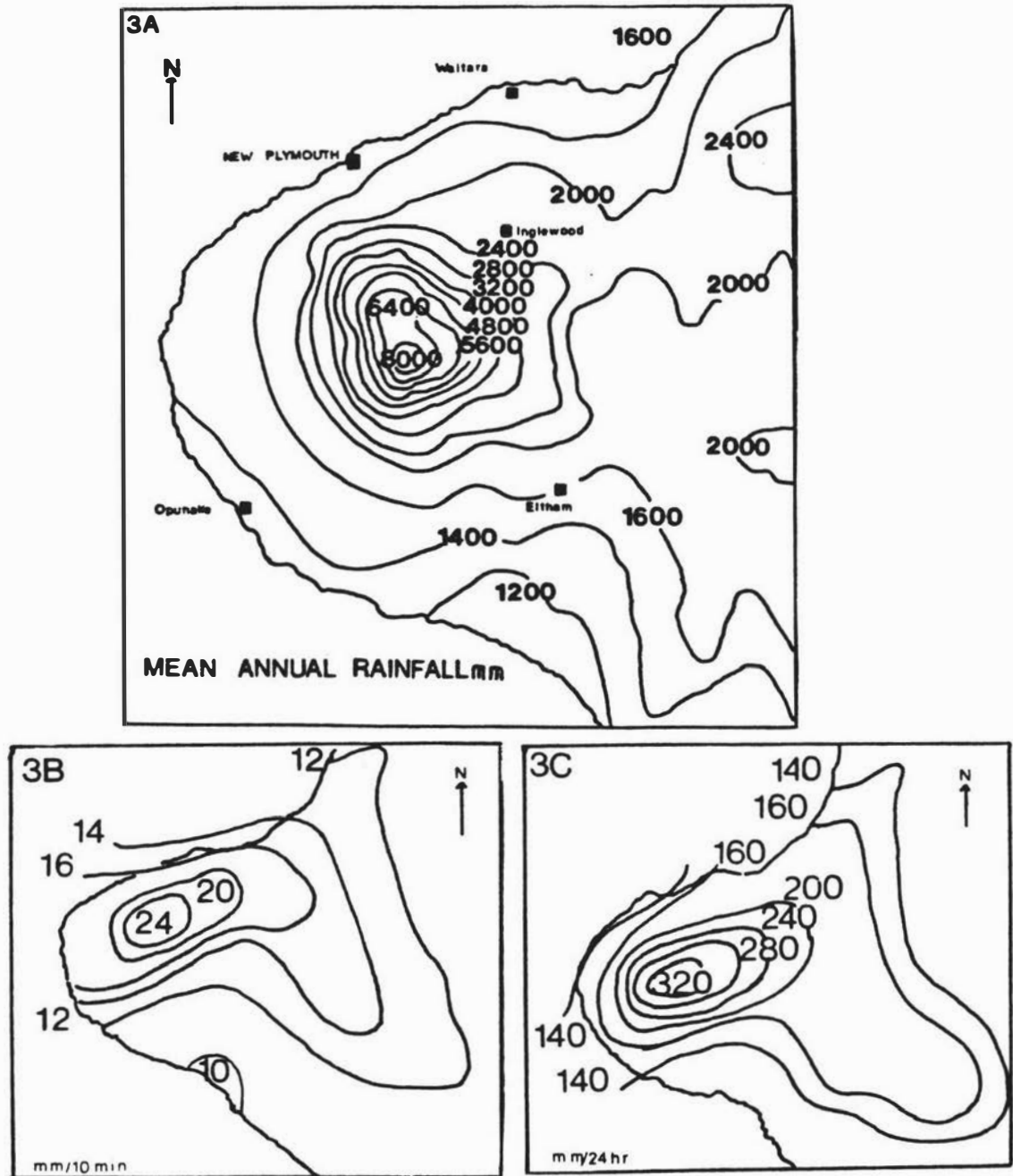
1.4.2 Temperature Data: The most complete set of data comes from the Stratford Mountain House (846m). Here, records for 1965-1979 show that the mean daily maximum temperature ranges from 18° C in January-February to 7° C in July. The highest maximum recorded was 27° C in February while temperatures as low as -5° C were recorded in

July, August and September. July has an average 11.8 frost days per annum while February is the only frost free month. The freezing level in the atmosphere in mid-summer lies between 2800-4200m, falling to 1150-2500m in mid-winter (N.Z. Met. Ser. in Tullett 1980). The structure of the snowpack on Mount Egmont has revealed that even in winter, temperatures on the upper slopes can be above freezing and that precipitation then falls as rain and not snow (Marcus and Moore 1983). The vagaries of mountain weather within a single day have been detailed by Coulter (1967). Frosts are not common on the coast but inland at Stratford over 70 frosts a year can occur. These inland lowlands have a mean annual temperature 2-3°C cooler than the coast average of 12-13°C (McGlone and Neall in litt.).

1.4.3 Wind Data: North to northwest winds give the greatest speeds, a maximum gust of 185km/h was recorded on the Plateau (1144m) in December 1979. As depressions approach from the west, winds come from a northerly quarter, temperatures are mild and the heaviest rainfalls occur at this time (N.Z. Met. Ser. in Tullett 1980). Winds from the west are usually laden with salt as they come off the sea. Salt burn is thought to cause the one sided crowns of some trees in the Park, in particular on emergent kaikawaka (Libocedrus) growing on northerly slopes of Egmont (Druce 1976a). East of Mount Egmont winds tend to be channelled between the volcano and the Taranaki Uplands (Druce 1976a).

1.4.4 Precipitation Data: The mean annual rainfall is shown by isohyets in Fig.3A (Tomlinson 1980). Rain bearing westerlies are forced to veer to the north by the mass of Mount Egmont but at the same time rise as they pass over the Kaitake and Pouakai Ranges. The general pattern of rainfall is thus orientated northwest to southwest except for the peak of Egmont where precipitation increases rapidly from 6400 to 8000mm. The rain shadow therefore lies to the southeast. There is a marked difference in the amount of rain falling on the northern Taranaki coast (1600mm) and the southern coast (1200mm). The north south trend of the wind funnelling between Egmont and the Taranaki Uplands further to the east gives a gradual falloff in rainfall with Inglewood in the north receiving more than 2000mm and Eltham only 1600mm. Intensity of rainfall is given in Fig.3B and the influence of the northerlies associated with passing depressions is shown by the general trend of the isolines. In contrast, Fig.3C shows the 24 hour rainfall centred on the mountain and the eastern uplands and reflects the contribution made by orographic rain at higher altitudes which is independent of wind direction (Tomlinson 1980). Although rain falls in every month, prolonged dry periods can occur in February ranging from 14 days to the longest spell of 23 days recorded at the Stratford Mountain House (Tullett 1980).

FIG 3 DISTRIBUTION AND INTENSITY OF RAINFALL



SOURCES

- 3A Mean Annual Rainfall 1941-70 based on normals in N.Z. Met Ser. Misc. Pub. 145.
- 3B 10 minute rainfall (mm) of return period 5 years.
- 3C 24 hour rainfall ((mm) of return period 5 years.
- B and C From Tomlinson (1980).

1.5 VEGETATION

1.5.1 Coastal Taranaki: Reconstruction of vegetation patterns at the time of European settlement has been made possible from notes made by early botanists during brief visits to the mountain (Buchanan 1869, Thomson 1917) and accounts by the first settlers (Heaphy 1842, Dieffenbach 1843, Hursthouse 1849 and Brooks 1892). Later recollections by Burgess (1901), Rutherford and Skinner (1969), Stronge (1973), Every (1974) and Standish (1984) are supplemented by the research of Druce (1966, 1974, 1976a and b), Clarkson (1977, 1981, 1985), and McGlone (1982), McGlone and Neall (in litt.) and McGlone et al (in litt.). From these sources it can be concluded that at about 1840 A.D., the coastal plains of Taranaki were covered in a dense tangle of fern (Pteridium), flax (Phormium tenax) and cabbage tree (Cordyline australis) except for a few patches still cultivated by the Maoris. There were a few areas of scrub containing numerous species of stunted trees and shrubs, together with palms, ferns and masses of white clematis (Clematis paniculata?) growing on the trees. There was an occasional remnant of heavy bush and the remains of forest trees were found in the flax swamps which occupied large areas of the plains. One report states that these swamps were firm at the base. In places where some of the many streams crossed the plain, remnants of lowland forest with abundant tree ferns persisted and in some places reached the coast. There is some evidence that a type of semi-coastal forest dominated by kohekohe (Dysoxylum spectabile) was formerly much more common on the coastal plain. (Clarkson 1985). Pukatea (Laurelia novae-zelandiae), tawa (Beilschmiedia tawa) and nikau (Rhopalostylis sapida) were also prominent, together with some karaka (Corynocarpus laevigatus), titoki

(Alectryon excelsus) and puriri (Vitex lucens). This forest now survives only in small coastal reserves and on the western flank of the Kaitake Range. Hursthouse (1849) writing of the area around New Plymouth described "many dells" varying in size from a half to three acres in size, densely wooded and generally containing an unfailing spring surrounded by tree ferns together with Fuchsia and karaka (Cornynocarpus laevigatus).

1.5.2 Western Taranaki: Inland of the coastal fern and scrub belt, warm temperate forest covered the lowlands and lower slopes of Mount Egmont. The forest was dominated by rimu (Dacrydium cupressinum), tree rata (Metrosideros robusta), kamahi (Weinmannia racemosa) and tawa. Many species of hardwood trees and shrubs such as mahoe (Melicytus ramiflorus), broadleaf (Griselinia littoralis), fuchsia (Fuchsia excorticata), pate (Schefflera digitata) and makomako (Aristotelia serrata) comprised the understory. Kahikatea (Dacrycarpus dacrydioides), the swamp maire (Syzygium maire) and pukatea were dominant in swampy areas.

1.5.3 Eastern Taranaki: on the eastern side of Mount Egmont there was dense forest. Brown (1975) quotes a description of the march of General Chute through the forest from Ketemarae, near Normanby, to Waiwhakaiho near present day Inglewood in 1866. An ancient Maori pathway had been cut over to make a bridle-path but in a few years this had become so overgrown that the force missed it and had great difficulty in making progress through the dense forest. Difficulties faced by settlers in clearing "heavy bush" in the new Moa block (near Inglewood) are described by an early surveyor (Brooks 1892). Four swamps occupied a

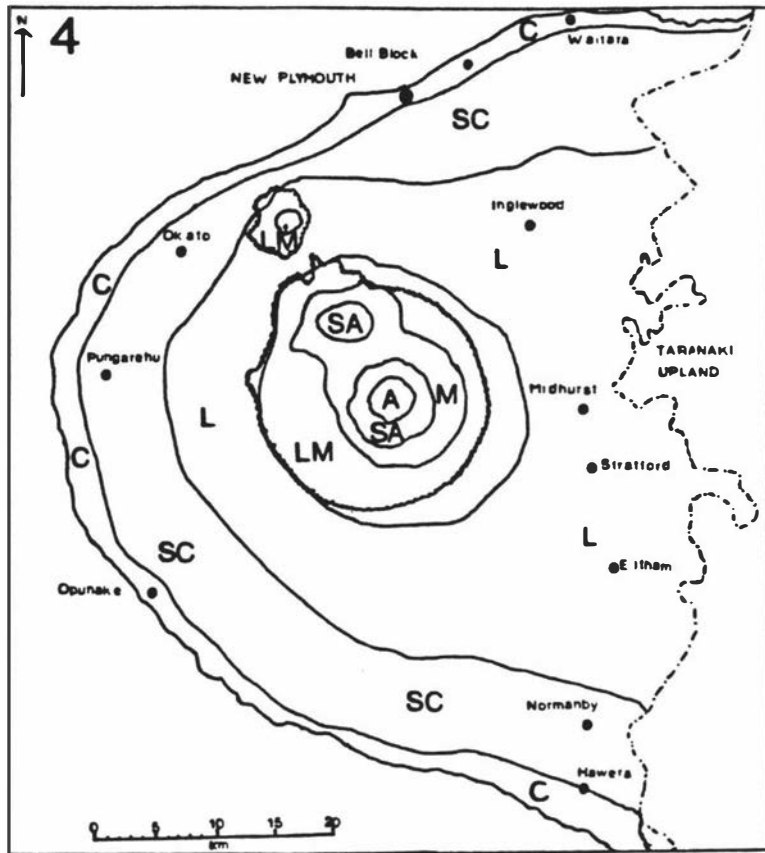
considerable part of the eastern lowlands. Two have been described. Standish (1984) quotes early accounts of Eltham swamp and Every (1974) recalled details of Ngaere swamp. Two thirds of Eltham swamp was in native bush, chiefly rimu and manuka (Leptospermum scoparium) with niggerhead (Carex secta), toitoi (Cortaderia) and flax in the herb layer. Near the centre were rushes, flax and manuka with "standing silver pine" (Lagarostrobos colensoi) 3 to 6m high. It is not stated whether these trees were alive or not. Logs of silver pine have been recovered in abundance from the swamps but Every states that no European had ever seen living trees of the species in this area. A 1912 photograph (Every 1974) of Ngaere swamp shows many standing dead trees which had died when consolidation occurred following drainage. A ridge of dry land, later named Rawhitiroa, separates Ngaere (1516 ha) from Eltham swamp (1214 ha) 15m below. Native bush containing rimu, matai, totara (Podocarpus totara), pukatea, kahikatea, tawa and many tree ferns formerly occupied the ridge. Second growth after felling produced many stands of poroporo (Solanum aviculare) (Every 1974).

The present extent of indigenous forest and scrubland in the Taranaki region is shown in Fig. 36 (see Volume II) reproduced from D.S.I.R. maps NZMS 1 N108, 109, 118, 119, time of publication between 1976-1981. In the northwest quadrant, centred on Stony (Hangatahua) River, patches of forest have long sinuous shapes orientated between the summit of Mount Egmont and the coast indicating gullies and riverine bush within the numerous debris and pyroclastic flows of Late Holocene times (Neall 1972, Neall and Alloway 1986). There is an almost complete absence of any forest on the western and northern coastal plains. Inglewood, Midhurst and Eltham have few forested areas and

these are either small round patches or riverine bush. In the southwest quadrant it is noticeable that forest remnants have a straight edge usually on at least one side indicating a fence line. Forest covers most of the Egmont National Park (see also Fig.4) and there are some small areas just outside the Park boundary.

1.5.4 Egmont National Park: Within Egmont National Park, lowland forest with emergent rimu and rata persists over an altitudinal zone occupying 3km in width up to 550-570m. Sub-canopy species in this forest include kamahi, fuchsia, pate and wineberry (Aristotelia serrata). Above this level rimu and rata are present but no longer emergent. Kamahi becomes the most common species until it disappears suddenly at 900m. Associated with kamahi in the canopy are tawa, toro (Myrsine salicina) and smaller trees such as mahoe, putaputaweta (Carpodetus serratus), raukawa (Pseudopanax edgerleyi), kaikamako (Pennantia corymbosa) and the shrubs raurekau (Coprosma grandifolia), five finger (Pseudopanax arboreus), and tree ferns. Pate, fuchsia and wineberry persist into this zone also. At 845m Hall's totara (Podocarpus hallii) and kaikawaka (Libocedrus bidwillii) become the canopy species. Broadleaf, fuchsia and (Pseudopanax colensoi) form most of the sub-canopy. At 1140m the vegetation is scrub 2m high, composed largely of leatherwood (Brachyglottis elaeagnifolia) together with Pseudopanax simplex var. sinclairii and P.colensoi a small leaved Coprosma, the nitrogen fixing Coriaria plumosa and ferns of the Blechnum capense group. In the herb layer Pratia angulata, Helichrysum spp. and Ourisia macrophylla var. macrophylla occur. Hebe odora and red tussock (Chionochloa rubra) extend up to 1650m and above this level alpine herbfield becomes increasingly sparse (Druce 1976a). This

FIG 4 BIOCLIMATIC ZONES, TARANAKI, N.I. NEW ZEALAND.



- C COASTAL 1km inland, subject to salt laden winds.
- SC SEMI COASTAL 10km inland to 150m, limit of D.spectabile.
- L LOWLAND FOREST Dominance of Beilschmeidia tawa.
- LM LOWER MONTANE Upper limit tree sized
D.cupressinum about 760m.
- M MONTANE W.racemosa, P.hallii dominant treeline
at 1095m (Mount Egmont).
- SA SUB-ALPINE B.elaegnifolia dominant, shrubline 1280m.
- A ALPINE Tussock, mossfield, herbfield above shrubline.
- SOURCE Bayfield and Benson (1986).

apparent altitudinal zonation is not so distinct on the ground. Species often occur at much lower altitudes than their normal zone distribution, mainly in disturbed areas along river banks, seral vegetation sites and wet margins of swamps. Kaikawaka, for example, is found around the margins of Potaema bog at 670m but it normally occurs above 800m (Clarkson 1977). Kamahi occurs in more than one zone and the abundance of this tree is a reflection of the disturbed environment on Mount Egmont. Other plants are quite rare, of particular interest is Ascarina lucida, an indicator of equable climate (McGlone and Moar 1977).

1.5.5 Factors Affecting Vegetation Patterns.

1.5.5.1 Soil Fertility: Soil fertility contributes to the variety of vegetation patterns on Mount Egmont, which is dependent on age of volcanic parent materials (Neall 1982) and amount of precipitation. It has been found that there is a trend towards a decrease in available magnesium at higher altitudes probably due to increased leaching with greater precipitation (Turner and Neall 1978). In a study of Stratford soils, 70% of potassium applied in fertiliser was lost, in some cases within three months in areas of higher rainfall compared with only 14% in areas of lower rainfall (Thomson 1982). The distribution of tawa appears to be governed by soil fertility, this species reaches an altitudinal limit of 150m on the less fertile soils of the western slopes but on better drained more fertile soils of the southeastern quadrant it can be found up to 750m (McGlone and Neall in litt.). Although forest dominated by this species now covers only 1600ha of Kaitake Range it is thought to have covered most of the ring plain in

former times (Clarkson 1985).

1.5.5.2 Temperature Range and Precipitation: Glacial and post-glacial changes have been commented on in (1.4.1). Temperature range and precipitation also affect present distribution. For example, kamahi which is most abundant on the eastern side of Mount Egmont between 760-840m declining abruptly at 900m, is present down to sea level on the wetter western side (McGlone and Neall in litt). On the Kaitake Range it is dominant on the wetter, cooler and steeper slopes on the inland side of the range. It appears that factors favouring this species are thus higher rainfall, increased humidity, cloudiness and low temperatures (Clarkson 1985). Most of these factors also govern the development of what has been called "Goblin Forest" (Cockayne 1928, Clarkson 1980), largely of kamahi, which occurs on Mount Egmont at an altitude where cloud is frequently present. This belt continues around the mountain except where it has been destroyed in the last few hundred years by volcanic activity (Neall 1979, Neall and Alloway 1986).

1.5.5.3 Volcanic Activity: Clarkson (1981) believed that the lower treeline on Mount Egmont was due to recent eruptions and was not climatically controlled. Early work on Mount St. Helens in Washington State, U.S.A., reported a lowered treeline that advanced steadily upwards over 40 years which was attributed to re-colonisation after an eruptive event and an increasing number of sub-alpine species was also recorded during this period (Lawrence 1938). There are about 460 species found on comparable sites in the North Island which do not occur on Mount Egmont (Druce 1986). This deficiency is mostly among the sub-alpine and alpine species (Druce 1974). Whether this is due solely

to isolation or to recent eruptions cannot be verified. Mount Egmont is more isolated than Mount St. Helens. It is however, just possible that in the 100 years since Buchanan's visit some new plants may have arrived and others may now be more visible.

Increased cover of inaka (Dracophyllum filifolium), which Clarkson (1981) identified as a pre-climax species in leatherwood succession, is attributed to greater instability of Mount Egmont slopes compared to those of the Pouakai Range. The nitrogen fixing species, mountain tutu (Coriaria plumosa) was found by Clarkson (1981) in about 20% of his Egmont sites but was never seen on Pouakai. Other species which emphasise this difference in slope stability are Muehlenbeckia axillaris, Pimelea prostrata and Cyathodes fraserii all pioneer species present on Egmont but absent or insignificant on Pouakai (Clarkson 1977). At sites with an eastern aspect at 1158m on Pouakai, major species such as red tussock, kamahi, kaikawaka, broadleaf, inaka, mountain tauhinu (Cassinia vauvilliersii) and Hebe odora are all found together; such an overlap in distribution never occurs on Egmont (Clarkson 1981). This may represent a long term adjustment of communities at the shrub-tussock interface not yet developed on Mount Egmont. While the comparatively low altitudinal limit of emergent rimu is the same on both Pouakai and Egmont, the kamahi limit is lower on Egmont. This has been attributed by Clarkson (1981) to volcanic action. He found correlation at some sites between a lower altitudinal limit for kamahi with greater depth of Burrell Lapilli.

1.6 DAMAGE TO VEGETATION BY VOLCANIC ACTIVITY

1.6.1 Mount Egmont: No eruptions of Mount Egmont have been observed since European settlement in 1840. It has however, been estimated (Druce 1966) that within the last 450 years about one fifth of the vegetation within Egmont National Park has been destroyed and another fifth damaged by eruptive showers through impact, burial or fire (Druce 1966). The earliest comments on damage came from A.W. Burrell who is quoted as follows, "Old cone shaped kakawa (Libocedrus), totara (Hall's totara) and rimu stumps may be found fully half a mile higher up the slope of Egmont than the living trees are now growing. There are hundreds of dead boles of totara and kawaka standing loosely in holes in the ground (the sap having rotted off) with their lateral roots about twelve inches below the surface under a layer of ash and scoria, the same layers that cover the oven near Stratford Mountain House" (Oliver 1931). Burrell commented further that charcoal could be found in the forests at varying depths up to nine feet.

It has been observed that in the present kamahi forest immense totara trees could still be found, and some large ones near a stream though dead on one side were still alive and bore branches (Oliver 1931). Some short boled kaikawaka and Hall's totara with their root flanges buried by Burrell Lapilli are still alive. At Jackson's Lookout these trees have a maximum altitude of 1067m; elsewhere on the mountain they reach 1200m (Druce 1966). Burrell Ash was believed by Druce to have burnt vegetation on upper and western slopes causing leaf fall, which formed a humic layer he identified as "buried litter" under the cooler Burrell Lapilli. Manuka within the forest and fuchsia on the

interfluves, both seral species, were attributed to opening up of the canopy by the impact of Burrell Lapilli, which stripped leaves and branches (Druce 1966).

Carbonised logs, a feature which occurs only when oxygen is limited by partial burial (Waitt 1981), have been found associated with the earlier Newall tephra and under "Newall alluvium" (Druce 1966). Druce considered that the Newall shower, which he compared to a directed blast similar to that described by Loomis (1926), caused fires which destroyed all vegetation on the upper slopes "down to 1067m on Fantham's Peak". Vegetation was burned up to 10km from the summit over a 90° arc from the Okahu Stream to Ahukawakawa swamp. This shower had a low trajectory component which was directed down Stony River. The directed blast during the eruption of Mount St. Helens in 1980 devastated extensive areas of coniferous forests, caused charring of logs and some log piles smouldered under the ash, but there is no record of widespread fires (Waitt 1981).

It may be difficult after 350 years to differentiate between cause and effect on these Newall sites as they have been disturbed by the more recent of the Maero Debris Flows described by Neall (1979). Two of these Maero flows have now been recognised as pyroclastic flows because of the palaeomagnetic alignment of the clasts within the flow. One of them (Unit 1A) has been dated <250 yr B.P. Within an area of old kamahi forest on the Puniho track, 100 year old trees have been felled by a pyroclastic flow. Many have continued to grow, and several trunks have developed from an original tree. This area was thought by Druce (1966) to have been destroyed by a debris flow and he records a

photograph of a large rock debris fan taken by H.M.Skeet in 1898 about 1500m north of Kahui Hut which shows only very sparse vegetation. Areas of mossy herbfield and scrub near the upper tree limit which are dominated by manuka are thought to be due to debris flows which have depressed the treeline (Clarkson 1980).

1.6.2 Mount Tarawera: The only large scale eruption to have occurred in European times in New Zealand was of Mount Tarawera in central North Island in 1886 A.D. This eruption had an unusual feature in that the floor of Lake Rotomahana was erupted covering surrounding land with mud. It is therefore not entirely comparable to any event on Mount Egmont. Destruction of forests was still evident when Burke (1964) made a study of re-vegetation. Only one small patch of forest above the present treeline survived the eruption and deposition of up to 1080mm of ash. Surviving trees have some or all of the following features; trunks continuing below and above ground with no change in diameter, trunks broken and rotted for at least part of their length, crowns shrubby with many broken branches and scars.

1.6.3 Central Volcanic Plateau: The effects of some eruptions in the Rotorua district have been totally destructive close to vents due to blasts and glowing avalanches (Vucetich and Pullar 1964). After the Taupo eruption (1819 \pm 70 yr B.P. Pullar and Birrell 1973) vegetation recovery was good due to survival of pockets of vegetation in the hills. Present distribution of forests in Tongariro National Park is thought to be largely due to this eruption which destroyed two thirds of the park area leaving only the beech forests on the western side of Ruapehu unaffected (Atkinson 1974). Three large volcanoes of the

central volcanic plateau, Tongariro, Ngauruhoe and Ruapehu, have all erupted intermittently over the last few decades. Lava, volcanic blocks, ash and hot gas-charged ash clouds have all been erupted. Since 1861 A.D. more than 17 steam eruptions and 4 ash eruptions have been recorded from Mount Ruapehu and at least 12 lahars and floods have been generated in the Whangaehu Valley. These volcanoes are all over 1900m and so mostly alpine and sub-alpine vegetation has been damaged by these recent eruptions.

1.6.4 White Island: White Island is an andesitic volcano which has been continuously but variously active throughout recorded history. It lies 45km offshore to the northeast of Whakatane and covers 260ha. Distribution of forest there is regarded by Hamilton and Baumgart (1959) as being governed by topography of the crater rim and the direction of the wind which transports toxic fumes of hydrochloric and sulphuric acid. The forest is unique in that it contains only one tree species pohutukawa (Metrosideros excelsa). The fern Histiopteris incisa and flax (P.tenax) occur very occasionally as the only other species in the forest. A grass-herb complex is related to nesting of gannets and burrowing of petrels (Hamilton and Baumgart 1959).

1.6.5 Tristan da Cunha: Observation of eruptions from other volcanic areas of the world supply evidence of damage as it occurred. Toxic fumes similar to those from White Island caused variable amounts of damage to vegetation of Tristan da Cunha during the 1961 eruption (Dickson 1965). Margins and tips of New Zealand flax (P.tenax) which had been introduced for shelter belts and thatching, were burnt by fumes but survived. Ferns of the Blechnum genus, which also has many species in

New Zealand, survived despite damage to fronds. Small, widely spaced fires were started by hot volcanic blocks but were soon extinguished by heavy rain and falling ash. Wind and rain redeposited ash into hollows and so there were only minor effects from the 60mm of ash (Dickson 1965).

1.6.6 Katmai and Irazu: During the 1912 eruption of Mount Katmai, in Alaska, fine ash, which had absorbed toxic fumes, and acid rain were carried for long distances. Eye witness accounts stated that leaves of garden plants at LaTouche 480km northeast of Katmai, were burnt by acid rain and subsequently fell off (Griggs 1922). The affinity of hydrochloric and sulphuric acids for water is so great that fumes will be absorbed during periods of high humidity without actual precipitation (Blong 1984). At Irazu in Costa Rica the most severe damage occurred when acid-bearing ash particles fell during the night, subsequently dissolved in dew, which later evaporated and left a concentration of acid salts on the foliage (Miller 1966).

1.6.7 Paricutin: Hot lava flows, which overwhelmed forests during an eruption of El Paricutin, Mexico, did not always set trees alight. As lava cooled, the crust insulated trees from the intense heat (Eggler 1948). They could be bent over and even buried but unless they were crushed as well they could survive. Direct correlation between depth of ash and survival was apparent but a more important factor was continuity of deposition. Plants were better able to survive intermittent fallout as they could recover in between. Wind direction was therefore also important in the severity of damage received. The grass Cynodon dactylon grew throughout the eruptions and survived

deposition of up to 381mm of ash, but under 508mm of ash this grass only survived if near a root stump. Cynodon rhizomes were traced back to the original surface. Pteridium aquilinum had sometimes grown throughout the deposition of 600mm of ash or had resprouted from the base. The greatest depth of ash was 6780mm and even under this some oak trees still had one living branch (Eggler 1948).

1.6.8 Mount St. Helens: Mount St. Helens, in the Cascade Range of Washington State, erupted on May 18 1980. The event and its aftermath have been well documented and detailed descriptions are available of all aspects of the event. Initially an earthquake fractured the upper cone, causing the collapse of the northern flank. This released the internal pressure and a large directed hot blast travelled very quickly to the north and northwest before the air resistance caused the flow to lift off the surface (Keiffer 1981). The temperature at the vent was 327°C and only 20°C less at the edge of the blast zone (Winner and Casadevall 1981). Trees were charred where they were not protected by earlier falls of ash but they were not carbonised. Within the blast zone trees were pulled apart leaving splintered stumps which were subsequently abraded by fast-moving flow particles (Waitt Jr. 1981). Most tree debris was carried out of the blast zone entirely. Some of it reached high altitudes and wood, cones and small branches up to 406mm long were deposited on Mount Adams 55km away to the east while charred twigs 25mm long and coated with ash fell on Mount Rainier 80km distant to the north (Rosenbaum and Waitt 1981). In the blow-down area the direction and fall of trees was to a certain extent topographically controlled. Beyond this zone a gradually ascending scorch zone indicated where the flow had lifted off the ground (Kieffer 1981). Ash from the

eruptive cloud was found to be of dacitic composition, had a pH of 5.7 and was not toxic in water supplies (Federal Co-ordinating Office 1980) or to crops (Gough et al 1981).

1.6.9 Summary of Effects of Volcanic Activity: Scarcely any two eruptions are the same and effects on vegetation are characterised by their random nature as so many variables are involved. From the foregoing accounts it is however, possible to make some generalisations.

1. A directed hot blast does not always set forest on fire.
2. Widespread fire is rare during an eruption.
3. Only a nuée ardente type of eruption appears to cause fires.
4. Carbonisation of logs requires both fire and burial.
5. Toxic fumes and acid rain are very destructive of aerial parts of plants.
6. Underground rootstocks or rhizomes have survival value.
7. Continuity of ash fallout is an important factor in the survival or death of plants.
8. Unless there is a great depth of ash these falls appear to do little harm and can be beneficial.
9. Depth of ash is an important factor but the response varies with the structure of a plant species.
10. Chance plays a large role in both damage and recovery of vegetation both during and after an eruption.

1.7 RECOVERY OF VEGETATION AFTER ERUPTIONS

1.7.1 Mount Tarawera: Vegetation recovery from large volcanic eruptions in New Zealand has only been seen by Europeans on Mount Tarawera. Recorded observations of travellers on the recovery of the forests soon after the Mount Tarawera eruption in 1886 tend to lack detail but are nevertheless valuable. These accounts were reviewed by Nicholls (1959) in which he quoted Thomas (1888) noting that small trees recovered by the following summer and at Mount Edgecumbe 24km away, large trees in an area covered by 355mm of ash had not been harmed. Turner (1928) recalled "Nothing but a sea of mud at first but four years later full recovery". Other reports mentioned that, large trees which had been defoliated and lost small branches, recovered within a year. Bracken emerged through 600mm of ash and then provided sites at which shrubs became established.

Much later, Burke (1964) examined recovery in one crater and the Plateau Dome in the vicinity of the 1886 vents. Within this crater only the nitrogen fixing species Coriaria arborea was established on loose pumiceous tephra. In the devastated area near the chasm, stabilisation of the sterile surface was largely due to the efficiency of Muehlenbeckia axillaris in binding loose material. Leucopogon fraserii was not quite so effective but colonisation by both these species allowed mosses to establish. The lichen Stereocaulon, the moss Rhacomitrium and the herb Raoulia trapped airborne particles within the mass of their living tissue, thus adding to the bulk, weight and stability of the plants. Ring growth patterns were abundant everywhere, particularly of a grass/herb/lichen complex. Establishment of shrubs was

slow. Of those measured, manuka was only 23 years old, whilst kamahi had an age of 68, indicating it must have started to grow within ten years of the eruption. Where tephra had been subsequently rilled or channelled by heavy rain Rhacomitrium was growing on the floor of the channel allowing Gaultheria oppositifolia and Dracophyllum subulatum to occupy the more stable sides. Cockayne (1919) included a photograph of Coriaria sarmentosa growing within channels in a deep layer of ash. Another photograph (see Frontispiece) shows a great depth of ash scooped out by wind and rain to such a degree that clumps of toitoi (Cortaderia fulvida) nearly two metres high, were contained therein. Cockayne commented that this species was not very common in the vicinity. Like most Tarawera colonists it had come from the immediate neighbourhood and had merely extended its range. Raoulia had been particularly successful in this respect (Cockayne 1919).

The recently established forests on Mount Tarawera where kamahi is dominant were considered by Clarkson (1981) to indicate seral recovery. The upper margin presently contains kamahi, Olearia, Gaultheria and Coprosma. Lower down the volcano kamahi had emerged over once dominant Olearia and Coriaria arborea which are now in decline. The lowest slopes have kamahi which was damaged but survived the eruption and have since resprouted and quickly resumed dominance. Within two small surviving forest remnants above the present treeline, Burke (1964) noted the ability of kamahi to survive damage and burial. Branches sprouted often from a very small amount of living tissue remaining in the broken trunk. "Apparent roots" extended over the new surface from which sucker shoots had later emerged. Dense mats of post-eruption epiphytes became established on damaged and rotting parts of the

trunks. Below these mats large numbers of adventitious roots about one inch long had grown from the trunk. Burke (1974) later studied regeneration of podocarps in this area. Rimu, Hall's totara, matai and toatoa (Phyllocladus glaucus) regenerated in the vicinity of surviving trees, but kahikatea, miro and totara had dispersed seed as far as 4.0, 4.8, and 4.8 km respectively. Hall's totara, and toatoa started regenerating after 25 years, kahikatea took 50 years. Hall's totara had regenerated prolifically, especially near surviving trees where the youngest members occurred closest to the parent tree, and the oldest up to 50m away (Burke 1974). It had been noted previously by Nicholls (1964) that an abnormally high number of Hall's totara had established on a generally deep, skeletal to gravelly soil after the Kaharoa eruption (665 \pm 58 yr B.P. Lawlor 1980). On the new 1886 A.D. surface, soil development and quantity of nutrients was greatest under kamahi forest. Soil was less well developed where kamahi and mangaeo (Litsea calicaris) were dominant and absent entirely under tawa/mangaeo forest. Nutrient values were higher under manuka than under grass/lichen/herb ring patterns. Values for nitrogen were twice as high if Coriaria arborea was among the species present (Burke 1964).

1.7.2 The Pioneering role of Coriaria: The pioneering role of Coriaria in colonisation has been noted by many workers and nodulation of the roots of this genus investigated (Bond 1958, Harris and Morrison 1958, Morrison and Harris 1959). All New Zealand species and some hybrids were found to be nodulated by Burke (1963). In his 1981 study Clarkson discussed the role of Coriaria plumosa as a successional species on Mount Egmont and contrasts this with its absence from older more stable slopes of Pouakai. Part of a study by Neall (1973) included an

investigation of moss and scrub ecosystems on Mount Egmont. Examining mossfield at 1200m in detail he found C.plumosa to have a key influence at a particular seral stage. The moss Rhacomitrium lanuginosum was the prime coloniser, but in sheltered sites, circular patches of C.plumosa together with leatherwood, Hebe, red tussock and inaka could occur. When C.plumosa was present, growth of other species was notably enhanced. Egunjobi (1969a) in a study of secondary successions involving gorse (Ulex europaeus) found that leaves and stems contain more nitrogen than roots. It was suggested that nitrogen fixed in root nodules was rapidly translocated to aerial parts but returned to the soil in the autumnal leaf-fall. Thus nutrients were not immobilised in the plant but recycled rapidly. He further found that under woodland, two thirds of elements removed from soil were returned in leaf litter (Egunjobi 1969b). Neall (1973) found that even when dead, moss mats of Rhacomitrium provided a useful rooting medium for establishment of higher plants but had low availability of cations. When C.plumosa was present a clear thin A horizon developed and the amount of exchangeable cations was increased. Although actual quantities of nitrogen and phosphorus were low, values were higher under Coriaria. He quoted findings of Johnston (1969) on the ability of some organic acids to extract phosphorus and suggested that similar acids might be released from Coriaria species which enable them to extract phosphorus from andesite.

1.7.3 Tristan da Cunha Eruptions: The paucity of first hand observations and initial recovery stages after eruptions in New Zealand can be supplemented by overseas information. In the 1961 eruption on Tristan da Cunha the dominant tree Phyllica arborea was killed by toxic fumes and did not resprout from adventitious shoots or root structures. Seedlings did however, come through the ash near the bases of dead trees. Such plants as Rumex sp which had undamaged rhizomes and grass of the Cynodon genus which grew throughout the eruption soon covered new volcanic deposits. Nearly all damaged plants of the dwarf tree fern Blechnum palmiforme were producing fronds within a year. Furrowing of ash caused by heavy rain provided suitable sites for colonisation (Dickson 1965).

1.7.4 Paricutin Eruption: On the volcano Paricutin in Mexico seedlings were growing two and a half years after the eruption where recently erupted ash had been eroded to exhume the original soil surface. Thus indicating the viability of the seeds in the buried soil. Nevertheless where the depth of ash was 50mm or more seeds failed to germinate and this was probably due to a lack of oxygen (Eggler 1948).

1.7.5 Surtsey Eruption: Detailed records of the island of Surtsey which formed in 1963 off the south coast of Iceland, provide further information about primary colonisation of a sterile surface. In contrast to mainland lava flows, where lichens are the first plants to appear, lichens on Surtsey were only seen in 1970, but the first moss Funaria hygrometrica appeared in 1967. Two species of Rhacomitrium became the most common mosses and the preferred habitat of both was a moist, shaded hollow with some sand present. Establishment of higher

plants was directly related to the supply of organic matter; in this case usually dead seabirds washed up on the beach (Fridriksson 1975).

1.7.6 Mount St. Helens.

1.7.6.1 Introduction: Different phases of this 1980 eruption deposited a variety of volcaniclastics over a range of ecosystems and altitudes. Critical factors that emerge from all these studies are 1) the large part played by chance in the survival of individual plants, 2) the creation of microsites and 3) the reservoir of life in the original soil. Frequently fallen logs provided microsites which acted as refugia, from which survivors initiated recovery during the first two growing seasons.

1.7.6.2 Flow Deposits: Rock avalanche and pyroclastic flow deposits, where original soil had been buried under 10-200m of debris, contained within them organic material and living plants scraped off the mountainside during transit. Mudflows also contained much vegetative debris capable of resprouting (Means et al 1982, del Moral 1983). On the Muddy River mudflow, of 108 species found, most occurred in stump bases, rootstocks, soil clumps, buried soil and log jams carried in the flow. Reworking of flows was destructive in that new growth was damaged, or removed but constructive in that new sites and sources were uncovered. The role of fallen logs in providing shade, organic matter and nutrients, in stabilising surfaces and protecting seedlings, was crucial to initial recovery of the flows. Later the arrival of propagules from outside the immediate area led to a diversity of seral stages. Density of seedlings declined with increasing distance from the forest edge and

was negligible beyond 200-250m, though this varied from species to species (Halpern and Harmon 1982).

The element of chance in both proximity of a seed source and favourable microsites continued to determine the recovery of mudflows beyond the initial stages. At Kautz Creek in Mount Rainier National Park, plant succession has been surveyed at 9, 16 and 33 years after an event in 1947. Seral stages were directly related to abundance of standing dead trees in the vicinity, which had influenced recovery of vegetation 1) by providing seed 2) as a moderating influence on soil temperature and moisture and 3) as a source of nutrients from accumulated litter. Also the dense mat of Rhacomitrium canescens and Stereocaulon sp. which covered most of the open surface of the mudflow was inhibited by overstorey litter. Crevices filled with litter provided prime sites for establishment of tree seedlings (Frézenⁿ et al in print).

1.7.6.3 Sub-Alpine Zone: On the surface of cold mudflows in the sub-alpine zone of Mount St. Helens only a few residual survivors were present and there were no seedlings in 1981. Flows were deficient in nitrogen, phosphorus and cations. Where severe erosion had exposed the original surface, several species were seen. Some rootstocks of the nitrogen fixing species Lupinus lepidus and the grass Agrostis diegoines were washed down and deposited on the surface of the flows. These plants flowered in 1981 and could be important in the continuing revegetation process. Vegetation in one area of the sub-alpine zone did survive the deposition of 60-80mm of coarse tephra and many species emerged from beneath the tephra later in 1980 (del Morel 1983).

1.7.6.4 Forest Zone: A study conducted in old forests outside the blast zone found that tephra 23mm deep had no effect on vascular plants, and reduced Bryophyte cover for only two years, yet tephra 45mm deep destroyed all Bryophytes. Refugia with thin tephra cover, such as in microsites under logs were vital to the survival of some plants, particularly Bryophytes. Deciduous herbs damaged by 45mm of tephra, recovered by 1982 but some evergreen species did not. At two sites with 150mm of tephra, almost all herbs were eliminated except in microsites where tephra was thinner (Antos and Zobel 1985c).

Burial by tephra causes change in soil temperature, aeration and chemical composition. Plant survival depends on ability to tolerate these changes and also to extend roots into the tephric layer. Eight species of conifer under 100-200mm of tephra "containing fine to very coarse layers" were found to have developed adventitious roots in tephra by 1981 (Zobel and Antos 1982). Of 28 shrub species examined, all had produced adventitious roots in tephra layers of 50-200mm and all the herbaceous plants, except bulbous Liliaceae, out of 109 examined had moved perennating buds into the tephra although the methods used varied from species to species. (Antos and Zobel 1985a and b). Laboratory trials of tree seedling establishment on ash showed that while the seed germinated, the radicles were unable to penetrate the ash once it had been wetted. They grew horizontally and then withered (Radwan and Campbell 1981). Field trials with conifer seed showed that seed loss during winter was up to 50% by rodent predation and surface wash. On tephra which had been "cultivated" by the experimenters, the majority of seeds in crevices were established but in undisturbed tephra, radicles were unable to penetrate hardened ash (Frézen and

Franklin 1985).

1.7.6.5 Establishment of Fungi: The recovery of an ecosystem depends on more than the easily-seen vascular plants. Carpenter et al (1982) investigated colonisation of Mount St. Helens 1980 tephra by fungi and found both sexual and asexual stages of Anthracaulia melaloma present within 20 days of the eruption. By July 1981 both Penicillin and Aspergillus were found. Here again erosion of the tephra was important in exposing original buried surfaces from which fungal colonisation of tephra could proceed. Carbonicolous Ascomycetes, normally found on burned soils were the primary colonisers. Establishment of Endogonaceae which form saprophytic and mycorrhizal associations with forest species in sterile tephra, were found by Allen et al (1984) to be enhanced by the mixing of old soil and tephra by gophers (Thomomys talpoides) and by ants in all areas except on the sterile plain formed by pumiceous pyroclastic flows.

1.7.6.6 Effect of Snow Cover: The presence or absence of a snowpack had significant though different effects in different areas. In the sub-alpine zone, plants on the edge of the blast zone protected by snow, received little tephra because they were so close to the vent. Vegetation in this area was normal in September of 1981 (del Moral 1983). In forests at 1100-1300m, snowpack is usually between 2-5m. The snow is wet, due largely to the maritime climate and melts from the base. Shrubs and small trees are normally flattened by the weight of snow, but once it has all melted they resume an upright position. Where tephra fell on snow-covered sites it eventually reached the ground after snow melt as a wet sticky mass. Leaves were often pinned to the

ground by tephra, and shrubs were unable to regain their upright habit. Shoots of fine branches buried by ash died back from their tips. After the eruption vegetative cover on snow-covered sites was only 1.6%, but on sites free of snow at the time of tephra deposition, cover was 15.4%. In snowfree areas tephra fell through upright shrubs and tree seedlings and no damage was done even though depths of tephra at the sites examined was 45 and 150mm (Antos and Zobel 1982). In the directed blast zone where trees were blown down the snow gave some protection to the forest floor and the resultant vegetative cover was 3.3% compared with only 0.6% in those areas without snow (Means et al 1981).

1.7.7 Beneficial effects of ash: Beneficial effects of minor ash fallout has been mentioned by many authors. In New Zealand, Vucetich and Pullar (1964) noted the fertilising effect of ash fallout. When ignimbrite is covered by ash, the ash enhances colonisation by plants and protects against erosion. The harmless nature of the ashfall from Mount St Helens has been mentioned previously, and an actual increase in the yield of some wheat crops is recorded (Gough et al 1981). Another Mount St Helens study examined increment data on height growth and lateral branch elongation of conifer saplings showered by tephra. An early thin silty deposit fell wet and adhered to foliage. Tree crowns of Abies sp. accumulated between 0.7-1.0g/cm² on exposed branches. A thicker deposit of coarse pumice and rock fragments which fell later was not retained by the trees. Some trees were subsequently cleaned of tephra by brushing and their growth compared with uncleaned trees. With the exception of Abies, all trees of all species showed a significant increase after the eruption. This was attributed to an

unknown beneficial effect of the tephra on the soil, which more than overcame any adverse effect of the tephra on the foliage. The two species of Abies in the test trapped more tephra than any other species. The effect of cleaning the trees was therefore greater and there was a significant increase in height growth in the cleaned over the uncleaned trees of this species (Zobel and Antos 1985).

1.7.8 Summary of Recovery after Volcanic Activity:

1. Variables which can affect survival include; distance from vent, wind direction and continuity, presence or absence of rain or snow (all have some advantages), particle size, depth, chemical composition and temperature of the tephra.
2. Erosion and redeposition of mudflows and tephra can expose original soil and disturb crusts formed on tephra which may inhibit radicle penetration.
3. Entrainment of plant debris, which is capable of rooting, resprouting or vegetative propagation, within a mudflow, initiates recovery in a very short time.
4. The reservoir of propagules in original soil can survive limited burial and directed blasts.
5. Addition of organic matter to a sterile surface, such as by autumnal leaf-fall, can assist seedling survival.
6. Abilities of plants to recover from regular adverse changes; dormancy, tolerance to fire, burial and high light intensity; all have survival value after an eruption.
7. Nitrogen fixing species (Coriaria in New Zealand) are pioneers in the succession.

8. Some vegetative structures minimise damage, springy branches may allow tephra to fall through. Others, such as rhizomes can resprout after severe foliar damage by acid rain.
9. Ash may have beneficial action as a fertiliser.

1.8 MAORI OCCUPATION

1.8.1 Historical: Occupation layers identified on the basis of the following criteria were described by Wellman (1962) in a study of North Island, Holocene coastal sites. Arranged in order of decreasing abundance and increasing diagnostic value they are:- darkening of soils due to finely divided charcoal, visible charcoal fragments, shells of edible molluscs, scattered burnt stones, ovens (umu), usually with associated charcoal, shells and the bones of mammals and birds usually burnt and broken. The oldest cultural charcoal giving evidence of earliest human occupation in New Zealand has been found above the Taupo Pumice and below the Loiseles Pumice (McFadgen 1981). The age of the Loiseles Pumice must be < 700 yr B.P. because it overlies the Kaharoa Ash which has been dated at 665 58 yr B.P. (Lawlor 1980).

The actual date of first occupation by Maori people has been and still is a contentious issue. This is compounded by the transient nature of Maori artifacts. Cassels' Waitore site near Patea in Taranaki had the earliest dated collection of artifacts in New Zealand at the time of publication (1979). This fifteenth century assemblage, associated with an outrigger canoe, was found in a small swamp behind the seashore. Layers of peaty clay in sand dunes near the site were examined for fossil pollen during this study but none were

found.

1.8.2 Coastal Settlement 800-1800 A.D.: The generally accepted idea is that Maoris came from tropical islands, possibly the Marquesas, to the northeast of New Zealand between 800-900 yr A.D. (Leach 1974). They had to adjust from a readily available food supply (breadfruit, bananas, coconuts) to a severe food shortage. Until taro (Colocasia antiquorum) and kumara (Ipomoea batatas) were introduced later, the rhizomes of bracken (Pteridium aquilinum) were used. Large numbers of hinau (Elaeocarpus dentatus) and (Beilschmiedia tawa) berries were collected and stored for winter use (Best 1976). Changes in the life style of Maoris who settled at Palliser Bay on the south coast of the North Island have been investigated. Over a period of 500 years both the coastal and forest environment deteriorated due to increased population, exploitation of natural resources and fire (Leach 1981). Signs of poor health and intermittent food shortages have been detected in bones and teeth of human remains at this settlement (Leach 1974). Kumara was the most important of the introduced foods but cultivation was limited to warmer sheltered sites and when stored was subject to mould. Considerable ritual is associated with the planting and harvesting of the crop (Best 1925).

1.8.3 Maori Deforestation: Many fossil pollen sites outside Taranaki contain evidence of deforestation during the period of Maori occupation prior to the arrival of Europeans (McGlone 1983b). The effect of Maori fires is shown in pollen spectra by a fall in the pollen of forest species, a rise in grassland pollen and bracken spores and the persistent presence of fine charcoal in the profile (McGlone

1978c). Bracken land under natural conditions is usually a brief seral stage (Levy 1949) however, continual burning will halt succession and lead to its dominance. It is known that rhizomes of bracken formed a staple part of the diet of Maoris in those parts of the country where growth of kumara was poor and uncertain (Leach 1974).

Deforestation and subsequent changes in settlement patterns have recently been attributed by archaeologists to climatic change (Leach 1974 and Leach 1981). In a review of current literature from many disciplines, McGlone (1983b) has discussed this aspect in full but he discounts this possibility of climatic change being the cause of the large amount of fernland on the coasts. He states that Polynesians were responsible for forest destruction in the areas in which they settled. Most of this was accomplished by fire between 800-600 yr B.P. Areas with low rainfall were totally denuded.

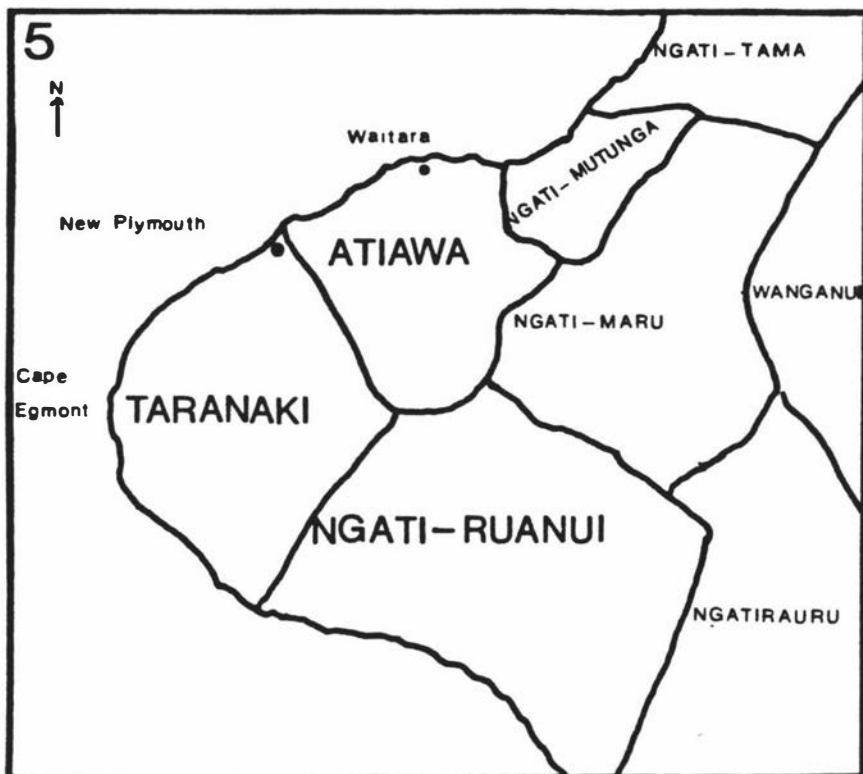
Precipitation in New Zealand is strongly influenced by the high axial ranges of both the North and South Islands, the rainfall being much greater in the western part of the country. It has been argued that, apart from the drier eastern areas of Hawkes Bay and the South Island, it would have been very hard for Polynesians to set the forest on fire. Europeans often found it very difficult to get a good burn-off in the indigenous forests. It is recorded however, that even after 3 days of heavy rain, an unattended camp fire spread through the drier litter below the wet surface (pers. comm. Dr. J.P. Skipworth). McGlone (1983b) also argues that given the right conditions such as a canopy damaged by windthrow, volcanic action or desiccation due to long dry spells, forests will burn. He suggests the Maori would have taken

advantage of any damage to the forests from storms, disease or volcanic activity to create clearings. He stresses that volcanic activity could lead to damage many kilometers from the source of an eruption. Rises in bracken spores and fine charcoal were found after both the Taupo and Kaharoa eruptions which pre-date occupation of the area by Maoris. Lightning discharges from the eruptive cloud could also start fires which would permit undergrowth to dry out under an opened canopy leaving the forest susceptible to later fires.

Recovery after repeated fires in different types of vegetation has been described for a catchment at Taita in the North Island (Druce 1957). Here second growth after fire was largely xerophytic and extremely susceptible to burning. Thus recovery could be extended by subsequent fires and would probably take 70-100 years. Once bracken had formed a dense cover on damp slopes, succession could be inhibited for from 16 to 30 years until a few shade tolerant species such as Pseudopanax, rangiora (Brachyglottis repanda) and hangehange (Geniostoma) penetrated the bracken canopy.

1.8.4 Population Changes: Captain Cook estimated the Maori population of New Zealand in 1770 A.D. at 100,000 this was later revised by Buck to 400,000 (McLintock 1959). Coastal Taranaki had a large population at this time and this is borne out by traces of a large number of open settlements and small pa sites located in the area (Day 1984). Areas occupied by the Taranaki tribes are shown in Fig. 5. By 1845 the Maori population had been reduced to 60,000 (Cumberland 1959). Contact with crews of European vessels introduced diseases which killed more people than all the Waikato raids which followed (Hill 1969).

FIG 5 MAORI TRIBAL AREAS, TARANAKI, N.I. NEW ZEALAND



SOURCE (Percy Smith 1910)

1.8.5 Waikato Raids: North Auckland tribes were first to acquire rifles and used them against the Waikato tribe, who then tried to trade flax mats to obtain rifles for themselves. The best quality and most vigorous flax was found in coastal Taranaki and tribes there were skilled in making flax mats. Waikato Maoris raided Taranaki to acquire slaves and collect tattooed heads (Greenland 1967). By 1831 the few members of the Atiawa tribe left were living on off-shore islands with gardens hidden in the forest (Day 1984). In 1839 the influence of the Methodist Missionaries in the north brought an end to the raids (Hill 1969). At this time F.A. Carrington selected land, for the New Zealand Company, between Ngamotu and Waitara as suitable for settlement due to its flatness, workability and lack of native population. The few remaining Atiawas agreed to sell the land (Hill 1969), but the freeing of slaves and captives by the Waikato meant a return of local Maoris just as the first settlers landed to found New Plymouth. These returning Atiawas disputed land sales. By 1849 Atiawas outnumbered settlers.

1.8.6 Maori Traditions of Volcanic Activity: Although local Maori tribes regarded the upper slopes of Mount Egmont as sacred (tapu), because bodies of important chiefs were buried in clefts on the upper slopes they did visit the lower slopes to gather forest fruits and birds and red ochre from Kokowai Gorge. Many topographical features on the volcano have Maori names. It is surprising therefore that there are few references in Maori oral history to eruptions since they have occurred since Maori occupation. Percy Smith (1908) described a large village, Karaka Tonga, on the northwestern flank of Egmont, which had a council house called kai mirumiru. Oliver (1931) quotes an account given by Stowell (1911) of the burial of this village

which is now thought to be covered by about 500mm of volcaniclastics of the Newall eruption (Rawson 1980). An affray between the Taranaki and Atiawa tribes is associated in oral history with the growth in height of the volcano. It is thought that, during the 1655 A.D. eruptions, a tholoid developed within the crater, which may have increased the height (Neall 1980). There is also one reference to a dark cloud with lightning coming in from the sea and of about 100 people being buried where they stood by sand. This occurred on the western side of the volcano a little to the south of Cape Egmont at Potiki-tawa (Percy Smith 1908). This appears to describe a pyroclastic flow or a lahar following heavy rain, of which there have been many on this side of the mountain (Neall 1973). Maori ovens buried under pumiceous lapilli (Oliver 1931, Topping 1974) on Mount Egmont, have already been mentioned.

1.9 EUROPEAN SETTLEMENT

1.9.1 Land Purchase Problems: The Plymouth Company for Colonisation of New Zealand was formed in Plymouth, England in 1840, just 12 days before the treaty between the British Crown and the Maori people was signed at Waitangi. There was however, some dispute about ownership of land among Maori tribes returning to the district after raids by Waikato tribes. By 1859 63,000 acres had been bought but none of this came from Atiawas in the Waitara area, who resisted land sales and harassed the settlers. Conflict of interests steadily worsened and following a confrontation at Waitara the situation deteriorated resulting in the Taranaki land wars in 1861 which continued until 1869. Those Maori tribes who had opposed the Government had some of their land confiscated after the war (Hill 1969). Although settlement of

these confiscated lands was very desirable, funds were lacking to carry out necessary and expensive surveys required in virgin bush. So the land remained unsettled until 1873 (Wood 1959). A handbook for new settlers published in 1849 by Hursthouse gives a clear picture of the problems of breaking in fernland and the possibilities for agriculture.

1.9.2 ^{THE} Settlement of Inglewood: Development of the Moa Block in Puketapu District now Inglewood, was on land confiscated from Ngatimaru, who occupied Waitara Valley. They were an inland forest-dwelling tribe existing on eels, birds and forest products, who exchanged smoked eels and preserved birds with their close relatives in coastal tribes for mussels and fish (Skinner 1975). Brooks (1892) describes the difficult journey he made with the first settlers to survey the new block. Dense forest commenced about a mile beyond Sentry Hill and the track soon became impassable for drays, and supplies had to be carried by hand. The successful settlement of this area in 1875, despite difficulties in clearing virgin forest, was attributed by Brooks to income derived from work on the railway. The railway commenced at Sentry Hill and was pushed south via Midhurst, Stratford, Ngaere and Eltham; the land being settled for about 5 miles on each side of the track as it progressed.

1.9.3 The Settlement of Eltham: Eltham was associated with the construction of Mountain Road that linked Hawera with Eltham, Stratford and Inglewood from 1873 onwards. It followed the old Maori path, known as Wakaahurangi. Those few Maoris who lived in the area were a sub-tribe of the Ngati Ruanui and they made only temporary settlements on margins of Ngaere and Eltham swamps to collect eels and water fowl. In 1865

Governor Grey had defined a confiscation line which retained better land for European farming and left rough hinterland and the swamps to the Maori. Military campaigns ended in Eltham district in 1869, but real peace did not come until the arrest of Te Whiti in 1881 (Standish 1984). Farms and ten acre blocks were established on the spur of dry land between the two swamps which was later known as Rawhitiroa (Every 1974).

Although a few Europeans arrived from the south about 1870, it was 1884 before settlers began to arrive in numbers. The whole area was densely wooded with excellent stands of tree rata and podocarps particularly kahikatea. Heartwood of matai was used for sleepers on the railway. Although dairy farming was developing, sawmills were very important and provided the essential cash flow. Butter box manufacturing provided an industry until supplies of kahikatea were exhausted in 1913. Milling finally ceased in 1975 when there was no more local timber (Standish 1984).

1.9.4 The Settlement of Warea: On the west coast at Warea, despite its proximity to the original settlement of New Plymouth and suitability of the land for farming, the deeply rooted feeling for the land of the returning Taranaki tribes delayed settlement for many years. The missionary Riemenschneider set up his station in 1846 and negotiations for land were first discussed in 1852, but it was not until 1881 that the area was peaceful enough for settlement (Day 1984). In 1888 a flax mill on Stent Road began operating and later there were two others. Settlement was not confined to the coastal plain. Farms were also opened up inland of the Main South Road which was at that time in "heavy bush"

(Day 1984).

1.9.5 European Deforestation: All accounts of European settlement have the common factors of exploiting the natural resources (timber or flax) and destruction of the forest. On the west coast this had some disastrous results. Burgess, in a paper written in 1901 stated that about 22 years previously, in forest clearings Maoris grew melons, maize, tobacco, kumaras and other tender plants, while in abandoned clearings old but healthy peach trees flourished. New settlers supposed that the climate suited these crops but removal of the forest and the shelter it had provided meant exposure to gales and salt laden winds. Heaphy had earlier advised "...it would, however, be a matter of providence in the settler, for several seasons, to leave a belt of forest round his section, should he have chosen to clear it near the coast" (Heaphy 1842). Burgess stated in 1901 "...the climate seemed to get worse every year." He went on to describe two severe storms which extensively damaged shelter belts which had now become necessary. Eucalyptus, Macrocarpa and Pinus radiata were felled by wind. Only Pinus maritima, cabbage tree and flax survived. Thousands of fruit trees were destroyed. "In two years peaches became extinct." (Burgess 1901) (This is an early reference to Pinus which is not indigenous to New Zealand.)

1.9.6 Introduction of Exotic Fauna: European settlement was followed by the introduction of exotic mammals into an environment previously free of them. Farmers tended to let cattle roam into the forest when feed was short. They introduced goats to clear rougher land. Inevitably some escaped due to poor fencing. Hares and rabbits were released to

supplement the food supply. Without natural predators these multiplied and soon came to threaten new grasslands. Stoats and weagels were then introduced to reduce the rabbits but they often ate eggs of ground nesting birds. Acclimatisation societies wished to establish a fur trade and introduced the Australian Brush-tailed Opossum (Trichosurus vulpecula). While these animals are not a pest in their own country due to forest fires controlling the population, in New Zealand opossums rapidly increased and caused great damage to canopies of native forest trees, especially tree rata (Howard 1966). Although the kiore or polynesian rat Rattus exulans had been in New Zealand since 1034 A.D. or earlier, it was the introduction of the ship rat Rattus rattus and Norway rat Rattus norvegicus together with the house mouse Mus musculus that affected the forests by eating tree seeds and eggs of ground nesting birds (Daniel 1974). Egmont National Park is at present free of deer, because most introductions were made into central North Island. Goats were introduced directly to the area in 1907 and 1909 by farmers. By 1930 they were causing extensive damage within the Park and an annual eradication programme is still conducted by the N.Z. Forest Service. Trapping and poisoning of opossums is also necessary. Stoats are established and hares live in the tussock and sub-alpine vegetation. Hares and rabbits are not yet a problem as their populations are still small. Earlier this century domestic stock numbers in the Park were high due to lack of good fencing, but this has now been improved (Mawhinney 1980).

1.9.7 Egmont National Park: The snow capped volcano encouraged many to attempt to conquer the peak, the first of these being Dieffenbach in 1839. Routes to the summit were explored from all sides and accommodation houses soon became established. As farm settlement advanced closer to the volcano the more astute settlers realised the necessity for continued forest protection of the slopes. Eventually the volcano was protected by the Egmont National Park Act of 1900 (Scanlan 1961). Until the discovery of pumiceous lapilli in the forks of living trees, (Burrell in Oliver 1931) the settlers considered the volcano to be extinct. Although they noted severe earthquakes in 1848, 1854 and 1855 (Wells 1878) they do not appear to have associated any of these with volcanic activity. Wells did note that after the 1854 shock at 8pm on January 1st. " a remarkable round cloud, which sent out a long tail like a streamer, hovered near the peak of the mountain". A record of rumblings and rainfall during the 1880s, kept by the post-master at Opunake is quoted by Neall (1973) who attributed them to distant debris flows, there is now unpublished evidence that these may have been hot pyroclastic flows or blasts (Neall and Alloway 1986). The tourist potential had been appreciated from the very first meeting of the Park Board in 1900 (Scanlan 1961), but it was not until the eruption of Mount St. Helens in Washington State, U.S.A. in 1980 that serious consideration has been given to volcanic hazards associated with the volcano. A scenario of the possible effects from an eruption of Mount Egmont has been made by Neall (in litt. 1981c).

1.10 PALYNOLOGY

1.10.1 Historical: Analysis of fossil pollen in peat deposits stemmed from early research in Sweden that related changes in peat macrofossils to changes in climate. About the turn of the century von Post realised that percentage data would give a much better representation of fossil sites than raw counts of pollen, but this work was not published in English until 1944. The foundations of pollen morphology were laid by Wodehouse (1934) and Erdtman (1952). This was followed later by the standard work on extraction techniques, nomenclature and interpretation by Faegri and Iversen (1975). The pollen atlas for the New Zealand flora is still in preparation (Moar 1981), but Cranwell has described the southern beeches (Nothofagus), the Podocarpaceae and the New Zealand monocotyledons (1939, 1940, 1953). She also produced a key to the New Zealand pollen taxa but this is not now used (Cranwell 1942). More detailed studies of Nothofagus have been made by Harris (1956a & b) and of the Podocarpaceae, Phyllocladus, Agathis and Libocedrus by Pocknall (1981a, b, c). Pollen of dicotyledons so far described include the Hydrocotyle and Callitriche genera (Moar 1960a & b), the Myrtaceae (McIntyre 1963), the Epacridaceae (McGlone 1978a & b) and the root parasite Dactylanthus (MacPhail and Mildenhall 1980). The spores of the New Zealand Pteridophyta have been examined by Harris (1955).

1.10.2 Development of Technique.

1.10.2.1 Representation of Vegetation: Early palynological studies were conducted primarily from a geological viewpoint to define the chronology of climatic change. Development of Quaternary palynology in the British Isles from the early 1920's to 1967 has been recounted by Godwin (1968). This covered the many diverse fields in which pollen analysis had been applied during that period. Since that time many advances in the basic analytical procedures have been made as new technology became available. A common assumption that the proportion of fossil pollen had a direct relationship with the same taxa in the field began to be questioned by Davis and Goodlett (1960). So Davis (1963) defined an R factor which related these two values based on studies of pollen rain and field vegetation. The validity of the R factor was first examined in New Zealand by Pocknall (1978), who found that when modern pollen rain from six localities near Harihari, South Westland was examined, the extreme values of some genera made the concept difficult to apply. For example R values for Coprosma were found to range from 2.4 to 210 (Table 1). He also found that proximity of other trees and vegetation structure influenced R values of rimu. Under a closed canopy where air circulation was reduced pollen falls close to the tree. Under these conditions rimu is over represented and has an R value of 1.9. At sites where logging had opened up the canopy or grazing by goats has removed the under story the R values were 0.7 indicating under-representation. It appears however, that the concept may have some relevance when the vegetational data are collected from a very large area as was found in eastern Canada (Livingstone 1968) and in Michigan (Thompson Webb III 1974).

1.10.2.2 Data Analysis: With conventional sampling methods the possibility of statistical errors has been considered by Faegri and Ottestad (1948) and they recommended the retention of the entire sample column so that re-sampling of a monolith is possible if a check is required. Judging the significance of change in taxa from one sample to another had been rather subjective, but a statistical method has been derived by Mosimann (1965) which compares the significance of percentage values in adjacent samples within pre-set confidence limits; overlap between these confidence limits indicates that taxa have come from the same population. Significant differences in pollen taxa percentages can now be objectively identified. Computer technology has made handling of large amounts of data possible. Computer programs compiled in Australia cover pollen analysis (Dale and Walker 1970), a retrieval system based on pollen grain morphology (Dodson 1972) and comparison of profiles from different sampling cores (Raine 1974). Specific analysis problems such as the ecological significance of recurrent groups of pollen and spores in Quaternary New Zealand samples can now be studied (Harris and Norris 1971).

1.10.2.3 Absolute Pollen Counts: The disadvantage of percentage data is the complementary rise and fall of taxa, a problem that can be overcome only by using "absolute" pollen counts which generate a large amount of data. The accuracy of the term "absolute" is disputed by Colinvaux (1978) and the term concentration is more accurate. As early as 1962 it was suggested that the addition of a known quantity of exotic pollen to a measured amount of sample would produce a ratio that could be related to the actual number of pollen grains (Benninghoff 1962). Tablets containing a specified number of Lycopodium clavatum

spores within statistical limits were produced for this technique in Sweden (Stockmarr 1971). A Lycopodium spores technique has been used to estimate the duration of short term volcanic eruptions of Mount Mazama in the Cascade Range, U.S.A. (Mehring et al 1977). Another version of this method used a suspension of fresh Nyasa sylvatica pollen in glycerine, the concentration being determined by a haemocytometer. A known amount of the suspension was then added to a known amount of the sample (Matthews 1969). An alternative approach is to suspend the entire sample in a known volume of liquid from which accurately measured aliquots can be placed on a slide and the entire slide counted. This procedure is repeated and the mean number of each pollen type per slide calculated. Confidence limits can then be set (Davis 1966). Jorgensen (1967) counted all the pollen in very small weighed aliquots of the sample to obtain his absolute pollen counts. Combining concentration data (grains/cm^3) with the rate of deposition gives a sedimentation rate ($\text{gr/cm}^2/\text{yr}$) for pollen now described as "influx" (Birks and Birks 1980, Davis 1969). This method has been widely used in the study of lake sediments.

1.10.3 Problems.

1.10.3.1 Differential Preservation: The chemical composition of sporopollenin which forms the highly resistant exine of pollen grains and allows their preservation as fossils was elucidated by Shaw (1971). It is now known to be a complex polymer of carotenoids and carotenoid esters. Microscopic and chemical studies of the exine have also indicated the localities and roles of enzymes located within the exine (Heslop-Harrison 1976). Pollen analysts recognise that differential

preservation of pollen taxa can influence the validity of results. Research on the preservation qualities of Populus, Pinus and Typha (Sangster and Dale 1961), the relationship between amount of sporopollenin and degree of corrosion (Havinga 1964) and classification of types of corrosion (Cushing 1967) have all contributed to the understanding of this problem.

1.10.3.2 Dispersal: Actual dispersal routes of pollen within a forest have been investigated by Tauber (1965,1967). He suggested that dispersal would take place through the trunk space as well as above the canopy and finally some would be brought down by rain. Vegetation would act as a differential filter and pollen and spores above the canopy could be entrained in thermals and carried to great heights and over long distances.

1.10.4 New Zealand Palynology.

1.10.4.1 Long Distance Transport: The isolation of New Zealand and its distinct flora have enabled long distance transport of pollen to be identified. Modern Nothofagus pollen from the South Island of New Zealand has been recorded on Stewart Island (Pocknall 1982a) where this genus does not at present grow. Nothofagus, Podocarpus and Phyllocladus were found in moss polsters on Chatham Islands, 700km from the nearest source (Dodson 1976). Ascarina pollen which is confined chiefly to the west coast of the South Island and Coromandel Peninsula in the North Island has been identified in Late Pleistocene deposits on the Chatham Islands (Mildenhall 1976). New Zealand pollens have also been found on Antipodes Islands (Moar 1969a) and on Macquarie Island (Salas 1983). In

the reverse direction pollen of Acacia which is not indigenous to New Zealand has been identified in Plio-Pleistocene deposits in the Pohangina Valley, North Island (Mildenhall 1972). Casuarina pollen thought to have come from Australia has been found in snow on the Tasman Glacier (Moar 1969b). Lake muds on the west coast of the South Island also contain Australian pollen (MacPhail 1979). Specific studies of Nothofagus pollen dispersal have been made by Myers (1973) who found that this pollen was still an important component of the spectrum even when the source was 60km distant.

1.10.4.2 Modern Pollen Rain: Marked differences between insect and wind dispersed pollen were found in modern pollen rain collected at three South Island localities (Moar 1970). Upward drift of pollen from lower to higher altitudes which had been noted earlier (Moar 1967), was confirmed in this study and that by Pocknall (1982b). At Lady Lake in north Westland (Pocknall 1980) compared pollen spectra from moss polsters and lake sediments with local vegetation. Kamahi, kahikatea and Cyperaceae were found to be under-represented though most tree taxa were well represented. High values of Cyathea spores in the lake sediments were attributed to remobilisation. Over representation of the lianes, Metrosideros perforata and M. diffusa was due to their low rating on basal area (Pocknall 1980). Tree taxa Metrosideros robusta and kamahi however, were both underrepresented in forests where they were dominant (Moar 1970). Within Egmont National Park, McGlone (1982) examined modern pollen rain using moss polsters from Ahukawakawa swamp and Potaema bog, also recording the local vegetation in great detail. A summary of the ecology and pollen representation of over 150 pollen taxa has also been made based on a wide ranging review of New Zealand

Cenozoic data (MacPhail and McQueen 1983).

1.10.4.3 Indicator Species: The pollen of some species have particular value as climatic or association indicators. The present distribution of Ascarina lucida suggests that it is susceptible to droughts and frosts. In modern pollen sites where this species could be expected to grow it is present as only < 1% of the total pollen. The decline of this pollen between 5000-2000 yrs B.P. with a brief resurgence between 3400-1800 yrs B.P. shown in pollen diagrams has been interpreted as a climatic deterioration followed by an interlude of more equable climate (McGlone and Moar 1977). Dactylanthus can confirm the presence of several different host plants (MacPhail and Mildenhall 1980). At present no associations of pollen and spores have been established which will indicate the presence of tawa Beilschmeidia tawa (a very poor pollen producer) the pollen of which is seldom found (MacPhail 1980).

1.10.4.4 Quaternary Studies: The first New Zealand pollen analysis of peats was made at South Island sites (Cranwell and von Post 1936). Although some studies were made of peat resources (Moar 1952, 1953, 1954) the next investigations which had a palaeoclimatic bias and sought to establish a Late Quaternary chronology for New Zealand were made by (Moar and Gage 1973, Suggate and Moar 1970, 1974, Moar and Suggate 1973, 1979). More recently bogs in coastal Southland (McGlone 1980) and in the Longwood Range (McGlone and Bathgate 1983) have contributed to the knowledge of the Holocene period. In the central North Island the late Quaternary palaeoclimatic record has now been elucidated (McGlone 1973, McGlone and Topping 1977, McGlone et al 1978, McGlone and Topping 1983). Sites in this area contain dated

tephras which have provided valuable marker beds (time planes) for these studies. The most recently described sites are in the Bay of Plenty and Gisborne regions (McGlone et al 1984a) and a coastal site near Inaha in southern Taranaki, where palynological changes over the last 100,000 years are recorded in a continuous 38m stratigraphic section of coastal cliff (McGlone et al 1984b). Pollen and stratigraphic evidence exists in New Zealand for a period of rapid warming about 14,500 yrs B.P. continuing to the present. This time interval has been named the Aranuiian by Suggate (1958). It is not equivalent to the terms "post-glacial" and "Holocene" as used in the northern hemisphere for the period from 10,000 yrs B.P. until the present day. Vegetation change due to Holocene climatic changes have been included in (1.4.1).

1.10.5 Soil Palynology: The potential for pollen analysis of moroid soils was first recognised by Iversen (1964) and a pollen diagram from a mor forest soil at Mantingerbos, Drenthe, in the Netherlands was later recorded by Stockmarr (1975). Although the technique is now widely used in many countries because it gives a greater flexibility in the choice of sites, it has been criticised by more traditional analysts (Dimbleby 1985). These criticisms were first discussed by Dimbleby (1957) and much later by Havinga (1974).

The problems are; firstly the possible oxidation of pollen exines and differential preservation which was found to be related to the amount of sporopollenin present in the exine (Havinga 1964). Secondly the downwash of pollen, discussed by Dimbleby (1961a and b) who found that pollen in soil was held in organic aggregates which somewhat

mitigated the effect of downwash. Also he found no evidence to show that smaller pollen types were found lower down the profile. Thirdly the lack of stratification. It has been stated that due to the continuing nature of downwash most of the older pollen is lower down the profile while the bulk of the recent pollen is in the top 40mm. The peak abundance of pollen of intermediate age lies between these two levels when the data is based on absolute pollen counts. (Dimbleby 1985). Thus although the stratification is crude it does exist and is capable of interpretation at a general level (Dimbleby 1961a and b). Fourthly the mixing of the pollen by soil fauna. This is easily identifiable by the lack of any pattern in the soil profile. Earthworms and some millipedes are the main agents of soil mixing but they are inhibited by low pH values (pH 4.5) which favour the preservation of pollen. Considerable potential exists for pollen analysis of podocarp forest soils in New Zealand because these forests produce moroid profiles (i.e. those having organic matter that is practically unmixed with mineral soil) (Taylor and Pohlen 1979).

CHAPTER 2

OBJECTIVES, METHODS AND PROBLEMS.

2.1 OBJECTIVES

The aim of this study was to identify and explain changes in the vegetation composition of Taranaki over the last 5000 years. It was anticipated that these changes would involve climatic change, volcanic action, Maori occupation and European settlement.

2.2 METHODS

2.2.1 Selection of Sites: Dated tephras and lahars of the last 5000 years are mainly confined to an arc north of a line drawn from Opunake in the west (NZMS 1 N118/455435) to Eltham in the southeast (N119/869468). Sampling was therefore restricted to this area. Core sites sampled included bogs, swamps, pukatea/maire swamp forests, kahikatea and podocarp/broadleaf forests. Buried soils between tephric and lahatic layers were sampled in exposures on roadsides and a farm drain.

2.2.2 Collection of Cores: A one metre length of rigid PVC tubing of 50mm diameter was hammered into the deposit to maximum depth and then retrieved by excavation of the surrounding material; the base of the tube being covered with plastic film as soon as it was accessible. The entire tube and contents were then wrapped in plastic film to prevent contamination and desiccation. To remove the core, the tube was placed in a freezer overnight and then allowed to thaw for about two hours. A

device which included a close fitting rubber bung was used to push the partly frozen core out and onto a half round tube. Another half round tube was placed over the core and the core was then split in half longitudinally with a long sheet of stainless steel. Exposures were sampled by removing a series of channel samples, usually of 50mm vertical length; these were then stored in glass vials. Each site is identified by year and number of the core collected in that year.

2.2.3 Identification of Tephra: Freshly cut surfaces of cores were closely examined and a description of the stratigraphic details recorded. If confirmation of a tephra layer was required the following method was used. Hydrogen peroxide was added slowly to about 10cm³ of the deposit on a warm waterbath, capryl alcohol being added to control foaming. This was repeated until all organic material was removed. The tephra could then be examined under a microscope and the mineralogy determined to assist identification. In those cases where a precise identification could not be given, wood or peat samples were taken for radiocarbon dating. It was then possible to correlate a tephra with a known dated deposit. Use was made of sample bulk density data when the presence of tephra was suspected but could not be seen macroscopically in the stratigraphic column.

2.2.4 Sampling Procedures: After examination, one half of the core was resealed in plastic film and stored for reference. Samples from the core centre were removed at every other 10mm. Representative samples were taken from the channel samples. Sufficient material was taken to half fill a spoon of known volume (1.25ml); every effort was made to pack to a consistent standard. In homogeneous material the dry weights of

samples obtained by this method were remarkably close. When tephra was present, dry weights varied considerably but often showed consistent change with depth. Pure tephra was not sampled. Samples of known volume were placed in a weighed beaker, dried overnight at 100°C and then re-weighed.

2.2.5 Processing of Samples: Five Stockmarr Lycopodium tablets# were added to each sample together with 1-2ml of 10% HCl to release the spores. The samples were then centrifuged, rinsed and centrifuged again. The standard procedures of Faegri and Iversen (1975) were then used:

- a) 5mls of 10 % KOH for 10 minutes in a warm water-bath.
 - b) Hydrofluoric acid in "Tripor" beakers on a warm water-bath for at least 1 hour, adjusted according to sediment present.
 - c) Flocculation by gentle warming in 10% HCl.
 - d) Up to 2 hours (maximum) in bleaching reagent; (Glacial Acetic acid, Sulphuric acid, Sodium Chlorate).
 - e) 4 minutes in acetolysis reagent in boiling water-bath (Acetic anhydride and Sulphuric acid).
 - f) Stain in Basic Fuchsin.
- Appropriate rinsing procedures followed by centrifuging were carried out between stages.

#Tablets containing Lycopodium spores were obtained from the Department of Geology, Tornvagen 13, S-22363, Lund, Sweden.

Batch No: 006720 10850 \pm 200 spores/tablet

Batch No: 201890 11300 \pm 400 spores/tablet

2.2.6 Identification of Pollen: The Massey University Reference Pollen Collection of 125 slides prepared in 1980 (Lees 1981) was extended to 215 slides. Significant pollen grains which could not be easily recognised from the collection were identified in consultation with Dr.M.S.McGlone of Botany Division, D.S.I.R., Lincoln.

2.2.7 Counting of Pollen: A preliminary count of slides at 50mm intervals was made, using a minimum of 300 fossil pollen grains and spores including at least 150 from woody species. All Lycopodium spores observed during the count were recorded. Slides from intermediate samples were counted if additional information was required. All samples adjacent to tephras were counted where possible.

2.2.8 Charcoal Abundance: All slides processed were examined for charcoal. A graduated scale in the ocular was used and shards touching the scale were tallied. The mean of 50 fields was used as a measure of the amount of charcoal on the slide.

2.2.9 Analysis of Data. Computer programs were designed to cover the analysis of pollen data and pollen diagrams. Two programs were compiled, the first analysed the data and presented it in a readable form for each of three data sets. Program 2 permitted a choice of data sets and produced the pollen diagrams from this data. The procedures carried out by the programs are listed below.

2.2.9.1 Program 1 Analysis of Pollen Data:

- a) Copies data file and prints out as "Pollen count".
- b) Calculates total sum at each depth and percentage for each taxon.
+ sign = < 1%, * = "Low power scan after formal count"
- c) Calculates percentage of each of 5 life forms (Tree, Shrub, Fern, Herb, Mire plants) and presents data as summary.
- d) Calculates differences between every taxon at adjacent depths with confidence levels of 95 and 99%. Creation of new data files with selected depths and/or taxa gives a flexible system of analysis (Mosimann 1965).
- e) Calculates the same data for grains/g dryweight and grains/cm³.
- f) Each taxon has a 3 letter code plus a single letter for the life form viz. Knightsia KNI T (for tree).
- g) The program searches for errors in data input file and reports these.

2.2.9.2 Program 2 Production of Pollen Diagrams:

- a) Checks the existence of correct data files.
- b) Asks for user choices on presentation (on screen, paper, percentage or grains/cm³, titles, references).
- c) Calculates from the depths given the vertical interval scale to utilise the full display space.
- d) Calculates the average interval (in mm) for each sample and plots a standard polygon width at the centre of

sample depth and labels that depth.

- e) Calculates horizontal scales being used and for grains/cm³ data uses a triple scale to reproduce the large range of values encountered. The variable scale is displayed by depth of shading and scale statements.
- f) Calculates the space taken by the display and adjusts per screen or per page.
- g) Draws a polygon of appropriate size or symbol of type to display pollen data.
- h) For percentage data indicates < 1% by a circle and "seen on general scan only " by an "*".
- i) Interprets the three letter taxon code used and labels each taxon at the top of the display. Taxon names are angled to enable them to be read without rotating the diagram.
- j) Distinguishes and labels trees, shrubs, ferns, herbs, mire plants and "others" in different colours. "Others" includes lianes, epiphytes and parasites.

2.2.10 Validity of Data: Literature on the recovery of vegetation after an eruption, particularly from Mt St. Helens (1980), indicates that initial recovery can be seen within a few weeks. Chance plays a very large part and in some areas recovery would be complete within a short time. Sampling at 10mm intervals in these circumstances may well be too coarse. On the other hand sampling as close as possible to the tephric layers to obtain maximum information inevitably means that some tephra is entrained in the sample.

Four sets of data were obtained from the raw grain and Lycopodium, counts; percentage, grains/g, grains/cm³ and grains/cm²/yr. Pollen diagrams of two critical sites comparing the first three data sets were prepared, see Figs. 11B and 14E (All pollen diagrams are bound in Volume II). It can be seen that grains/g data varies indirectly with bulk density values (g/cm³) and is thus influenced by tephra deposition and sedimentation. These data were therefore discarded. Values for percentage and grains/cm³ are very similar except for samples in which pollen concentration is low. This is the case in sample 615 mm in Fig. 14E (Coriaria at Potaema Bog) which is in the organic layer between the Burrell Ash and Burrell Lapilli. Table I shows values of percentages, grains/cm³, total concentration and influx data for Coriaria at Potaema Bog.

TABLE I COMPARISON OF DATA FOR CORIARIA AT POTAEMA BOG

Depth	%	<u>Coriaria</u>	Total	<u>Coriaria</u>	Total
mm		gr/cm ³	gr/cm ³	gr/cm ² /yr	gr/cm ² /yr
15	2.1	3287	155050	316	14908
95	2.3	3767	160890	362	15470
155	1.2	2411	208523	231	20050
175	4.7	3626	77190	348	7422
195	3.0	2590	86774	249	8343
255	+	1261	180380	121	17344
295	8.2	15625	190844	1502	18350
315	12.5	15739	125914	n.d.	n.d.
615	12.3	4717	38256	n.d.	n.d.
715	3.4	2739	79716	n.d.	n.d.
735	2.6	5136	195695	933	35580
755	1.1	944	87804	171	15964
775	+	251	61522	45	11185

It can be seen that for samples at 295 and 315mm, percentage values are 8.2 and 12.5 respectively but the grains/cm³ values are similar. In sample 615mm the concentration (grains/cm³) is only a third of that in sample 315mm but the percentage is 12.3. This could be interpreted as Coriaria having survived deposition of the Burrell Ash, but the sample at 715mm has a very low concentration of Coriaria. Total concentration values were reduced by approximately 50% after deposition of this hot Ash. The probable interpretation is that sufficient time elapsed for an organic layer to develop and during this period Coriaria increased. The fourfold rise in the percentage of Coriaria confirms the pioneering role of this plant, when few other plants were present. The two sets of data complement each other. Table II compares influx (gr/cm²/yr) with percentage data of three adjacent samples.

TABLE II COMPARISON OF INFLUX OF CORIARIA AT POTAEMA BOG

Depth mm	gr/cm ² /yr	Difference	%	Difference
155	231		1.2	
)	117 gr)	3.5 %
175	348		4.7	
)	99 gr)	1.7 %
195	249		3.0	

A similar change of approximately 100 grains/cm²/yr causes quite different amounts of change in percentage values. It is not possible to calculate sedimentary rates for samples which are within the tephras themselves or for the organic layer between the two tephras. These considerations indicated that it was not possible to use influx data in this research.

2.2.11 Presentation of Data: It was decided to use gr/cm³ data for full pollen diagrams because of the additional information obtained from the independence of the data. Percentage and comparative data have been used to examine critical points or special features of pollen profiles. For those sites where European influence is dominant percentage pollen diagrams of total woody species have been presented.

A large range of values is typical of pollen concentration data. In the diagrams presented here depth of colour is related to degree of magnitude; this highlights more prominent taxa. Since interpretation depends largely on changes in shape of taxa curves, depth of colour supplies instant additional information not so readily available in percentage data. Because each value is independent, taxa could be grouped into ecological communities (bog or swamp, subalpine scrub and forests). The use of different colours for trees and shrubs etc facilitates reference to that particular group.

Some departures from traditional pollen diagrams have been necessary. Detailed descriptions of tephras and deposits could not be explained in a simple key, therefore stratigraphic tables have been

placed to face pollen diagrams. A letter code system has been used for greater clarity and a list of all pollen diagrams presented for that site is also included. Pollen zones are numbered from the base. In the calculation of life-form data only indigenous species have been included. For logistical reasons "European taxa" have been placed to the right of bog or swamp data, as has Nothofagus.

2.2.12 Sources for Maps: Metric series maps (NZMS 260) are presently available for western Taranaki only (P19 and P20). The study area is covered by four maps of series NZMS 1 (N108, 109, 118 and 119). All maps have been based on this series and a full scale map (1:63,360) has been reproduced. All pollen sites, important towns, roads and rivers which assist in the identification of sites, and places mentioned in the text, have been included on this map (Fig. 36), placed in a pocket in Volume II. Radiocarbon dates obtained in this study have metric grid references (Table XXXI Chapter 4).

2.3 PROBLEMS ENCOUNTERED

2.3.1 Limitations of the Sampling Method Due to widespread sedimentation of alluvium into bogs and swamps cores extracted from coastal sites did not extend as far back in time as was expected. Every effort was made to be consistent with volume measurements, but the occurrence of woody fragments, raupo (Typha orientalis) leaves and tephra inclusions made this difficult at times.

2.3.2 "Clumping" of Pollen during Processing: This term has been used for the observed tendency of pollen grains to adhere together. Pollen grains were entrained in a mass of uniform brown globules, which appeared to be organic in nature but not to be directly related to the original organic matter of the sample. The following investigation was made.

2.3.2.1 Identification of Common Factors:

- a) Clumping occurred in cores extracted from swamp or kahikatea forests.
- b) The presence of weathered tephra increased the degree of clumping.
- c) Clumping occurred at a specific processing stage when dissolving the fluorosilicates in warming Hydrochloric acid, particularly when the treatment had to be repeated due to the large amount of fluorosilicates.

2.3.2.2 Literature Search: It was hypothesised that such samples were likely to contain large amounts of lignin and that this was being precipitated by Hydrochloric acid. The literature on the chemistry and properties of lignin is extensive due to its importance in the wood pulp industry but the constitution of this substance is still under review because it exists in several forms (Freudenberg 1965). One investigator stated that "Over the years the term lignin has come to mean different things to different persons" (Pearl 1967).

It is known that composition of original plant material affects

organic matter in a deposit. In low moors and forests, lignin or lignin humus and protein predominate and under anaerobic conditions lignin is decomposed only in traces or not at all because of the absence of specific organisms (Waksman and Stevens 1929). Solution of lignin has been thought to occur when an equilibrium between lignin and Hydroxyl ions exists but repeated treatments with hot alkali are necessary to achieve this (Beckman et al 1923). Recovery of previously soluble lignin has been found difficult in practice because the very fine particles were more or less electrically charged (Brauns 1952). The addition of Hydrochloric acid appeared to be related to lignin solubility and when it was added to dissolve fluorosilicates lignin was precipitated. A further complication was that certain samples contained material derived from andesitic volcanic ash. An amorphous hydrous colloid, allophane, results from weathering of rhyolitic or andesitic tephras (Fieldes 1979). Such clays are known to have a very strong affinity for organic matter and to protect it from decomposition (Taylor and Pohlen 1979).

2.3.2.3 Practical Work: R.C. Wallace of the Department of Soil Science kindly carried out an X-ray diffraction analysis on a series of samples removed at various stages of processing and found clay present even after extensive treatment with Hydrofluoric acid. Increasing this treatment produced even more fluorosilicates and increased clumping of pollen at the next stage of processing. A method described by Bates et al (1978) for clay rich samples, using Sodium pyrophosphate to alter electrical charges of colloids was attempted, but was only partially successful. Clumps were smaller but still present. Addition of the detergent "Pyroneg" at the final pre-staining stage was almost as

effective.

2.3.2.4 Solution to the Problem: It was realised that with the control established by the addition of a known quantity of Lycopodium spores it was possible to remove most of the tephra from difficult samples by frequent rinsings and decantings at the KOH stage. Thus the HF stage did not have to be so prolonged and the amount of fluorosilicates to be removed could be lowered. By transferring the residue after HF to 100ml beakers it was possible to achieve good results with only one HCl warming. Eventually reasonable slides were produced from all samples. The problem was avoided rather than solved.

2.3.3 Possible Contamination by Modern Pollen:. Alien Pinus pollen found immediately above and below Tahurangi Ash, previously thought to have been erupted about 200 years ago (Druce 1966), implies the last eruption of Mount Egmont is much younger. It was essential therefore to verify that this was fossil pollen and not modern pollen from the laboratory. The following procedure was carried out.

1. From the three Manganui cores, four small samples were taken at the lowest level where Pinus pollen had previously been found.
2. Each sample was paired with a blank of distilled water.
3. Complete processing of the set of eight tubes included the addition of Lycopodium spores.
4. From each sample and blank four slides were made so that 32 slides (16 core, 16 blanks) were examined for each core. The entire slide was scanned at low power.
5. No Pinus pollen was found on any blank slide.

In fact only one grain of pollen was found on the total of 48 blank slides.

6. Pinus pollen was found on at least one slide of the samples from all three cores.

These results indicate that there was no contamination of pollen of any kind in the processing laboratory and that the Pinus pollen in these cores was fossil pollen.

CHAPTER 3

FOSSIL POLLEN SITES

3.1 INTRODUCTION

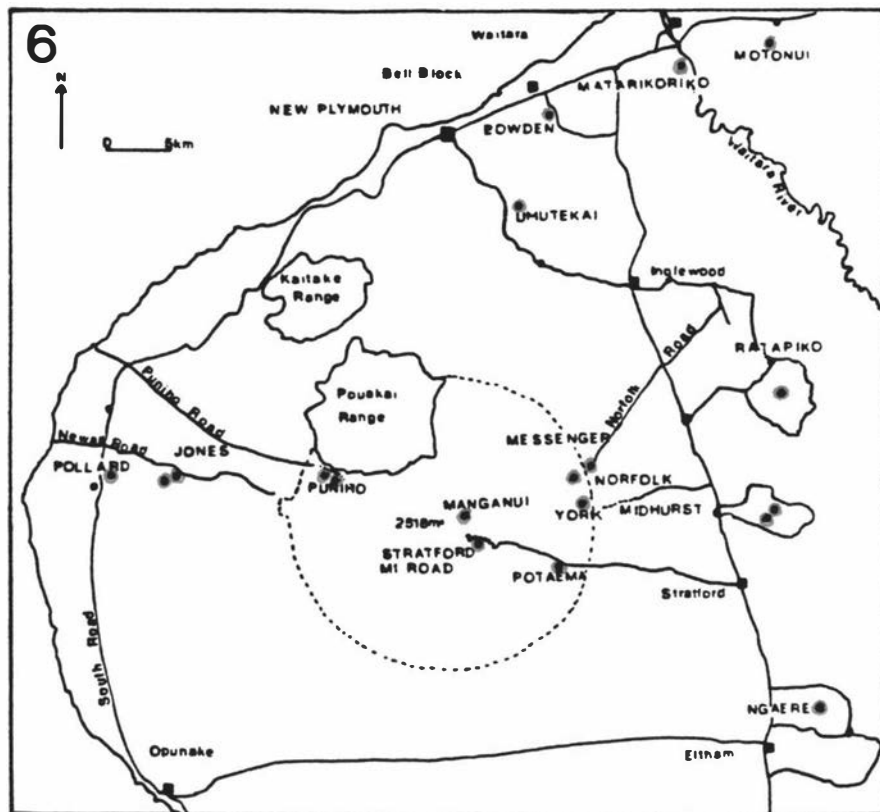
This chapter describes the location, sites, stratigraphy, vegetation and fossil pollen spectra of the 22 sites examined. Changes due to volcanic activity are discussed in Chapter 4, anthropogenic activity in Chapter 5 and climatic change in Chapter 6. Fourteen sites sampled have identifiable tephras or lahars. Nine of these sites are on the eastern side of Mount Egmont; five of them within Egmont National Park and four on the ring plain. Details are given in Table III. The five sites on the western side of the volcano, are listed in Table XVIII, and associated new radiocarbon dates are given in Table XIX. Dates of all tephras are given in Table XXXI (Chapter 4). The four coastal northern sites did not contain any identifiable tephras and are listed in Table XXV. Site locations are shown in Figs. 6 and in detail on the large map Fig. 36 in Volume II. All pollen diagrams are presented in Volume II together with the stratigraphic table for each site.

3.2 EASTERN HIGH ALTITUDE SITES

For the two sites above tree-line, Manganui bog and Stratford Mountain Road, the following assumptions have been made:

1. All tree taxa pollen has been carried by updraft from forests at lower altitudes (1.10.4.2.)
2. Many of the shrub taxa in the subalpine scrub zone occur

FIG. 6 LOCATION OF STUDY SITES, TARANAKI, N.I., NEW ZEALAND



SOURCE NZMS 159 Taranaki (1st Ed.) 1970

also in the forest. Hebe odora is found also in the bog and tussock zones. The shrubs selected as representing the subalpine scrub zone are all entomophilous and their pollen is likely to be of local origin (1.10.4.2).

3. Hebe pollen is from Hebe odora growing on the bog.
Compositae pollen represents Brachyglottis elaeagnifolia.
Panax group pollen is from Pseudopanax simplex.
Gramineae pollen is from Chionochloa rubra.
Nothofagus pollen is from a distant source.

At the high altitude site, Manganui Bog, the pollen is derived from three communities;

1. Local pollen from bog vegetation.
2. Pollen from the surrounding subalpine scrub.
3. Forest pollen carried by updraft from low altitudes.

The pollen spectrum from each source is displayed in a separate pollen diagram

At Stratford Mountain Road sites the local pollen from the sub-alpine scrub is presented first in the % data graph, with the regional low-altitude pollen next. The graph for 82/4 has been presented in two parts for easy reference.

TABLE III LOCATIONS AND SAMPLING DATA, EASTERN SITES

Site name	Code	Grid Ref.	Alt.	Total	Type	Dated Tephra
		N119	m	Depth mm	#	Present
Manganui 1	83/1	673214	1200	570	C	TA, BL, BA.
bog 2	83/14	"	"	290	C	TA, BL.
3	85/1	"	"	640	C	TA, BL, BA, NA.
Stratford 1	85/2	684614	1082	90	E	(Below BL), BA.
Mt. Rd. 2	82/4	684614	1080	2520	E	BL, BA, NA, K, M, I.
Potaema bog	83/2	725606	675	785	C	BL, BA, NA.
York bog	84/2	745644	525	620	C	BL.
Norfolk bog	84/1	735660	525	600	C	BL.
Messenger's	82/2	746675	450	250	E	M.
Midhurst 1	82/7	865642	285	600	C	BL.
Swamp 2	83/13	874645	285	436	C	BL.
Ngaere	82/1	905490	210	690	C	BL, K, M, I.
Swamp						
Ratapiko	82/3	875728	180	690	C	BL, M.
Swamp		N109				

C = Core E = Exposure

TA = Tahurangi Ash BL = Burrell Lapilli BA = Burrell Ash

NA = Newall Ash K = Kaupokonui tephra M = Manganui tephra

I = Inglewood Tephra

3.2.1 Manganui Bog: N119/673214 at 1200m.

This small, sub-alpine, cushion bog (Harris 1968) lies just below the Manganui Ski Hut on Mount Egmont. It is in a depression on an exposed ridge surrounded by leatherwood scrub (this community is described with the Stratford Mountain Road sites). The bog sedge Oreobolus pectinatus forms firm cushions on which grow scattered plants of Celmisia glandulosa var. latifolia, Hebe odora, Coprosma pumilo, Dracophyllum filifolium and sparse tufts of Chionochloa rubra. Between the cushions, mosses dominate with Hypnum cupressiforme, Polytrichum commune and Rhacomitrium languinosum prominent.

Three cores were collected. The finding of Pinus pollen in close association with Taurangi Ash in core 83/1 required a second core for verification. An attempt was made to get this in winter but the bog was very wet and only a short core (83/14) was retrieved. Core 85/1 was collected the following summer. Each site is discussed in turn, then a short summary is presented for each community in all cores.

3.2.1.1 Manganui 1 Core 83/1

Both Burrell Ash and Burrell Lapilli are present and there is an organic layer between these two tephras which is missing in the other two cores. This organic layer indicates incipient peat development and thus a lapse of time between the tephras.

Anisotome, Umbelliferae and Gunnera pollen rise at the top of the profile. After the Burrell Lapilli, pollen of all subalpine shrubs is reduced but soon rises again (Fig.7B). Tree pollen (Fig.7C) decreases

from those values in the organic layer between the Burrell Ash and Lapilli. Podocarpus hallii rises slowly, but tree pollen from lower altitudes has larger increases in the next sample at 95mm. There is a decline in all Podocarp pollen towards the top of profile, coinciding with a large rise in Gramineae and Pteridium and occurrence of pasture weed pollen (Taraxacum and Plantago). Pinus pollen was found at 100mm and in a duplicate sample at 110mm, just above the "peaty ash".

3.2.1.2 Manganui 2 Core 83/14 Tahurangi Ash and Burrell Lapilli are the only tephras present.

Cyperaceae pollen (cf. Oreobolus pectinatus) increases rapidly in the upper samples of this profile (Fig.11A), Anisotome also increases suggesting the development of a sedge cushion at this site. Gramineae pollen does not show the same large increase as in Core 83/1 and Pteridium declines after the Tahurangi Ash. Subalpine shrub pollen shows different recovery patterns after the Burrell Lapilli. This is interpreted as the response by individual shrubs, with intact root systems to the sudden removal of the canopy and higher light intensity. Later competition is indicated by decline in Hebe, Dracophyllum, P. colensoi and P. simplex pollen but rises in Coriaria and Compositae (Fig.8B). Only P. hallii of the trees show a rise immediately after the Tahurangi Ash. This may be due to a tephra fertilising effect at high altitude, Fig.2G. None of the tree taxa from lower altitudes show a similar rise. There is a marked decline during European time in all Podocarp pollen in the upper part of the spectrum (Fig.8C)



Plate 1. Recent tephras as found in sampling cores.

3.2.1.3 Manganui 3 Core 85/1 This is the deepest core with Newall Ash present at the base and Burrell Ash and Burrell Lapilli above, (Plate 1).

The pollen profile indicates that a sedge cushion was present above the Newall Ash and several dicotyledonous herbs were established on the cushion at the time Burrell Ash was deposited (Fig.9A). After the deposition of the Newall Ash, both Hebe and Gramineae have lower values but soon recover. Among the subalpine shrubs Coprosma, Hebe, Myrsine and Pseudopanax simplex pollen show recovery. Exceptions to the general rising trend are Coriaria and Compositae. P.hallii also rises after the Newall Ash, declines in sample 555mm and is very little altered by later deposition of Burrell Lapilli. There is no indication of peat forming above Burrell Ash in this core but the pollen spectrum indicates a significant decline ($P < 0.05$) (1.10.3) of Cyperaceae suggesting that 170mm of Burrell Ash (g) markedly changed the ground surface conditions. Above the Burrell Lapilli a rise of Anisotome pollen (also significant ($P = < 0.05$)) indicates colonisation of the new surface, followed later by a slower rise of Cyperaceae, Gunnera, Haloragis and Umbelliferae as the sedge cushion redeveloped. Subalpine shrubs again rise after the Burrell Lapilli and then show different rates of decline as the canopy closes. Nearly all tree taxa are abundant above the Burrell Lapilli but decline towards the top of the profile (Fig.9C). Pteridium spores are abundant in the peat above the Burrell Lapilli but decline in the uppermost sample; Gramineae has a similar curve. These changes coincide with the first appearance of pasture weed pollen. Pinus pollen occurs in the peat below the Tahurangi Ash in this core.

3.2.1.4 Bog Community The stratigraphy of all three cores is plotted in Fig.10 (Total pollen grains/cm³) with the top of the Burrell Lapilli as the base correlation line. The depth of any one tephra varies from site to site and core 85/1 has a greater number of pollen grains/cm³ in most samples than either of the other two cores. Variation in the three pollen profiles could be explained by differences in the sites. The high values of Cyperaceae and dicotyledonous herbs at the base of profile 85/1 (Fig.11A) suggests that this site was a sedge cushion except for a brief time after the deposition of the Burrell Ash and Lapilli which together total 420mm in thickness. When the Tahurangi Ash was deposited core 83/1 was in a transition stage between mossy pool and sedge cushion and the ash mixed with the moss to form "peaty ash", Site 83/14 received 55mm of this tephra deposited into a pool, on which a sedge cushion later developed.

3.2.1.5 Subalpine Scrub Zone. Subalpine scrub surrounds the bog so the pollen is from local sources. The most striking feature of the three pollen profiles is the randomness of the values. Although individual species show a steady increase or decrease no one species shows dominance in all cores at the same time (Fig.11B). The only common factor is that the values of almost all shrub species are lower immediately above the Burrell Lapilli than in the next sample above.

3.2.1.6 Forest Zones. Libocedrus pollen has consistently low values. MacPhail and McQueen (1983) regard this species as "well to under represented" while McGlone (1982) considers it to be one of the better represented species. These trees are less plentiful on eastern slopes below Manganui bog than on western slopes. P.hallii pollen shows

lower values after deposition of the Newall Ash in core 85/1 and after the Burrell Lapilli in all cores. Of the lowland forest taxa, M.robusta pollen (also regarded as under represented (1.10.4.2)), has a slight rise after the Burrell Lapilli in all cores but values fall quickly, as does all Podocarp pollen, in European times.

3.2.2 Stratford Mountain Road: N119/684614 at 1082/1080m.

These sites are in a roadside exposure in the subalpine scrub zone, from which 43 channel samples were collected but only 20 of these had enough pollen for valid counts. Site 85/2 is about 20m further up the road than 82/4, and was sampled specifically to obtain more information about the organic layer directly below the Burrell Lapilli. 82/4 is a composite stratigraphic section from three adjoining sites. Pollen from forests at lower altitudes has been carried by updrafts. Those volcanic events which were most destructive, eg. pyroclastic flows, probably eliminated all trace of fossil pollen. Comparisons between two pollen samples when they are separated by several tephras and a long time span were not considered to be relevant. Only percentage data are available.

Present vegetation is a dense scrub dominated by Brachyglottis elaeagnifolia. Other shrubs are Griselinia, Dracophyllum P.colensoi, Hebe stricta, Gaultheria, Cassinia vauvilliersii, Coprosma spp and Carmichaelia. Herbs include Astelia, Helichrysum sp, Chionochloa rubra, Pratia angulata, Ourisia macrophylla var. macrophylla, Haloragis, Epilobium nerterioides, Euphrasia cuneata, Helichrysum bellidioides. Ferns of the Blechnum capense group

are present among the shrubs.

3.2.2.1 Stratford Mountain Road 85/2: Nine samples were collected from this roadside exposure of Burrell Ash and Burrell Lapilli. Only four samples contained enough pollen for valid counts. Pollen was abundant in the upper two samples (10-20mm) from the organic layer below the Burrell Lapilli. There is a significant increase ($P = < 0.01$) of P.colensoi between samples below Burrell Ash and those in the organic layer below Burrell Lapilli. Forstera, Haloragis, Gunnera, Epilobium and Pratia occur only in the samples from the organic layer (Fig.12A). Pollen of forest taxa Elaeocarpus, Quintinia, Weinmannia, Malvaceae, Leptospermum, Rubus and Muehlenbeckia is present in trace amounts (Fig.12B). None of these occur in the lower samples. There is also a significant decrease ($P = < 0.05$) in P.simplex between the two samples within the organic layer, and both Compositae and Coriaria pollen increase. A pollen sum of woody species only (Fig.12 B) does not alter the interpretation.

3.2.2.2 Stratford Mountain Road 82/4: Two samples from below the Manganui tephra show very similar spectra for forest taxa (Fig.13A). In the upper sample of the two, monoletic fern and Pteridium spores increase. Several inorganic deposits separate these samples from the next polleniferous layer above, so no direct comparison has been made.

The next two samples 1805mm (v) and 1385mm (t) represent vegetation before and after a 300mm thick pyroclastic flow was deposited. P.simplex previously common was eliminated, while both Coriaria and Compositae increased and Anisotome became

prominent. P.hallii has a value of 3% before and < 1% after this event, but other low altitude tree taxa pollen show little change.

Samples at 1005mm (o) and 755mm (m) bracket the 2000 yr old pyroclastic flow deposit. Coriaria again has a larger value after the flow. All other shrub pollen types were already at low percentages or absent due to earlier events. High values of Gramineae pollen may indicate a downslope extension of the tussock zone. The high altitude tree taxa pollen show little change, both Libocedrus and P.hallii having low values.

The next two samples (755mm (m) and 705mm (k)) show a large increase in Dracophyllum associated with a decrease in Gramineae, whilst Coriaria again has a high value. P.hallii pollen continues to rise through the next sample, but is reduced after the Kaupokonui tephra. Of the lower montane tree pollen types only D.cupressinum pollen decreases after Kaupokonui tephra. Shrub pollen is scarce except for the dominance of Dracophyllum. Coprosma increases and Coriaria decreases between the Kaupokonui tephra (j) and the "layered fine ashes" (g).

Sample 475mm is taken from the lower half of these ashes (g) and represents vegetation which had recovered from deposition of the Kaupokonui tephra with tree pollen at high levels (Fig.13A and C, pollen sum = total pollen). Very little pollen was found in the next sample but at 375mm depth all pollen taxa are reduced except for monolete fern spores which have a very large increase. It is likely that the fern spores are an over representation in samples which have a

low pollen concentration. When the pollen sum is of woody species only (Fig.13B) it appears only Dracophyllum, the dominant shrub is severely affected and Coriaria slightly so. This pollen spectrum suggests that only vegetation of the upper slopes was damaged and that the dominant species may have protected other plants. The pollen spectrum of sample 225mm (e) which includes the Newall Ash shows what appears to be a beneficial effect because generally values rise except for Myrsine which declines abruptly ($P = <0.05$). Early changes may have been masked however, by using a representative sample. The uppermost sample is from Burrell Lapilli, which has an organic component and shows a large increase in Coriaria. Pseudopanax species become prominent which agrees well with spectra from the organic layer between the Burrell Ash and Burrell Lapilli at site 85/2.

3.3 EASTERN LOW ALTITUDE SITES

Three spring-fed bogs (Clarkson 1981) at low altitudes within the Egmont National Park vary in the degree of dominance of Leptospermum in the sedge/shrub communities. They show different stages of succession in that Potaema has open water and Sphagnum, York Road is dominated by Leptospermum within forest and Norfolk Road has stunted trees established on the surface of the bog. The pollen profile at Potaema bog shows that 400mm of tephra deposited in the last few hundred years had quite different effects on the swamp and forest ecosystems. It is therefore assumed here; that all Leptospermum pollen has been derived from the swamp and Weinmannia from the forest, to assist in interpretation of the pollen profile.

3.3.1 Potaema bog: N119/ 725606 at 675m: Newall Ash has been tentatively identified at the base of the core below a peat layer underlying Burrell Ash. An organic layer between this Ash and the Burrell Lapilli is also present. Graded lapilli found in this core indicate the three phases of the eruption (Topping 1972) (Plate 1).

Potaema bog lies to the west of Stratford Mountain Road at 675m. One core of length 785mm was collected from near the centre. Sphagnum hummocks and open water dominate the centre but towards the margin, the surface is largely stunted Leptospermum and Gahnia xanthocarpa. Vigorous clumps of Phormium tenax up to 2m high dominate the margin and extend into the forest. Encroaching onto the bog are the marginal species Cyathodes fasciculata, Astelia grandis, Dracophyllum filifolium, Cassinia vauvilliersii, Olearia virgata and Weinmannia racemosa. Weinmannia is also very common in the surrounding forest, where D. cupressinum, D. dacrydioides and Metrosideros robusta are emergent. Libocedrus bidwillii, Prumnopitys ferruginea and Podocarpus hallii are also present. The sub-canopy contains Griselinia littoralis, Melicytus ramiflorus, Pseudowintera colorata, Schefflera digitata, Coprosma spp, Pseudopanax crassifolia and the tree ferns Cyathea smithii and Dicksonia squarrosa.

3.3.2 Swamp Community. Above the basal sandy ash (thought to be Newall Ash) both Leptospermum and Cyperaceae pollen rise consistently. The marginal taxa (listed above) do not show a definite pattern (Fig. 14A). Just below the Burrell Ash the charcoal abundance value is a comparatively high 14.4, but recent work suggests this Ash was a lateral cloud deposit and was probably not hot. Charcoal is present in all

samples from this site. Swamp pollen then show a decline in the sample (715mm) at the base of this ash (Fig.14C). In the organic layer (615mm) between the Burrell Ash and Burrell Lapilli. Herb, Cyperaceae pollen and Blechnum spores are absent, whilst pollen of most other swamp taxa are present but reduced. Above the Burrell Lapilli the large increase in Cyperaceae pollen suggests a rise in the water table due to blockage of the stream channel by lapilli. Although pumiceous, these lapilli do not float.

The rapid rise of Leptospermum and complementary fall in Cyperaceae which is seen in the next two samples show that drainage improved and drier edaphic conditions favoured Leptospermum (Fig. 14C). The large amount of organic matter in the next two samples is probably from the death of sedge plants. Pollen of Phormium and marginal shrub taxa show a general rise suggesting encroachment on the bog (in both gr/cm^3 and % data). Values of individual taxa vary indicating competition and not seral change. Complementary curves of Gramineae and Cyperaceae suggest that the former (possibly Cortaderia) is local rather than regional. Above the 150mm level there is little change in the pollen spectra indicating a state of equilibrium had been reached (Fig.14C).

3.3.3 Forest Community. After the deposition of the sandy basal ash, pollen of all forest species rises, in the gr/cm^3 data but not in the % data. This suggests that the concentration data is affected by the presence of Burrell Ash due to compaction by the weight of tephra above (Fig.14D). There is little change in the % data but Coriaria increased after the sandy ash at the base. Larger increases in this taxon occur

after the Burrell Ash and Burrell Lapilli. Most tall tree pollens have lower values at 315mm after the deposition of the Burrell Lapilli. When Leptospermum has its highest value (in both data sets) at 255mm, all tall tree and epiphyte pollen types are reduced, as are fern spores. This may be an indication of Leptospermum in the forest as well as on the bog. In the next three samples only the emergent species D.cupressinum shows a consistent rise. Weinmannia reaches high values but the rise is not consistent. Canopy and sub-canopy species pollen also varies but there is a general rising trend. Nestegis, Knightsia, Laurelia, Hebe and Rubus present in the organic layer are absent from the first sample after the Burrell Lapilli.

Recovery after the Burrell Lapilli was fairly rapid but D.cupressinum pollen never regained the high value attained just before the deposition of the Burrell Ash. Weinmannia pollen prominent in the spectrum after the Burrell Lapilli, shows some decline in the upper three samples as D.cupressinum pollen rises. In the upper portion of the profile (above 180mm) the influence of European settlement is seen in the first occurrence of Pinus, the pasture weeds, Taraxacum and Plantago and the rising curve of Pteridium. Spores of this fern are absent from the base of the profile.

3.3.4 York Road bog: N119/745644 at 525m: This bog is to one side of the main axis of the Burrell Lapilli and only 85mm of Burrell Lapilli are present. The scattered lapilli in the mineralised peat above the dense layer of lapilli may be redeposited.

This site is better drained than Potaema bog and is essentially a

wet area within lowland forest, making location difficult because the site is not open. The species list for this forest is similar to that for the Norfolk Road bog and is given in the next section. Leptospermum forms continuous canopy about 2m high over the sedge Gahnia xanthocarpa. Towards the margin Weinmannia up to 3m high is more prominent in the canopy. A tree of this species was present near the coring site.

The gr/cm^3 data in Figs.15A and B shows a general rising trend from from the base of the profile followed by a decline. Coriaria has only low values. There is some inverse correlation with bulk density values (Fig.15C) indicating the addition of inorganic matter but no tephric layer was apparent. Pteridium levels and charcoal values increase in the third sample from the base but the low value of charcoal suggests the fire was not on the site. A critical level of change in the pollen curves seen in both diagrams (Fig.15C and D) occurs at the 480mm level when the bulk density rises sharply. At and above this level there is a large amount of organic matter present, pollen grains are crumpled and some clumping of the pollen (indicating the presence of tephra) occurred during processing (2.3.2). Cyperaceae decreases, Phormium pollen disappears and there is a decline in Potamogeton pollen suggesting a change in the drainage pattern, with some sedimentation and inwash of tephra. The organic layer (408-428mm) (d) contained insufficient pollen for analysis but a large amount of in situ fibrous roots and leaves, possibly of Phormium.

Above the Burrell Lapilli, rising pollen curves of Coriaria and Leptospermum indicate that an opportunity existed for colonisation of a

new surface. Changes in the marginal swamp pollen taxa suggest some infilling and reduction in swamp area. Typha pollen occurs for the first time in the spectrum above the Burrell Lapilli, but disappears as Phormium pollen reappears. Podocarp pollen is reduced after the Burrell Lapilli. Opening up of the canopy is indicated by the rise of several species of ground ferns of which Blechnum may be on the bog surface. Changes above the 150mm level are due to European activities. Weinmannia is prominent throughout the profile but this may be directly related to a tree of this species being present in the canopy at the site.

3.3.5 Norfolk Road bog: N119/735660 at 525m: This swamp lies further to the north than the York Road swamp and even further away from the main axis of deposition of Burrell Lapilli (Fig. 2E). A 60mm thick layer of Burrell Lapilli containing lapilli up to 10mm in diameter is present and overlies 40mm of scattered lapilli up to 4mm in diameter, from the initial phase of the eruption.

A shrub sedgeland dominated by Lepidosperma australe with Leptospermum up to 2m high, forms about 40 % of the canopy emergent over sedges. Lepidosperma is the most common plant but Gleichenia dicarpa, Baumea and Phormium occur throughout. Occasional clumps of Pseudopanax crassifolia, Weinmannia racemosa and stunted D. cupressinum are found in drier areas. Denser Leptospermum, low growing Weinmannia, Coprosma tenuifolia, Astelia grandis and Gahnia xanthocarpa form the undergrowth at the swamp margins. These grade into a forest containing D. dacrydioides, D. cupressinum, and Weinmannia with an understory of Myrsine salicina, P. hallii, Hedycarya

arborea, Pseudowintera colorata and occasional Beilschmiedia tawa and Cyathea smithii. Blechnum discolor, Microlaena and Uncinia form the ground cover in drier places with Astelia grandis, A. fragans and Gahnia xanthocarpa frequent in wetter areas.

At the base of the spectrum (Fig.16C) all tree, fern and Leptospermum pollen increase coincident with a rise in bulk density while swamp taxa pollen declines. The grains/cm³ data therefore records forest either recovering from a previous event or advancing onto the swamp subsequent to increased sedimentation into the swamp. The percentage data (Fig.16D) show similar curves to the grains/cm³ data (Fig.16C) for the same groups of taxa. Two samples at 485mm and 525mm, have increased amounts of charcoal and Pteridium also rises at this time. These fires were not at the coring site but represent windborne ash from distant fires. Clumping of pollen (associated with the presence of a weathered tephra) occurred from 510mm up to 450mm. Samples at this higher level also contain large pieces of organic material and pollen is sparse due to the rapid rate of accumulation of organic material. Bulk density values rise steadily up to the 270mm level when they fall abruptly after the Burrell Lapilli.

Above the Burrell Lapilli fern spores continue to rise with Blechnum being prominent; (B. capense frequently grows on swamp margins). Pollen of forest taxa (summarised in Fig.16C and including epiphytes Fig.16D) increases after the Burrell Lapilli but Leptospermum and Cyperaceae pollen, initially unchanged, increase later. Bulk density values are low. The lapilli would have partially infilled the bog allowing marginal species to encroach. Weinmannia is particularly

prominent among these after the Burrell Lapilli. The quantity and size of the lapilli are small but some damage may have occurred as Coriaria has higher values above the Burrell Lapilli. European influence is clearly indicated above the 170mm level when Pinus is present.

3.4 EASTERN RING PLAIN SITES

Of sites outside the Egmont National Park, one is an exposure in a deep drain on Messenger's farm, Norfolk Road, dated at <3125 yr B.P. where a buried soil developed on a lahar. The other three locations were all swamps which have now been drained and are in, or surrounded by, pasture and are located on the edge of the ring plain. The Midhurst location from which two cores were collected is closest in a direct line to the summit and nearest the main axis of Burrell Lapilli distribution (Fig 2E). Ngaere swamp to the south, near Eltham, is 28km distant from the summit and Ratapiko swamp, southeast of Inglewood is 23km away but is closest to the main axis of Inglewood Tephra distribution (Fig.2A).

3.4.1 Messenger's farm: N119/ 746675 at 450m: Five channel samples of 50mm depth each were collected from a buried soil developed on a lahar that was subsequently buried by the Manganui tephra c. 3125 yr B.P. One sample was collected from the base of the tephra and one from the top of the lahar. Wood from this lahar was identified as D.cupressinum.

The site which is in a deep drain adjoins cutover forest and it was possible to collect a detailed species list, no D.cupressinum was sighted. Tree species included Podocarpus

ferruginea, P. taxifolia, P. totara, Weinmannia racemosa, Beilschmeidia tawa, Knightsia excelsa, Hedycarya arborea, Nestegis lanceolata, Dacrycarpus dacrydioides and Carpodetus serratus. Sub-canopy species included Pseudopanax crassifolia, Pennantia corymbosa, Leptospermum scoparium and Syzygium maire. Tree ferns Dicksonia squarrosa, D. fibrosa and Cyathea smithii were present over a shrub layer containing Coprosma rhamnoides, C. australis, C. tenuicaulis and Brachyglottis repanda. Lianas Metrosideros diffusa, M. perforata, M. fulgens, Freycinetia baueriana var. banksii, Rubus, Ripogonum scandens were abundant, while Astelia solandri, Earina mucronata, Asplenium flaccidum and Trichomanes reniforme were among the epiphytes. Pteridium aquilinum and Acaena were present in the ground layer.

The pollen spectrum in Fig. 17A indicates that the forest c. 3125 years ago was very similar to that now present. D. cupressinum and most likely Beilschmeidia tawa were the dominants. There is a slow decline of D. cupressinum and a rise of Elaeocarpus pollen. These spectra represent changes at the margin of the flow where damaged trees may have died later. Subsequently Elaeocarpus declines when D. cupressinum pollen rises, closing the canopy. Panax group pollen dominates the early seral stage. Its prominence in the sample from the lahar at the base suggests it was a component of the undamaged forest and extended its range onto the new surface. Leptospermum has a similar curve but Coriaria increases slightly at 235mm. Neither Coriaria nor Weinmannia are prominent in the succession. Cyathea spores, over-represent these tree ferns in the later stages. Phymatodes spores rise with the increasing availability of epiphytic sites. P. scandens is frequently abundant on the trunks of B. tawa. Pollen of forest margin

species, Rubus and Muehlenbeckia rises then declines as the forest becomes closed. A pollen sum of woody species indicates a change in podocarp pollen which increases towards the top of the profile (Fig.17C).

3.4.2 Midhurst 1: N119/865642 at 285m: This core contains both the Burrell Lapilli and Kaupokomui tephra. The site is in a direct line with the main distribution of the Burrell Lapilli. A dense layer of Burrell Lapilli, 26mm thick, lies between two layers of fine lapilli scattered through a matrix of mineralised peat. These two layers represent the early and late phases of the eruption described by Topping (1972).

A core (82/7) 600mm long was extracted from a former swamp now in pasture. A later core (83/13) referred to as Midhurst 2 was collected from a small remnant of swamp forest about 1km to the northeast of the first site. The area has been drained and cattle use this bush for shelter so the shrub and herb layers are almost non-existent. The following species were seen in this forest remnant. Dacrycarpus dacrydioides; Laurelia novae-zelandiae, Beilschmeidia tawa, Melicytus ramiflorus, Nestegis lanceolata, N. cunninghamii, Syzygium maire, Pseudopanax crassifolia and Cyathea. Epiphytic plants were, Collopermum, Pyrrosia serpens, Asplenium flaccidum, the liane Metrosideros diffusa and climbing fern Blechnum filiforme.

Summary graphs are presented for forest and swamp communities, arranged side by side for comparison. The data on charcoal values, bulk density and taxa indicating European time are included in Fig.18C. Selected species showing important changes in pollen spectra have been

graphed in Fig 18D for both grains/cm³ and % data. Samples within the Burrell Lapilli are strongly influenced by the tephra in the gr/cm³ data and the % data presents a more accurate record of the vegetation in this section of the profile. The profile records a change from lowland forest to the much wetter sedge/shrub swamp dominated by Leptospermum. This change in drainage is associated with indications in the pollen spectra of European settlement. The pollen spectrum can be divided into four zones.

Zone 1 606-365mm

This zone includes the Kaupokonui tephra but there is little indication of damage. Coriaria does not increase but Cyperaceae is absent from the profile after the deposition of this tephra. Temperate lowland forest is present at the site. Cyperaceae (Fig.18D) is insignificant and there is a steady rise of all forest taxa (Fig.18C). D.cupressinum dominates the pollen spectrum, while Leptospermum and D.dacrydioides have somewhat erratic pollen curves. The base of this zone is >1400 yr B.P.

Zone 2 365-205mm

This zone includes the Burrell Lapilli and after its deposition Potamogeton pollen appears in the profile for the first time. Cyperaceae pollen is always present. Laurelia appears near the top of the zone, all these changes indicate increasing wetness at the site.

Zone 3 205-90mm

There is a marked increase in the concentration of pollen suggesting that the increase in wetness evident in this zone provided better preservation conditions for pollen than the forest soil in Zones 1 and 2. The pollen spectrum indicates sedge/shrubland has become established, with some open water, surrounded by lowland forest with a

swamp forest element. Syzygium appears for the first time, Freycinetia and Knightsia increase, indicative of disturbance in the forest possibly by browsing animals. Cyperaceae and Leptospermum pollen are prominent and D.dacrydioides rises to high values towards the top of the zone. (Fig.18D). The advance of European settlement towards this area is indicated by the first appearance of the windborne pollen of Plantago.

Zone 4 90-0mm

The increase in pasture weed pollen (Plantago and Taraxacum) and the presence of Pinus indicates European settlement closer to the site. D.dacrydioides has much lower values in this zone and Cyperaceae also declines, Potamogeton is absent from the upper 3 samples. All these changes are indicative of artificial drainage. At the same time Gramineae continues to have high values. All forest life form groups decline and this is not related to bulk density which also declines but represents destruction of the forest.

The change from forest to forest/swamp at this site is also indicated in the stratigraphic column which shows compacted mineralised peat at the base and peat above the Burrell Lapilli. Sedimentation rate increased from 0.2mm/yr between the Kaupokonui and Burrell tephras to 10mm/yr above the Burrell Lapilli and bulk density values increased from 0.3g/cm³ at the base and 0.6g/cm³ between the tephras to 0.9g/cm³ above 210mm. These changes are associated with a consistent charcoal presence from 190mm upwards and indicate forest clearance.

3.4.3 Midhurst 2: N119/874645 at 285m: This core was collected in a degraded wet lowland forest remnant on the same farm as Midhurst 1. The short core contains only fine Burrell Lapilli scattered in a matrix of loamy peat. The stratigraphic column suggests the area has always been in forest.

The pollen spectrum in the summary graph (Fig.19C) indicates the presence of a lowland forest with a small swamp forest component throughout the profile, Laurelia, Syzygium and Freycinetia being present but recorded sporadically with low values. Species composition is very similar to the present forest. Continuous sampling throughout the Burrell Lapilli was possible but little information was gained. The small size and dispersal of the lapilli is unlikely to have caused much damage. Low values for grains/cm³ data reflects the presence of the lapilli in the samples and the percentage data gives a better basis for interpretation. Very little change occurred in the pollen curves before and after the fall of the tephra, a slight rise in shrub species and a fall in ferns (Fig.19C). Generally the forest remains stable despite the deposition of the tephra. There may have been some fertilising effect since slight rises are recorded in some taxa. The first occurrence of Pinus together with Taraxacum and Plantago is later than at Midhurst 1 and corresponds to Zone 4 of that pollen profile.

3.4.4 Ngaere swamp: N119/905490 at 210m: This site was cored following a long spell of dry weather and the deposits are therefore dry and compacted. Four tephtras are present, the Inglewood Tephra (3800 yr B.P.), Manganui tephra (3125 yr B.P.), Kaupokonui (1400 yr B.P.) and the Burrell Lapilli (1725-1750 A.D.). The latter is disturbed due to

farming activities, (Plate 1).

This former large swamp lies to the northeast of Eltham and is now in pasture. There is no indigenous vegetation in the vicinity but some Cupressus macrocarpa (alien) trees have been planted on a small rise. Both the Eltham and Ngaere swamps are thought by Franks (1984) to have been formed by laharic debris, channelled down the Waingongoro River, which accumulated in the mouths of tributary valleys draining to the east thus blocking the valleys which drained to the west. The average depth of the swamps is 12m. A core of 9.3m has previously been recovered from the Eltham swamp for pollen analysis, the base of which had an age of c. 13,000 yr B.P. (McGlone and Neall in litt.).

Since European settlement, the history of the swamp is one of major changes due to the extraction of Lagarostrobos colensoi logs and drainage which caused rapid shrinkage of the peat (Every 1974 and 1.5.2). The top 150mm of the core are set out in a separate diagram (Fig. 20D) and Figs. 20A-C end at 150mm. Fig. 20B shows the pollen curves of species in which change occurred throughout the spectrum together with groups of forest taxa. D. dacrydioides, Leptospermum, Laurelia and Syzygium are excluded from the "Tree" data because they were considered to be swamp margin species. Laurelia and Syzygium occur only rarely, the former is regarded as being severely under-represented and there is no information available about the representation of the latter (MacPhail and McQueen 1983). The pollen sum in Fig. 20C excludes Leptospermum, spores and aquatics, but this does not really change the interpretation. Only percentage data is available for this site. The pollen diagram is divided into four zones.

Zone 1 710-645mm

The Inglewood tephra is at the base of this zone, D.dacrydioides and Coriaria both rise within the tephra. The profile indicates lowland forest dominated by D.cupressinum with D.dacrydioides prominent. The presence of Potamogeton indicates some open water close to the site.

Zone 2 645-475mm

Cyperaceae pollen rises steadily throughout this zone (Fig.20 A and B). Potamogeton pollen present at the base of the core disappears from the spectrum at this time. After an initial decline Leptospermum increases. D.dacrydioides pollen prominent at the base of this zone, declines above the Inglewood Tephra to its lowest values before increasing again. It falls slightly as Leptospermum increases towards the top of the zone.

Zone 3 475-235mm

Both the Manganui and Kaupokonui tephras are present in this zone. Readjustment of the bog surface is shown by the decrease of Cyperaceae pollen and the reappearance of Potamogeton at the time of the deposition of the Manganui tephra c. 3125 yr.B.P. Potamogeton pollen is present throughout the spectrum above this point which suggests a change in drainage pattern. After an initial decline Leptospermum rises steadily until the deposition of the Burrell Lapilli. Cyperaceae has generally lower values in this zone.

Zone 4 235-145mm

Leptospermum and Cyperaceae pollen rise but this is short lived and may have been due to a temporary blockage of the drainage system. Coriaria pollen also rises and falls at the base of the zone following the deposition of the Kaupokonui tephra. There are some changes in podocarp pollen, D.cupressinum rises but other podocarps except P.taxifolia

decline.

Zone 5 145-0mm

The pollen profile in this zone is strongly influenced by European farming. Swamp tree pollen, particularly D.dacrydioides declines and Potamogeton disappears from the spectrum. At the same time Gramineae and pasture weed pollen increase. In this percentage data lowland forest pollen continues to be represented but comparison between Figs. 20C and A shows that it has in fact been reduced by the farming activities. It is also possible that disturbance at this site may have remobilised older pollen as suggested by the solitary appearance of Lagarostrobos and the possibility of regional pollen from Egmont National Park can not be ruled out. Gr/cm³ data would have been useful to compare the data before and after European settlement.

3.4.5 Ratapiko swamp: N109/875728 at 180m: A 690mm core containing several tephric layers was collected. The lowest of these is regarded as redeposited Inglewood Tephra. The Manganui tephra is positively identified by its scoriaceous lapilli. Above the Manganui are three lapilli layers comparable with those found in the Midhurst 1 core. Alien Pinus pollen just above this layer, indicating commencement of European settlement, confirms them as the Burrell Lapilli. The uppermost tephric layer is 6mm of fine pumiceous sand redeposited during the drainage of the swamp that occurred in European time.

This site is approached through a farm on Mangatea Road across Mangaotea Stream. The swamp has been drained and is now in pasture. The pollen diagram is divided into 4 zones of which zone 2 is sub-divided. Zone 4 is strongly influenced by European farming and the

upper 155mm of the profile is presented separately in Fig.21F.

Zone 1 690-565mm

The base of the core is loose, largely undecayed fibrous organic material. Bulk density values are high in the first four samples suggesting influence by a sedimentary factor (Fig.21B). Typha pollen is prominent among the swamp taxa. A sharp change occurs in the next sample above when a large amount of organic material reduced the total pollen concentration. Above this organic layer lies the redeposited Inglewood tephra.

Zone 2 565-395mm

Between this band of redeposited tephra and the Manganui tephra the peat is compacted, twigs are present, bulk density values are low and the pollen curves are independent. The sedimentation rate is 0.15mm/yr calculated on the basis of a 1075 year interval. This zone has been divided into two sub-zones.

Zone 2A 565-495mm

At 565mm Typha values are high (Fig.21A) but as this pollen decreases in the next sample, D.cupressinum and Leptospermum pollen rise followed by a reversal of these changes. The non-mire to mire ratio in Fig.21E (% data) shows that mire plants reach their highest representation at this level.

Zone 2B 495-395mm

Pollen concentration is low in the basal sample due to the very large amount of organic matter. Death of some mire plants, possibly Phormium may be indicated. Towards the top of the zone Typha, Cyperaceae and Potamogeton are all reduced. These changes coincide with the first appearance of Taraxacum pollen. As this is below the Manganui tephra this is due to contamination. This core was sampled using the whole

10mm slice from the half core and taking a representative sample. This method was abandoned.

Zone 3 395-225mm

Between the Manganui tephra and Burrell Lapilli (3125-295 yr B.P.) there is less than 50mm of peat. Both D.cupressinum and "Tree" pollen rise during this interval. Sedimentation rate is a very low 0.02mm/yr and suggests the site may have been much drier during this period. The ratio of non-mire to mire plant pollen (% data) remains fairly constant throughout this zone showing that the environment in general was stable, although it is possible that with slow peat growth changes would not be detected by the sampling interval used. Above the Manganui tephra Typha pollen declines steadily and is replaced by Cyperaceae pollen, a trend which continues into European time and shows that part of the original Typha swamp became a sedge/shrubland.

Zone 4 225-0mm

Changes in the pollen spectrum in this zone are related to European activity. Replacement of swamp by pasture is seen in low values for swamp trees (Fig.21F) and the decline of Leptospermum while Gramineae and Cyperaceae rise steadily. Typha which had very high values in zones 1 and 2 has only traces here. Podocarpus pollen is very low and the decline of Pteridium in the uppermost sample is an indication of success in establishing pasture.

In the forest community data and the non-mire to mire plant pollen ratio (Fig.21D) minor changes occur from one sample to the next both within taxa and between taxa, but no long term trends are apparent. In the grains/cm³ data (Figs.21 B and C) there is a distinct difference in the curves below and above the 500mm level.

3.5 WESTERN POLLEN SITES

Five sites on the western side of the volcano contain tephras, but none of these are from high altitudes. Two soil cores collected from the Puniho Track at 420 and 370m are the highest sites and they only contain very recent deposits. Of the other three, one probably has a paraconformity near the base (Pollard), but all three supplement each other in recording climatic changes over the last 4000 years. The zonation of the pollen diagrams of these three cores is on the basis of climatic change.

TABLE XVIII LOCATIONS AND SAMPLING DATA, WESTERN SITES

Site name	Code	Grid Ref.	Alt.	Depth	Type	Dated	Tephras
		N118	m	mm	#		Present
Puniho 1	83/10	549664	420	110	C		P
2	83/11	548664	397	160	C		P
Jones 1	83/6	445661	152	380	C		NA, K.
3	83/8	449668	137	575	C		NA, K, I.
Pollard	83/9	414657	91	500	C		K

C = Core P = Puniho Lapilli, NA = Newall Ash,

K = Kaupokonui tephra I = Inglewood Tephra

TABLE XIX NEW RADIOCARBON DATES, WESTERN SITES.

Site name	Grid Ref.	Depth	NZ RC	Age	Material
	P20	mm	No:	yrs B.P.	dated
Jones 3	829158	42-45	6705	2750 ₋ 60	peat, twigs
Pollard	807149	188-260	6918	795 ₋ 60	Podocarp seeds
		410-413	7007	11900 ₋ 950	wood #
		480-490	6907	9350 ₋ 730	peat

Identified by Dr.R.N.Patel as Dacrydium or Podocarpus

3.5.1 Puniho Track

The Puniho Track continues into Egmont National Park from Puniho Road. The area in which the two cores were collected was devastated about 100 years ago either by a lateral blast, pyroclastic flow or pyroclastic surge.

3.5.1.1 Puniho 1: N118/549664 at 420m: A short core was obtained in forest soil, clumping was encountered during processing (2.3.2) and the core was re-sampled. Clumping increased in severity with depth and was most severe at 65mm where bulk density values rise. At 95mm there was very little organic matter but pollen was well preserved. Charcoal, present in all samples, had maximum value at 65mm, suggesting that the underlying deposit had been emplaced by a hot flow.

This site lies just to the north of the track in an area of young regrowth. The present vegetation is almost entirely saplings from 2-3m high and 30-70mm in diameter including Pseudopanax crassifolia, Knightia excelsa, Weinmannia racemosa, P. ferruginea, Geniostoma ligustrifolium and Coprosma australis. Dicksonia and Astelia were also common. Fig. 24A and B include the pollen spectra of Puniho 2 set out below those of Puniho 1. The data have been graphed in the same positions and scale for ease of comparison. Because these are soil cores it is possible that the higher values nearer to the surface could represent the typically higher pollen concentration as discussed in section 1.10.5.1. The curves however, do not vary synchronously and therefore the pollen spectra portray forest regrowth after the volcanic activity of c. 100 years ago.

The pollen profile is dominated by the steeply rising curve of Weinmannia together with D.cupressinum and M.robusta. Phymatodes has unusually high values which rise steadily and indicate an increase in epiphytic sites. Blechnum values are also high, both these ferns are often associated with Beilschmiedia tawa. Tree and ground fern spores are abundant. Pinus occurs down to the 65mm level.

3.5.1.2 Puniho 2: N118/584664 at 397m: This core was also resampled due to clumping problems. Charcoal values are high at the base, peak at 95mm then decline steeply, possibly reflecting their origin in the pyroclastic flow material. Density values show little change until the uppermost sample.

This site is about 200 metres to the northwest of Puniho 1 in an area where there are many fallen trunks, and where former branches of W.racemosa have developed into trunks. Weinmannia is the most common tree, other species present are Pittosporum eugenioides, Myrsine australis, Myrsine salicina and Quintinia. Ferns present were the epiphytic Trichomanes reniforme and the ground ferns Asplenium bulbiferum, Blechnum minor/capense group, Paesia scaberula and Rumohra and the liane Ripogonum.

Coriaria pollen rises at 95mm but declines at 35mm and Panax group pollen has a similar pattern. Weinmannia has a large rise between 95 and 65mm and then continues to rise. Shrub pollen is more prominent at this site and ferns less so compared to Puniho 1, although Phymatodes and Blechnum spore values are high. A feature of both pollen spectra is the temporary disappearance of the pollen of all podocarp species

just above 45mm in Puniho 1 and 95mm in Puniho 2, this occurs in European time.

3.5.2 Jones' Farm 1: N118/445661 at 152m: The Kaupokonui tephra and Newall Lapilli were identified in this core. Neither has a very strong expression here. The Kaupokonui eruption was directed to the south east and the Newall Lapilli are small and scattered.

A short core of 380mm was retrieved from the edge of a Typha swamp located in a small depression, presently surrounded by pasture on the farm of Mr Peter Jones, Newall Road. A small Pinus plantation was established about 10 years ago. Degraded forest covers one hillside. Melicytus ramiflorus is the most common tree but all specimens were wind-shorn or salt-burned on the seaward side. Other species included D. dacrydioides, Laurelia novae-zelandiae, Cordyline australis, Pseudopanax crassifolius, and several Coprosma. Earina autumnalis and Pyrrosia serpens were noted, the latter being abundant. Metrosideros perforata, M. diffusa and Freycinetia were also present. The lower half of this core is from forest soil and the low pollen concentration may be due to poorer conditions for pollen preservation. The pollen diagram has been divided into three zones on the basis of climatic change.

Zone 1 345-245mm

This pollen spectra indicate lowland forest but the representation of each taxa is very small. High values of Potamogeton indicate flowing water close by. Abundant spores of several species of tree and ground ferns and Astelia indicate a marshy fern grove. Ascarina has a high value at the top of this zone. Kaupokonui tephra is present in this

zone, but no changes in the pollen profile are apparent.

Zone 2 205-145mm

Scattered Newall Lapilli in this zone date it at 400 yr B.P. The pollen profile indicates recovery of the forest, M.robusta increases and Weinmannia appears in the spectrum for the first time. Ascarina rises after a lower value at 205mm. The abrupt rise in the pollen counts of all taxa at 145mm is probably related to a high concentration of pollen at the soil surface (1.10.5) which was subsequently preserved by rapid sedimentation following erosion after forest clearance. In the % data Coriaria has higher values after the Newall Lapilli than in zone 1.

Zone 3 145-0mm

The clearance of forest in European time is clearly illustrated by the absence of tree and sub-canopy taxa pollen which coincides with the appearance of Typha pollen, disappearance of Potamogeton pollen and presence of Pinus and pasture weeds. The edaphic changes were severe from free flowing water to the impeded drainage of a Typha swamp. Low pollen concentration data in this zone are related to forest clearance (Fig.25A). The % data (Woody spp. only) shows a rise in D.cupressinum and shrubs in this zone, but the absence of subcanopy species pollen, epiphytes and lianes (except for Metrosideros) indicates very degraded forest. Regional pollen from Egmont National Park must be considered.

3.5.3 Jones' Farm 3: N118/449668 at 137m: The core contains the Inglewood and Kaupokonui tephras and scattered Newall Lapilli. A radiocarbon date obtained from peat and twigs between 420-450mm gave an age of 2750 \pm 60yr B.P. (NZ6705) and confirmed the identification of the Kaupokonui tephra above this deposit.

This small remnant of swamp forest on the same farm has been fenced off so that cattle have not had access to it over the last decade. Plants close to the coring site were Cordyline australis, Melicactus ramiflorus, Dicksonia tree ferns, Carex and Phormium tenax. Metrosideros diffusa, Freycinetia and the ground fern Asplenium bulbiferum were abundant. About 20-30m away Leptospermum surrounded a small area of Typha swamp. This site is on flatter ground than Jones' 1 and the pollen profile indicates that there has always been forest near the site. The pollen diagram is divided into 6 zones on the basis of climatic change.

Zone 1 565-505mm

An unusual feature of the pollen profile is the exceptionally high values of Ascarina pollen which persist in the profile for over 2000 years. Pollen curves of Ascarina, D. cupressinum and Schefflera rise, while those of podocarps and Nestegis are slightly out of phase but show the same general trend. The Inglewood Tephra (3800 yr B.P.) is present at the base, podocarp pollen and Coriaria rise within the tephra suggesting that the tephra caused some damage.

Zone 2 505-425mm

From peak values at 505mm the pollen curves of all the above species decline, again Nestegis is slightly out of phase (Fig. 26B and C). A radiocarbon date (NZ6705) has been obtained from peat between 420-450mm giving an age of 2750 \pm 60 yr B.P.

Zone 3 425-375mm

All the above species increase steadily in this zone. Subcanopy and some shrub taxa are absent but regrowth species such as Leptospermum, Coprosma, Myrsine and Coriaria and the tree ferns Dicksonia and Cyathea also have a steady increase.

Zone 4 375-185mm

There is a steady decline of Podocarpus, D.cupressinum and Ascarina. Nestegis is absent after high values and Schefflera disappears from the spectrum. D.dacrydioides, Syzygium and Potamogeton disappear in this zone while Laurelia has variable values and Knightsia continues to rise. Cyperaceae has lower values, Gramineae is absent. Leptospermum has very similar values throughout this zone, a period of 1000 years, which is unusual for a seral species. Nothofagus pollen is completely absent between 395-185mm. Although this pollen is from a distant source it has a consistent presence in nearly all pollen samples analysed from the entire study area. Kaupokonui tephra was deposited at this time but appears to have had little effect.

Zone 5 185-155mm

Ascarina pollen disappears from the spectrum but the pollen of all the other drought-sensitive species rise. The zone is dominated by recovery from the deposition of the Newall Lapilli. Many sub-canopy and shrub species reappear after a long absence or sporadic appearances. Elaeocarpus, Rhopalostylis, Fuchsia and the Panax group of pollen are prominent among these. Nestegis reappears but at normal values. Weinmannia appears for the first time in the spectrum at 175mm and increases steadily. This zone is markedly different from all other zones.

Zone 6 155-0

Tree and sub-canopy species decline but Coprosma, Coriaria, ground ferns (Monolete fern) and Histiopteris spores increase. Ripogonum is abundant among several other lianes, and has unusually high values. The abundance of Phymatodes may be indicative of Beilschmiedia tawa in the vicinity. Alien pollen is present at 85mm and changes indicating

clearance of the forest occur abruptly.

3.5.4 Pollard's Farm : N118/414657 at 91m: An unnamed tephra overlies a strongly allophanic peaty loam at the base of this 500mm core which proved to have a late glacial pollen spectrum. Peat from the base of the core has been dated (NZ6907) at 9350(+730 yr B.P. Wood from below the unnamed tephra was dated (NZ7007) at 11900+950 yr B.P. which is older than the base of the core. It is assumed that younger roots have penetrated the basal peat as the later date would be in agreement with the pollen spectra of a late glacial flora. Podocarp seeds from peat between 188-260mm were also dated (NZ6918) at 795+60 yr B.P. and this confirmed the Kaupokonui tephra above. There is a paraconformity in this core just below the Kaupokonui tephra.

The core was collected from a small swamp forest remnant on Mr. J.H. Pollard's farm on the Main South Road just south of Pungarehu. The site is about 21km from Mount Egmont summit and 5km from the coast and lies by a stream between two lahatic mounds of the Pungarehu Formation deposited c. 23ka yr B.P. The tops of both mounds were fortified by Maoris either as pa or kumara storage pits. The forest site is almost impenetrably entangled with Ripogonum vines. Several trees of Corynocarpus laevis surround the site together with Cordyline australis, Melicactus ramiflorus abundant Macropiper excelsum and Dicksonia squarrosa, Muehlenbeckia and Metrosideros diffusa; all species indicative of degraded forest to which stock have access. The portion of the core above 345mm (Zone 3) is considered to be undisturbed.

Zone 1 485-435mm

This zone contains a pollen spectrum usually associated with a subalpine bog, Lagarostrobos, Gaultheria and Dracophyllum pollen is associated with Gleichenia fern spores and the mire plant Restionaceae. Lowland swamp forest taxa are also present as is Ascarina. Peat from the base of this zone dated at 9350 yr B.P. but contamination from younger roots is suspected here.

Zone 2 435-345mm

The transition from Late Glacial bog pollen, to temperate lowland forest, occurs with the synchronous decline of all cold climate taxa, in this zone. Dracophyllum, Gaultheria, Coprosma, Haloragis, Gunnera and Compositae all decline. Wood at the top of this zone gave a date of 11900 yr B.P.

Zone 3 345-305mm

The synchronicity of change in all taxa relates to changes in the bulk density of the samples and is due to the presence of Kaupokonui tephra (1400 yr B.P.). Most taxa have high values at the 305mm depth including Ascarina.

Zone 4 305-245mm

M.robusta and D.cupressinum decline as do Pennantia, pollen of the Panax group and all tree fern spores. Schefflera disappears from the spectrum. Swamp forest tree taxa pollen decline sharply and Cyperaceae pollen are sporadic. Potamogeton pollen disappears from the spectrum in this zone only. Shrub pollen is absent with the sole exception of Myrsine. Pollen of both Gramineae and Nothofagus disappear from the spectrum. The top of this zone is dated (NZ6918) by podocarp seeds from between 188-260mm at 795 ± 60 years B.P. This zone correlates with zone 4 of Jones's farm 3 pollen profile.

Zone 5 245-85mm

Recovery of the forest is indicated by increased values of those taxa already present in the spectrum and the reappearance of sub-canopy and shrub taxa, particularly the fern Histiopteris. Epiphyte and liane pollen, notably Tetrapathaea increases. Weinmannia appears for the first time in the spectrum in this zone and increases steadily. Pteridium spores rise very sharply at the top of the zone as do Coriaria and Coprosma suggesting some destruction of the forest.

Zone 6 85-0mm

Pinus and pasture weed pollen is present, Pteridium maintains the high values it had at the top of the previous zone and Cyperaceae values increase rapidly. Coriaria and Coprosma are still prominent.

3.6 NORTHERN POLLEN SITES

Four cores were collected at sites close to the northern coast of Taranaki. Of these two, Motunui and Matarikoriko, had known associations with Maori occupation. The third, Bowden Reserve is dominated by Corynocarpus laevigatus a tree prized for food by the Maoris. The fourth site at Umutekai Road is part of a very large swamp and it was hoped to obtain a core containing a record of the last 5000 years. Table XXV contains the details of the sites. No identifiable tephrae were found.

TABLE XXV LOCATIONS AND SAMPLING DATA, NORTHERN SITES.

Site Name	Code	Grid Ref.	Alt.	Depth	Type
		N109	m	mm	
Motunui	85/3	844944	30	730	Core
Bowden	83/12	715938	30	390	Core
Matarikoriko	85/4	806965	30	730	Core
Umutekai	85/5	704882	60	690	Core

3.6.1 Motunui: N109/844944 at 10m: A core of 740mm length was extracted from a Typha swamp surrounded by dairy farms about 1.3km inland from the coast. The swamp is not so extensive as formerly, having been drained, leaving flat bottomed gullies containing sedges and herbs. The Synthetic Fuel Plant has recently been built on the seaward side and this has covered a large area of former grassland. All plant material in the core was very fresh Typha. One section between 420-600mm contained such a large amount of organic material that there was insufficient pollen to provide valid counts. The core was sampled and processed at every other 10mm but because Pinus pollen was found in the basal samples indicating the youthfulness of the core, counting was restricted to every 100mm. Maori artifacts have been recovered from this swamp. Despite the present treeless nature of the vegetation the pollen spectrum contains up to 40 forest taxa in most samples (Fig.28B). This must be regarded as regional pollen, the source of which may be from older fluvial sediments or modern pollen rain from Egmont

National Park.

Typha and Cyperaceae pollen dominate the swamp spectrum (Fig.27A). There is a notable absence of Phormium pollen although it is now present in some parts of the swamp (this species is very under-represented in pollen profiles). Potamogeton pollen is present above 405mm. Total mire plant pollen (including Potamogeton) decreases above this level, while Gramineae, Pteridium, Taraxacum and other pasture weed pollen increases. Charcoal is present throughout the core with high values at 305mm and 105mm. Bulk density continues to rise from the base throughout the core. Pollen concentration values are low, this could be due to poor preservation at this disturbed site. It is also possible that it indicates that pollen is very scarce in this treeless landscape where the grass is grazed, further reducing the pollen rain.

In the % data (woody species only) high values of Coriaria and Coprosma and little tree pollen indicate disturbance. The large amount of organic matter at 505mm may be a result of drainage activities. Above this level the number of pollen taxa rises but this may be due to erosion of older deposits.

3.6.2 Bowden Reserve: N109/715938 at 30m: This small forest area is now a Scenic Reserve. It lies about 2.5km from the coast and about 1km from Bell Block and includes a small rise on the western side of Henwood Road. A cut drain lies at the foot of this rise and the coring site was just to the north of this drain. Marattia fern surrounds the site. Corynocarpus laevigatus dominates the degraded lowland forest and seedlings of this species are abundant. Other tree species present

are Dysoxylum spectabile, Laurelia novae-zelandiae, Syzygium maire, Melicytus ramiflorus and Alectryon excelsum while the shrub layer is dominated by Macropiper excelsum and the tree ferns Cyathea dealbata, C. medullaris and Dicksonia. Ground ferns include Asplenium bulbiferum, Blechnum bifforme and Lastreopsis velutina. In the herb layer Elatosema rugosum is abundant and Typha surrounds the cut drain.

Taraxacum pollen is significant throughout the spectrum indicating European farming in close vicinity to the site and it must be concluded that the pollen spectrum represents only European time. Fig. 29A shows the change in dominance of mire plants from Typha in the lower half to Cyperaceae in the upper. Potamogeton is present in most samples. Among swamp tree taxa, Laurelia is consistently present while Dacrycarpus dacrydioides, absent in the middle section, rises and then declines above 165mm. The rising curve of Knightsia is coincident with that of Typha pollen and Pteridium spores. Above 245mm there is a marked change in small tree pollens with Alectryon, Griselinia and Pennantia absent until the uppermost sample. D. cupressinum increases steadily and Leptospermum, Coprosma and Coriaria are consistently present. Above this level Dicksonia spores are partially replaced by Cyathea. Epiphytes such as Phymatodes and Lycopodium billardierii are a feature of the spectrum and several liane pollen types are present. Ripogonum and Muehlenbeckia pollen only appear above 85mm. Fig. 29C emphasises disturbance at 245mm when renewed farming activity caused changes in species composition. Coprosma has high values but Panax group pollen was severely reduced.

3.6.3 Matarikoriko: N109/806965 at 30m: A core of 730mm length was extracted from a site close to a swamp forest remnant situated on the upper terrace of the Waitara River, about 0.5km west of Mamaku Road and about the same distance from the Waitara Valley Methanol plant. A small cut drain lies to the north of the coring site and a stream flowing through it appears to originate from a spring near the base of a cliff leading to a higher terrace behind. The surrounding land is in pasture with Pinus shelter belts. This forest remnant has been covenanted to the Queen Elizabeth Trust and a full species list is available. In pre-historic times a Maori pa, called Matarikoriko, overlooked the site. One tephric layer present was tentatively identified as "scattered Burrell Lapilli" but the pollen spectrum indicates this was probably redeposited when the drain was cut. One small segment of the core 150-190mm had insufficient pollen for a valid count. The occasional presence of Dodonaea, Dysoxylum and Rhopalostylis in the pollen spectrum indicates that semi-coastal forest was present at this site over the time period that the core accumulated. (Clarkson 1985, Bayfield and Benson 1986 and Fig.4).

This pollen spectrum could be divided into two zones based on the swamp pollen (Fig.29A) but when the forest pollen is considered four zones are more appropriate.

Zone 1 725-695mm

Both Metrosideros robusta and D.cupressinum decline in the lower two samples while all swamp forest tree taxa have high values. Restionaceae pollen, probably Empodisma, only occurs in this zone. Spores of Cyathea smithii occur in the lower four samples.

Zone 2 695-495mm

Dacrycarpus dacrydioides has fluctuating values and then disappears from the spectrum after this zone. Laurelia and Syzygium decrease steadily while Knightia pollen increases towards the top of the zone. After a large value at the base of the zone M.robusta declines. D.cupressinum pollen shows a declining trend while Ascarina increases steadily, as do tree and ground fern spores.

Zone 3 495-215mm

Both M.robusta and D.cupressinum decrease after having single large values at the base of the zone. Elaeocarpus, Nestegis, Leptospermum, Coprosma, Lophomyrtus and Paratrophis all follow a rising then falling trend. Monoletic ferns spores increase as Cyathea pollen decreases. Ascarina has a single high value and then decreases and the spores of Pteridium rise.

Zone 4 215-0mm

Within this zone both swamp and lowland forest tree taxa decrease markedly but mire plants increase, Typha and Cyperaceae become prominent. These changes coincide with a prominent presence of Pinus and pasture weed pollen. Values are also high for Gramineae. Pteridium values decline abruptly at the base of this zone and then remain constant.

The % data (woody species only Fig.30C) suggest a major change occurred at 405mm. Below this level M.robusta, Lophomyrtus and Metrosideros are all prominent but then decline abruptly. Above 405mm Knightia, Elaeocarpus, Leptospermum, Coriaria, Paratrophis and Freycinetia all rise sharply. These are all species which respond to disturbance in the forest. This is well before European time and before the redeposited tephra. There is no charcoal in the samples, so a natural disaster must

be the interpretation of these changes.

3.6.4 Umutekai Road: N109/704882 at 60m: This site lies within a fairly large swamp forest remnant surrounded by pasture, and an extensive area of swamp surrounds a nearby lake to the south. No tephrae were macroscopically visible within the 690mm of sediment but during sampling lapilli were found in the 420-490 section. Above this level well-rotted wood fibres were present and proved difficult to wet at commencement of processing. Between 290-400mm the core contained a lot of twiggy material. While driving in the PVC tube to obtain the core, difficulty was experienced in getting it through a resistant layer and this may have been due to the mass of twigs and branches. Pollen was too sparse to permit valid counts in this section. Laurelia, Coprosma, Freycinetia and Ripogonum were common close to the actual coring site. The pollen spectrum of this site has the same semi-coastal forest elements as Matarikoriko.

The pollen diagram can be divided into three zones as follows:-

Zone 1 685-535mm

The prominence of Potamogeton and Cyperaceae pollen and the absence of Typha suggest open water within the area of swamp forest. Swamp tree pollen is prominent (Fig.34A) and all taxa reach high values at the top of the zone. A floristically rich lowland forest dominated by D.cupressinum and Prumnopitys taxifolia is also present. Among the shrubs Lophomyrtus has the highest values and is always present. Tree and ground fern spores are abundant in this zone. Spores of Phymatodes and L.billardierii indicate the presence of mature trees on which these epiphytes have established. Metrosideros pollen is the most abundant of

the liane taxa and increases steadily throughout this zone.

Zone 2 535-155mm

All tree pollen is lower, particularly podocarps. Sub-canopy taxa and shrub pollen is also reduced and the occurrence of some taxa is sporadic. Typha appears in the upper portion of this zone and swamp tree pollen declines. At 305mm Plantago pollen indicates the approach of European farming.

Zone 3 155-0mm

The spectrum is dominated by an upsurge in Gramineae and Freycinetia pollen. Pteridium spores coincide with the first occurrence of Taraxacum and higher values of Plantago. All these features indicate disturbance of the swamp forest and the commencement of European farming in the immediate vicinity. The forest tree taxa, particularly M.robusta and D.cupressinum show a steady rise before declining at 45mm. Ascarina present in zone 1 shows a steady rise before declining in the uppermost sample. Leptospermum, Fuchsia, Lophomyrtus and Panax group pollen show a similar rise and decline but Coprosma and Coriaria continue to rise. Dicksonia, Cyathea, Blechnum and monolet ferns spores all rise. Spectacular increases are also shown by Metrosideros and Phymatodes. High values of these lianes may indicate an open canopy and Phymatodes may be established on the trunks of B.tawa, not recorded in the profile.

The pollen profile indicates a stable forest with only minor changes in the pollen curves (Fig.31A-C) until European time when D.cupressinum and M.robusta decline. Coriaria is never prominent but has a slight rise at this time. The pollen curves of Laurelia and Syzygium show by their decline, a long term change from a wetter environment, but

after the break in the profile they increase again.

3.6.5 Charcoal Data: Table XXX gives charcoal abundance data for all lowland sites except for Messenger's Farm site which is pre-Maori. Sites within Egmont National Park (Potaema, York, Norfolk and Puniho 1 and 2) have charcoal throughout their profiles. It is not possible to state on the present evidence whether this is solely due to volcanic activity, but the absence of charcoal except in trace amounts from all the eastern ring plain sites would appear to indicate that this is the case. It is apparent from the charcoal data that fire has been a component of the ecosystem in this area for at least the last four hundred years.

On the western side both the Pollard and Jones' 3 cores have considerable charcoal present consistently in five samples below the first palynological indications of European settlement. In Jones' farm 1 and Jones' farm 3 cores this charcoal is associated with the scattered Newall Lapilli. The proximity of these sites to the outer limits of the Newall eruptions suggests that the cause of this charcoal was the nuée^s ardentes of c. 400 yr B.P.

In the Pollard's farm core a possible date for the 125mm level, (based on the date of 765 ± 60 yr B.P.) at which the first of the persistent charcoal appears is 520 yr B.P. (based on a sedimentation a rate of 0.24mm/yr). Using the Kaupokonui tephra as a datum gives a date of 678 yr B.P. (based on 0.19mm/yr) which is still consistent with the dated seed deposit. This suggests that some charcoal pre-dates the Newall eruption and must be attributed to Maori fires. Of the four

TABLE XXXI_a CHARCOAL VALUES FOR LOW ALTITUDE CORES

Site	P	Y	N	P1	P2	M1	M2	NG	R	J1	J3	PO	U	MA	B	MO
Alt.	675	548	548	420	397	285	285	210	180	152	137	91	60	30	30	<30
	0.7	1.9	0.3	2.5	-	1.6	4.1	5.5	3.6	1.1	1.3	3.4	2.1	9.6	6.5	10.7
	0.7	1.3	1.3	2.4	1.0	1.6	2.1	5.5	1.9	.	1.7	3.5	0.5	8.5	3.5	.
	0.8	2.1	1.4	2.5	3.8	1.6	3.4	5.7	3.3	2.0	1.4	0.7	1.8	3.0	2.0	.
	1.7	3.5	1.3	5.3	11.3	3.0	2.0	2.7	3.9	.	0.9	2.4	0.7	3.0	3.1	.
	0.9	1.1	2.0	2.5	9.6	1.3	0.7	2.4	2.3	1.8	1.4	2.9	0.7	8.3	2.2	.
	0.8	1.6	2.2	1.4	9.2	2.2	0.8	2.7	1.7	.	1.7	1.9	0.9	9.1	2.4	22.6
	2.1	1.3	2.5			3.0	0.4	3.4	2.9	2.7	0.3	0.4	0.7	20.8	1.9	.
	1.0	0.7	2.1			1.7	-	2.1	4.0	.	T	-	0.5	14.5	1.8	.
	0.4	0.1	1.7			1.0	0.4	1.1	4.6	0.7	T	-	0.1	11.5	1.8	.
	0.9	0.1	2.3			0.5	T	T	1.3	0.9	0.5	-	-	8.8	6.8	.
	0.6	-	2.3			-	-	T	0.9	0.8	-	-	-	6.7	7.6	8.2
	0.2	1.1	1.8			-	T	T	T	T	-	-	2.9	7.0	6.2	.
	0.4	0.7	1.8			-	T	T	T	T	-	-	-	7.4	3.5	.
	0.7	0.6	1.7			-	0.6	-	-	-	-	-	-	3.1	3.2	.
	0.2	-	1.1			-	1.1	-	-	-	-	-	-	2.3	2.5	.
	0.7	-	1.3			-	T	-	-	-	-	-	-	2.7	5.8	13.1
	0.4	-	0.2			-	-	1.4	-	-	-	-	0.9	1.6	4.8	.
	3.2	-	0.4			-	-	-	-	-	-	-	-	2.6	3.3	.
	3.3	0.5	1.1			-	-	T	-	0.6	-	-	-	0.8	4.1	.
	4.4	0.4	1.7			-	-	T	-	-	-	-	-	-	4.1	.
	14.4	0.8	2.0			0.8	-	-	-	-	1.4	-	-	-	-	3.8
	2.4	T	1.8			-	-	-	-	-	-	0.7	-	-	-	.
	0.9	1.1	1.2			-	-	-	-	-	-	0.9	-	-	-	.
	0.4	0.5	1.6			0.9	-	-	-	-	-	2.0	-	-	-	.
	1.7	0.8	3.6			-	-	-	-	-	-	2.5	-	1.1	-	.
		0.7	3.5			-	-	-	-	-	0.6	-	-	-	-	4.2
			1.1			-	-	-	-	-	-	-	-	-	-	.
			0.8			-	-	-	-	-	-	-	-	-	-	.
			1.6			0.7	-	-	-	-	-	-	-	-	-	.
			0.3			-	-	-	-	-	-	-	-	-	-	.
						-	-	-	-	-	-	-	-	-	-	4.5
						-	-	-	-	-	0.6	-	-	-	-	.
						-	-	-	-	-	-	-	-	-	-	.
						-	-	-	-	-	-	-	-	-	-	.
						-	-	-	-	-	-	-	-	-	-	.
						-	-	-	-	-	-	-	-	-	-	7.5
						-	-	-	-	-	-	-	-	0.4	-	.

P=Potaema, Y=York, N=Norfolk, P1=Puniho 1, P2=Puniho 2, M1=Midhurst 1, M2=Midhurst 2, NG=Ngaere, R=Ratapiko, J1=Jones 1, J3=Jones 3, PO=Pollard U=Umutekai, MA=Matarikoriko, B=Bowden, MO=Motunui. T=Trace

+ - = No charcoal, . = Scan only, Alt. in metres, - = European time.

northern sites, only Matarikoriko has persistent charcoal below European level, between 300-360mm, which could be due to Maori fires. It is not possible to accurately date this section of the core.

3.6.6 Climatic Indicators:

Climatic change, to be discussed in Chapter 6, is interpreted from changes in the pollen spectra of two species, Ascarina and Weinmannia. Data from several sites has been summarised in two pollen diagrams. The only common datum, for those sites in which Weinmannia (Fig.34) is prominent, is the first appearance of Pinus, for which the accepted date is 1860 A.D. Stratigraphic columns, identifiable tephras and radiocarbon dates are available, for sites in which Ascarina lucida pollen is important, these are presented in Fig.35.

CHAPTER 4

CHANGES IN VEGETATION DUE TO VOLCANIC ACTIVITY.

4.1 INTRODUCTION

The 22 fossil pollen sites examined here contain tephras deposited over the last 4000 years. Sites containing a record of the last 500 years are largely confined to the eastern side of Mount Egmont. Debris and pyroclastic flows have swept across the northwestern flanks of the volcano burying the former landscape with 15km² of volcaniclastics (Neall and Alloway 1986). Tephras deposited in other areas are older than 5000yr B.P. (2.2.1). Reports of damage after volcanic activity in New Zealand and overseas have been reviewed (1.6) and accounts of recovery, particularly recent literature from the Mount St. Helens eruption, have been studied (1.7). No information is available on the interpretation of pollen spectra as indicators of vegetation damage. Some assumptions have had to be made. A sharp decline in pollen values following deposition of a tephra has been interpreted as vegetation damage. This is usually followed by a rise in most taxa, interpreted as recovery. The exception to these patterns is Coriaria where a high value frequently follows immediately after the tephra. Nitrogen fixing species of this genus are recorded from unstable sites on Mount Egmont (Neall 1973, Clarkson 1981) and from Mount Tarawera (Burke 1964). It is recognised as a pioneer plant on open sites (1.7.2).

Tephras older than c. 1500 yr B.P. however, have been compressed together with peat that developed above them so that recovery patterns

and the rise in Coriaria occur within the tephra layer. At high altitudes, changes in the pollen profile indicating the earliest stages of recovery may be masked by slow growth of plants and low sedimentation rates. As recognised in a pollen profile, recovery represents a return to pollen production which only requires development of flowering buds. Recovery from structural damage such as broken branches or wounds may take much longer and traces of this damage will be visible for many years after the event (Burke 1964). There may also be delayed deaths due to infection of damaged structures. Recovery, particularly at high altitude sites, is frequently interrupted by further volcanic activity, which may disturb or displace buried soils, destroying the pollen record. Despite these difficulties the Stratford Mountain Road site contains information from about 3500 yr B.P. and an almost complete record from 2000 to 400 yr B.P. Three sites at Manganui bog have a detailed record for the last 400 years. An advantage of high altitude sites is that pollen carried by updraft indicates changes in vegetation zones at lower altitudes as well as information about the immediate environment.

When all the sites are considered together it is possible to build up an overview of the effect of any one tephra on the vegetation. Discussion of vegetation change due to volcanic activity has therefore been developed here from an historical viewpoint. The distributions of those tephras for which isopach maps are available are shown in Fig. 2 of Chapter 1, while the present tephrochronology of the last 4000 years is given in Tables XXXI and XXXII

TABLE XXXIb RADIOCARBON DATES, MT. EGMONT TEPHRAS, LAST 4000 YEARS.

Name of Site	Age yrs B.P.	NZ RC Number	Comment
Newall Ash	404 \pm 44	NZ941A	Charcoal Log (Neall 1972).
Kaupokonui tephra	1390 \pm 150	NZ6508A	= Druce's P4 (1966) lies above this dated material. Neall and Jansen (1984)
Pyroclastic Flow	1980 \pm 60	NZ3886A	Unpublished
Manganui tephra	2890 \pm 100 3320 \pm 60	NZ3423A NZ3139A	Tephra lies between the two dated deposits.
Inglewood Tephra	3610 \pm 80 3950 \pm 50	NZ3353A NZ5527A	= Druce's P2 (1966) Tephra lies between the two dated deposits.

TABLE XXXII TEPHROCHRONOLOGY OF MOUNT EGMONT, LAST 400 YEARS.

Name	Date A.D.	Evidence for proposed date.
Tahurangi Ash	1755	Sedimentation rate in peat less 25%
Puniho 2	1655	Tree ring count of one
Puniho 1	1655	<u>Pseudopanax colensoi</u>
Burrell Lapilli	1655	Dendrochronology (11 cores from 9 trees, 2 species).
Burrell Ash	1655	Discussion on buried soil/litter (Page 16) in Druce 1966.
Waiweranui Ash/ Lapilli Newall Ash and Lapilli	1604	Dendrochronology based on 3 trees, 2 species (Page 32). <u>Revised to 1500-1550 A.D. (Neall 1972).</u>
Source Druce (1966)		

4.2 EFFECTS OF INDIVIDUAL TEPHRAS

4.2.1 Inglewood Tephra: As shown in Fig.2A the main axis of distribution of this tephra lies to the north of Mount Egmont. Lapilli were found at Ngaere swamp 32km to the southeast and at Jones' farm 3 on the western side of Mount Egmont close to Newall Road. At both sites Coriaria rises within the tephra and peat layer (Figs.20B and 26B). D.dacrydioides rises within, this and subsequent tephras at Ngaere swamp. Suggesting changes in water levels permitted some encroachment of trees onto the swamp. Above the Inglewood tephra at Ngaere D.dacrydioides and Cyperaceae decline while Potamogeton disappears. Other tree pollen rises which suggests that the environment became drier (Fig.20C). Samples from within the Inglewood tephra at Jones' farm 3 show that D.cupressinum, M.robusta and some subcanopy taxa have a rising trend which can be assumed to be recovery after damage. As the tephra forms the basal deposit in both cores no comparison can be made with pre-tephra values.

Changes within the tephra at Ngaere and Jones' farm 3 sites, which are at a considerable distance from the main axis of distribution (Fig.2A), suggest that closer to the main axis, damage would have been very severe. Unfortunately Ratapiko was a Typha swamp and it appears that Typha peat does not become compacted as much as other peats. Ratapiko, Jones' farm 1 and Motunui all have fibrous organic material in the stratigraphic column when Typha is abundant in the pollen profile. At both Ratapiko and Motunui this prevented the coring device reaching older sediments and the expected layer of Inglewood tephra was not found at Ratapiko.

Many tributaries on the northern flank of Mount Egmont join the Manganui River, which also drains the Ratapiko swamp (Fig.36, large map in Vol.II). Lahars deposited after this tephra could have been channelled down this river impeding drainage of the swamp. High values of Potamogeton at this time in the Ratapiko profile suggests open flowing water. Typha an under-represented species, also has very high values indicating a large area of swamp. A thin band of fine pumiceous sand between 570-584mm is assumed, because of its position in the stratigraphic column, to be redeposited Inglewood Tephra following adjustment of water levels in the swamp. Being redeposited it had no effect on the vegetation. The age of this layer (j) is unknown.

4.2.2 Manganui Tephra: This tephra dated c. 3125yr B.P. was found at Stratford Mountain Road 82/4, and overlies the lahar deposit at Messenger's Farm, but neither of these sites provides a pollen record of the event. It was also found in both Ngaere and Ratapiko swamps. At the former D.dacrydioides and P.totara rise and decline within the tephra. Indications of damage to the forest are seen in the rise of Coriaria, Leptospermum, Nestegis and a little later Knightia and Gramineae. All these species respond to opening up of a forest canopy. A decline in D.dacrydioides indicates readjustment of the water levels as compaction occurs. At Ratapiko it was possible to obtain valid pollen counts within the deposit as the lithic lapilli were scattered. Severe damage would be unlikely with this amount of lapilli and no changes are seen. Both sites have very low sedimentation rates following the deposition of this tephra and details of subsequent changes are masked by slow development of peat.

Lithic lapilli of the Manganui tephra were erupted from Fantham's Peak accompanied by basaltic lava flows, an unusual occurrence on this andesitic volcano (Neall and Alloway 1986). Lahars, mapped as the Ngatoro Formation (Neall 1979) deposited about 3300 yr B.P., were channelled down the Manganui River and again affected the drainage at Ratapiko swamp. A slow sedimentation rate and decline of mire plants indicates a drier environment at Ratapiko after this volcanic event (Fig. 21A). The mire to non-mire ratio (% data Fig. 21E) shows that many adjustments occurred. The high value of mire plants after the redeposited tephra is followed by a lower value just prior to the deposition of the Manganui tephra.

Between the Manganui (c. 3125 yr B.P.) and Kaupokonui tephras (c. 1400 yr B.P.) 12 layers were identified at the Stratford Mountain Road site 82/4 (Table IX). The paucity of taxa and replacement of dominant taxa by another after each event suggests highly unstable vegetation and it is difficult to envisage the upper slopes of Mount Egmont as anything but bare of vegetation at times during this long interval. High values of Gramineae suggest that there may also have been some extension downslope of the tussock zone. Charred tussock and twigs below one pyroclastic flow have been dated (NZ3886A) at 1980 \pm 60 yr B.P.

4.2.3 Kaupokonui Tephra: The Kaupokonui tephra is preserved as lapilli At Stratford Mountain Road (82/4), Ngaere swamp and Midhurst 1 on the east. On the west it is found as weathered lapilli (or ash?) at Jones' and Pollard's farm sites. Stratford Mountain Road site, prior to this eruption, was dominated by Dracophyllum with some Coprosma and

Myrsine also present. Pollen of the latter two shrubs was much reduced but Dracophyllum appears to have survived the fall of lapilli. "Coarse pumice and rock fragments" fell through branches of conifer saplings on Mount St. Helens without adhering to the foliage (Antos and Zobel 1982). The springy branches and needle leaves of Dracophyllum may have escaped damage in the same way (1.7.2).

This tephra is much younger than the previous two and is less compacted. At Ngaere swamp Coriaria is present within the tephra and increases above it. Other pollen taxa to rise are Cyathea, Leptospermum, Nestegis and Elaeocarpus. D. cupressinum also rises but podocarp pollen declines. These changes indicate damage to canopy trees by the lapilli, creating light gaps in which these subcanopy species could expand. This tephra was erupted to the southeast so Midhurst 1 site suffered less damage. Coriaria is present unchanged within the tephra but disappears after it. Coprosma and Myrsine are more prominent than Coriaria at this time. The pollen profile indicates lowland forest dominated by D. cupressinum.

All three western sites (Jones' farm 1 and 3 and Pollard) contain the Kaupokonui tephra but it is not clearly expressed. Jones' farm 1 core has a very low total pollen count throughout the profile. This may be because the lower portion is essentially soil, subsequently a Typha swamp developed but the forest was cleared at this time and the source of forest pollen removed. At Jones' farm 3 values are higher but many sub-canopy pollen taxa are absent from the profile at this time. D. cupressinum declines more quickly but this is only a slight increase on the general downward trend begun by this species, Ascarina

and some subcanopy taxa. There is no recovery pattern shown in the pollen profile after this tephra. In the Pollard core the deposit below this tephra cannot be dated with confidence. There is a steady decline in subcanopy, tree and ground ferns from the peak values at 305mm and no pattern of recovery. Climatic factors dominate the spectra at these western sites in the upper two thirds of the pollen diagrams.

4.2.4 "Layered Fine Ashes": The pollen spectrum in the lower of two samples from this layer (g) has high values of forest taxa derived from the lower forest zones and perhaps also from the ring plain. The upper of the two samples had very few pollen grains and in the next sample above, all values are lower than before the ashes. The only exception is the monolete fern spores which have a spectacular rise (Fig.13A and C). From this data and the recovery pattern above, it would appear that these ashes caused widespread damage however, when the influence of monolete spores is removed (by using only woody species in the pollen sum) the interpretation is quite different. Here only Dracophyllum among the subalpine shrub pollen is reduced (Fig.13B). The small value of Coriaria at this time compared to values after deposition of earlier tephras could suggest that little damage occurred. (Clarkson 1981) thought that Dracophyllum preceded Brachyglottis elaeagnifolia in the succession within the subalpine scrub. All other shrub pollen trends are unchanged. It must be concluded that these ashes did not cause much damage and the rise in monolete fern spores is a local over-representation in samples where pollen is scarce.

4.2.5 Newall Ash: The only eastern core in which Newall Ash has been positively identified is Manganui 3. Here there is no indication of charring and these two layers of fine ash are interpreted as lateral cloud deposits. Most taxa rise in the first two samples after the deposition of these ashes in Manganui 3 (85/1). Higher values of Coriaria decline again just before the Burrell Ash. P.hallii shows a marked rise above this tephra, these changes indicating that some damage occurred. At Stratford Mountain Road (82/4) the coarseness of the sampling has not recorded a post-tephra spectrum.

The lack of definitive dates for the base of the Potaema, York Road and Norfolk Road bogs presents a difficulty in interpretation. The thin layer of sand at the base of the Potaema core was provisionally identified as Newall Ash. It is not like the lateral cloud deposit of Newall Ash identified in Manganui 3. Since this layer (h) forms the base of the core a pre-tephra spectrum for the Newall Ash is not present. On the bog, Leptospermum and Cyperaceae rise and most forest taxa increase immediately after the tephra, but Coriaria does not rise until later.

A deeper core extracted from Potaema bog (McGlone et al in litt.) indicates that after the Newall eruptions Libocedrus and Cyathea decreased but Pteridium spores increased. Leptospermum pollen which already had high values, increased, and in a later sample Coriaria pollen rose to 35%. This delay in the expansion of Coriaria was attributed to slow dieback of a badly damaged canopy which led later on to substantial gaps in which Coriaria became established. On the basis of this evidence it could be suggested that the recovery pattern seen at

the base of Potaema 83/2 profile was due to damage by the Newall Ash. This could possibly be extended to the York Road and Norfolk Road profiles where rising pollen curves at the base also occur. The increase in mineralisation due to inwash at these bogs could be due to erosion of bare slopes above. Deeper cores and radiocarbon dates are required before firm conclusions can be drawn.

The Newall eruption deposited ash and lapilli across the northwest quadrant of Egmont National Park (Fig. 2B). Scattered Newall Lapilli were identified in the two Jones' farm cores, dispersed through peat and not as distinct layers. At both sites recovery patterns are prominent in the pollen profile. At Jones' 1, an initial decline in all taxa is followed by a steady rise from 145mm and the highest values recorded for most taxa are achieved just before destruction of the forest by Europeans. At Jones' farm 3, taxa already present recover rapidly and those subcanopy taxa, previously absent from the profile, reappear so that a species-rich forest developed quite rapidly. The rapidity of recovery and enrichment of the forest flora may be due to the fertilising effect of ash from the widespread fires recorded by Druce (1966) but may also be partly due to a change in climate, which is indicated at this site at this time.

During the processing of samples from the Pollard core, fine lapilli were found in the upper portion (188-260mm) of the peat section. Seeds from this peat were dated (NZ6918) at 795 ± 60 yr B.P. This date must be regarded as an average for the 72mm of peat. The pollen spectra indicate recovery, particularly of M. robusta, at this time. The fine lapilli are interpreted as deposits from the Newall

eruptions. This site is nearer to the coast than Jones' farm and further away from the summit of Mount Egmont. A striking feature of all three cores is the sudden appearance of Weinmannia at this time and its rise to prominence after the Newall eruptions following a virtual absence. Waiweranui Ash and Lapilli have not been identified.

4.2.6 Burrell Ash: None of the Manganui cores contains both pre- and post-tephra records of the Burrell Ash. Manganui 1 (Fig.7A) contains an organic layer above the Ash and values of most taxa are slightly higher than after the Burrell Lapilli which fell later, but there is no pre-tephra spectrum. Manganui 3 (Fig.9A) contains a pre-tephra spectrum in which Coriaria has decreased from higher values after the Newall Ashes. Generally values are lower than in the sample preceding the Ash. This is due to the difficulty in identifying the precise boundary between peat and Ash. The presence of the ash may influence the gr/cm^3 data.

Druce (1966) showed that Burrell Ash and Burrell Lapilli were different stages of the same eruptive episode. Stratford Mountain Road (site 85/2) contains a distinct organic layer which Druce (1966) identified as "buried litter" (Table VIII in Volume II) between Burrell Ash and Burrell Lapilli. Druce also discussed whether or not this layer is a buried soil. The significant change in P.colensoi ($P < 0.05$) and the occurrence of local herb pollen and pollen of several subcanopy trees, none of which occur in the Burrell Ash, confirms that it is a buried soil (Fig.12A). A similar organic layer forms part of the uppermost sample at Stratford Mountain Road site (82/4). This pollen spectra likewise had increased amounts of P.colensoi, P.simplex and

dicotyledonous herbs (Fig.13A). P.colensoi appears at this stage after an apparent absence of 2000 years. Coriaria has a low value at the base of the Burrell Ash at site 85/2 (Fig 12A) and the same value in the lower of the two samples in the organic layer. In the upper sample this value rises and indicates that the Ash caused some damage and also that some time elapsed between the two samples.

In the Potaema core an organic-rich layer (f) is present between the Burrell Ash and the Burrell Lapilli. Changes seen in this organic layer after the Burrell Ash include a rise in Coriaria and a decline in total trees, epiphytes, lianes and fern spores. There was a small rise in shrub pollen. Pollen of Cyperaceae is absent after having been prominent and Leptospermum is reduced. These values are different to those after the deposition of the Burrell Lapilli and the amount of change suggests there was a substantial interval between the deposition of these two tephras.

The isopach map of this tephra (Fig.2D) is very similar to that of the Newall deposits (Figs.B and C). Although the directed component of the Newall nuée ardentes was very hot the Ash cooled as it was swept up to high altitudes prior to its deposition at Manganui bog. The Burrell Ash is now thought to be from a similar lateral cloud deposit. Damage would therefore be due to burial, as seen in the elimination of Cyperaceae. Or to adherence of the tephra, which may have caused the decline in most taxa. Charcoal is always present at this site (Table XXX in Chapter 3) and the high levels of charcoal below this Ash are thought to be windborne ash redeposited after the Newall fires.

4.2.7 Burrell Lapilli: The fossil pollen record for the Burrell Lapilli is the most complete. Comparison of the stratigraphic columns of the three Manganui cores (Fig.10) shows that thickness of deposits varies from site to site. At this cushion bog (Harris 1968) a high value of Cyperaceae and dicotyedonous herb pollen is interpreted as an Oreobolus pectinatus cushion. Lower, wetter areas between "cushions" contain mosses (3.2.1.). Profiles of the three Manganui cores vary greatly (Fig.11A) as does the thickness of Burrell Lapilli (cores 83/1 and 85/1) Fig.10. This is attributed to site 83/1, being a mossy pool (very low Cyperaceae and herb pollen Fig.11A) while 85/1 was a "cushion" at the time the Burrell Lapilli was deposited (high values of Cyperaceae and herbs). A similar effect can be seen in comparing the profiles and thicknesses of Tahurangi Ash at sites 83/14 and 85/1. These differences could explain why an organic layer between Burrell Ash and Burrell Lapilli is present in only one of the three cores. It was failure to find an organic layer in a subalpine bog that influenced the decision to regard this organic layer as "buried litter" (Druce 1966).

All taxa at Manganui bog sites have lower values after deposition of Burrell Lapilli. There is no doubt that severe damage was caused to all vegetative structures by the impact of these pumiceous lapilli. Removal of the canopy in the subalpine shrub is indicated by the upsurge in all shrubs. This is fairly rapid and suggests that the area was not devegetated and that root systems survived. Only in the upper profiles does competition between taxa become evident. Prominence of individual taxa at this stage varies between sites. There is no evidence that there was a stage when Coriaria was the only shrub present although it is prominent in all the post-Burrell

profiles. Dobson (1985) has suggested that sites supporting cushion bogs are oligotrophic where the mean annual temperature is $< 6^{\circ}\text{C}$. Slow plant growth and peat development could have compressed the pollen record and masked a Coriaria dominated stage at Manganui Bog (1200m).

The uppermost sample at Stratford Mountain Road (site 82/4) is at the base of the Burrell Lapilli, the pollen spectrum shows a reduction in Compositae and indicates that B. elaeagnifolia, which is dominant in the subalpine scrub canopy at present, protected the shrubs beneath it. Other shrubs survived, the sole exception being Myrsine. Dracophyllum continues its decline as it is replaced in the succession (Clarkson 1981).

The pollen profile at Potaema bog is the most detailed record of vegetation damage by impact of the Burrell Lapilli (Figs. 14A to F). The "random nature of values" as seen in Fig. 14B and F shows that apart from an upsurge of Coriaria immediately following deposition of the Lapilli there is no distinct pattern of succession in the forest. Coriaria was soon suppressed and competition under an opened canopy governs recovery. The marked decline of D. cupressinum after the Burrell Lapilli (Fig. 14F) indicates that trees of this emergent species were severely damaged but probably suffered dieback and died later. Weinmannia was able to expand into the light gaps left by D. Cupressinum and became the most successful subcanopy species until it began to thin out in the upper samples. In the swamp the lapilli blocked drainage channels causing major changes and the reversals of Cyperaceae and Leptospermum pollen values. These changes dominate the spectrum and damage is only seen in the lower values and subsequent

rise of marginal taxa. Burrell Ash appears to have been more damaging to sedges than Burrell Lapilli but the change in edaphic conditions allowed them to re-establish very quickly.

The other two low altitude sites, York Road and Norfolk Road bogs, lie to the north of the main axis of deposition. Both show rises in Coriaria after the Burrell Lapilli but damage to the canopy was more severe at York which received a thicker layer of dense lapilli than Norfolk. Total tree values were reduced, ferns and later shrubs increased in the light gaps (Fig.15D). Very little change occurred^{red} at Norfolk Road (Fig.16D). Midhurst 1 was a forest at this time. Fig.18D shows the beginning of a change to more swampy conditions. This could be due to an alteration in the eastern catchment of the Manganui River, following the eruption. There is some reduction in the value of the dominant and emergent species D.cupressinum but Coriaria does not show a large increase and little damage occurred. Midhurst 2 (Fig.19D) shows a slight decrease in D.cupressinum and podocarp pollen. Again the emergent trees protected the plants beneath them.

In attempting to envisage the fall of lapilli on a forest, the closest comparison is to a very severe hailstorm. Unless the forest was wet the tephra would not adhere to the foliage (Antos and Zobel 1982). Burrell Lapilli, although pumiceous do not float and would have a greater density than ice and fall at higher velocity. The impact of 295mm of lapilli up to 25mm in diameter would create a continuous shower of torn leaves, broken twigs, shattered branches, flowers, fruit, seeds and insects which would be intermingled with the Lapilli. After the eruption a delayed shower of dead leaves and debris would

deposited. The forest would be fully open to the sky, trunks and branches bare and scarred. Fern fronds would be stripped but tree fern trunks would remain. Herbaceous plants would lose all aerial parts. The pollen spectrum indicates some epiphytes would still be hanging from the trunks of trees. Metrosideros pollen, possibly M. diffusa has high values. This liane has very springy branches which would give rather than break under impact. Phymatodes also has tough rhizomes closely adpressed to tree trunks and severance of a rhizome would not necessarily kill the fern.

With this scenario, organic matter would be a part of the Lapilli layer. Consistent values of carbon and nitrogen found throughout the A horizon of soils developed within the Burrell Lapilli were attributed to "melanisation due to illuviation" by Tonkin (1970). He offered this as an alternative explanation for the origin of the humic layer found below the Burrell Lapilli and above the Burrell Ash at Stratford Mountain Road (Druce's Standard Profile No: 37 (Table VIII)) described by Druce (1966) as "buried litter". Druce conceived this layer as being composed of leaves scorched by Burrell Ash and subsequently removed by impact of the Lapilli. Thus he considered that the two events followed each other in quick succession. This would require that only the first Lapilli removed leaves. Removal of entire leaves is not the most common occurrence in a hailstorm. There is a continuous attrition process with leaves being perforated and torn but often remaining attached to the twig. Entire twigs with leaves attached however, are frequently broken off (personal observation).

One stratagem used by plants when buried is to produce

adventitious roots. At Mount Tarawera, Weinmannia produced adventitious roots above the surface of the ash (Burke 1964). Studies at Mount St. Helens found that conifers and shrubs soon extended adventitious roots up into the covering tephric layer while herbaceous plants extended rhizomes to the surface either in the first year or as a series of steps in succeeding years (Zobel and Antos 1982, Antos and Zobel 1984). Study of the A horizon of Burrell soils showed that although most roots were in the litter above the Lapilli they were also present in the upper part and basal section (Tonkin 1970). Roots in the basal section are here considered to be from pre-Burrell plants in situ, whilst those in the upper portion were from post-Burrell establishment. Soils developed in Burrell Ash and Lapilli have shallow profiles but show dark brown or dark reddish brown slightly peaty A horizons, this peatiness increases with increased rainfall (Aitken et al 1978). The presence of organic matter from the shower of vegetative debris within the Lapilli layer would provide nutrients which were lacking in this tephra. These have high potential but low availability of ions (Tonkin 1970).

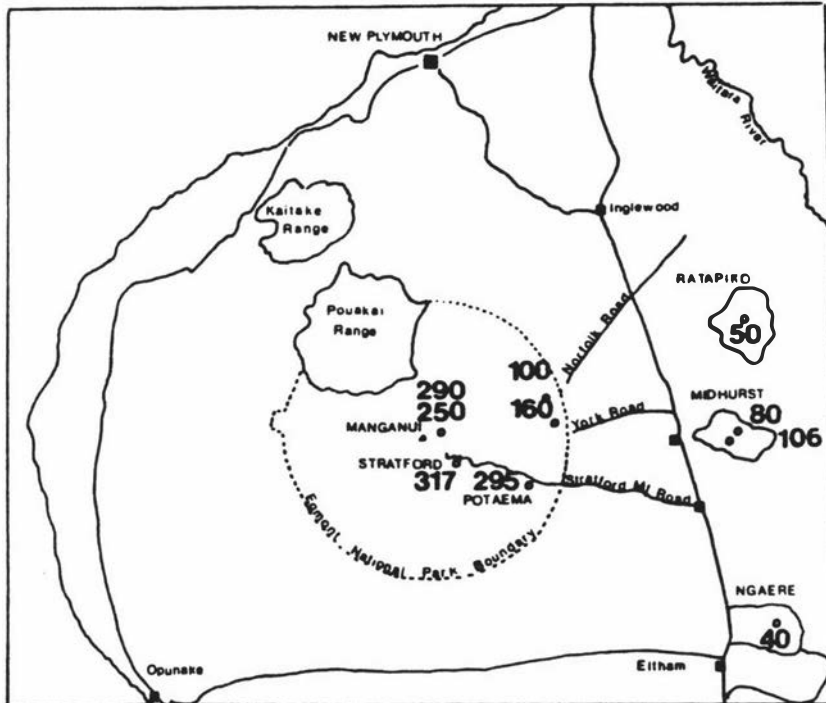
The ability of plants to produce shoots from buried rhizomes is well documented. Pteridium aquilinum grew up through 300mm of ash at Mount Tarawera (Nicholls 1959), while the same species penetrated 600mm of ash at Paricutin (Eggler 1948). Blechnum palmiforme produced new fronds within a year of being buried by ash on Tristan da Cunha (Dickson 1965). There is an interesting contrast in the curves of these two genera at Potaema. Blechnum capense is a conspicuous member of the swamp margin; spores of this species are consistently present throughout the spectrum except after the Burrell Ash. Pteridium has only

occasional low values and does not become prominent until European time indicating that the vigorous recovery of the forest excluded this aggressive fern from becoming established. The herbaceous Phormium and Astelia, both poorly represented in pollen rain (McGlone 1982 and McQueen and MacPhail 1983), are prominent after deposition of the Burrell Lapilli indicating rapid recovery and possibly extension onto the mire surface.

Recovery is also achieved by resprouting from epicormic shoots. The exceptional ability of Weinmannia in this respect is detailed by Wardle (1966) and in a study of recovery at Mount Tarawera (Burke 1964). The variability of the pollen curve of this taxon at Potaema is of particular interest (Figs. 14B and F). Values are high but vary from sample to sample finally decreasing steadily in the upper samples. McGlone et al (in litt.) attributed a similar decline of Weinmannia at this stage in their Potaema pollen profile to a thinning out of these trees due to competition.. This curve indicating competition between defoliated and structurally damaged trees with intact root systems and the ability to resprout can be compared with those at the Puniho sites. Here the colonisation of an area devastated by a pyroclastic flow is shown by the continuously rising curves of Weinmannia. This situation is similar to those described by Stewart and Veblen (1982) in Westland, where even aged Weinmannia and M.umbellata stands were found to be established on landslips.

The depths of Burrell Lapilli found at eastern fossil pollen sites (Fig. 32) are in good agreement with the isopach map of the Burrell Lapilli presented in Fig. 2E (from data in Druce 1966). Both show the

FIG. 32 THICKNESS OF BURRELL LAPILLI AT STUDY SITES



SOURCE Manganui 1 83/1 Manganui 2 83/14
 Stratford 1 85/2 Potaema 83/2
 York Road bog 84/2 Norfolk Road bog 84/1
 Midhurst 1 82 7 Midhurst 2 83/13
 Ngaere 82/1 Ratapiko 82/3

greatest depths are aligned with Stratford Mountain Road. Fig. 33 shows the stratigraphic columns of all eastern sites which contain a dense layer of Burrell Lapilli deposited in situ. The base of this layer has been used as a correlation dating plain. Potaema and Midhurst 1 and possibly Ratapiko, received lapilli from all three phases of the eruption (Topping 1972 and 1.3.3). Fine lapilli, sometimes scattered, below the dense layer represent the first phase of the eruption but when they occur above, the possibility of redeposition must be considered. Severe damage is not recorded from York Road, Norfolk Road or Midhurst 1 and no change occurred at Midhurst 2. The lapilli at these sites were smaller than at Potaema and this suggests that size is directly related to the severity of the damage.

4.2.8 Puniho 1 and 2: These ashes have not been positively identified at any of the sites examined in this study. Two cores from forest sites on Puniho Track, on the western side of the volcano, within Egmont National Park were collected. Although these cores are short, the pollen spectra together with charcoal and bulk density information would appear to indicate more than one event. The very low pollen values and high charcoal at the base of both cores suggests removal of vegetation by a previous event (Puniho 1 and/or 2 Lapilli?). Recovery is then interrupted by a second event which damaged the emergent species. High charcoal levels at 65mm depth in Puniho 1 and at 95mm in Puniho 2 may be due to scorched foliage following this event. Pollen associated with European settlement occurs in the upper half of these short profiles, indicating these events were fairly recent.

In an aerial photograph (Fig 6. Neall 1979) the contrasts between

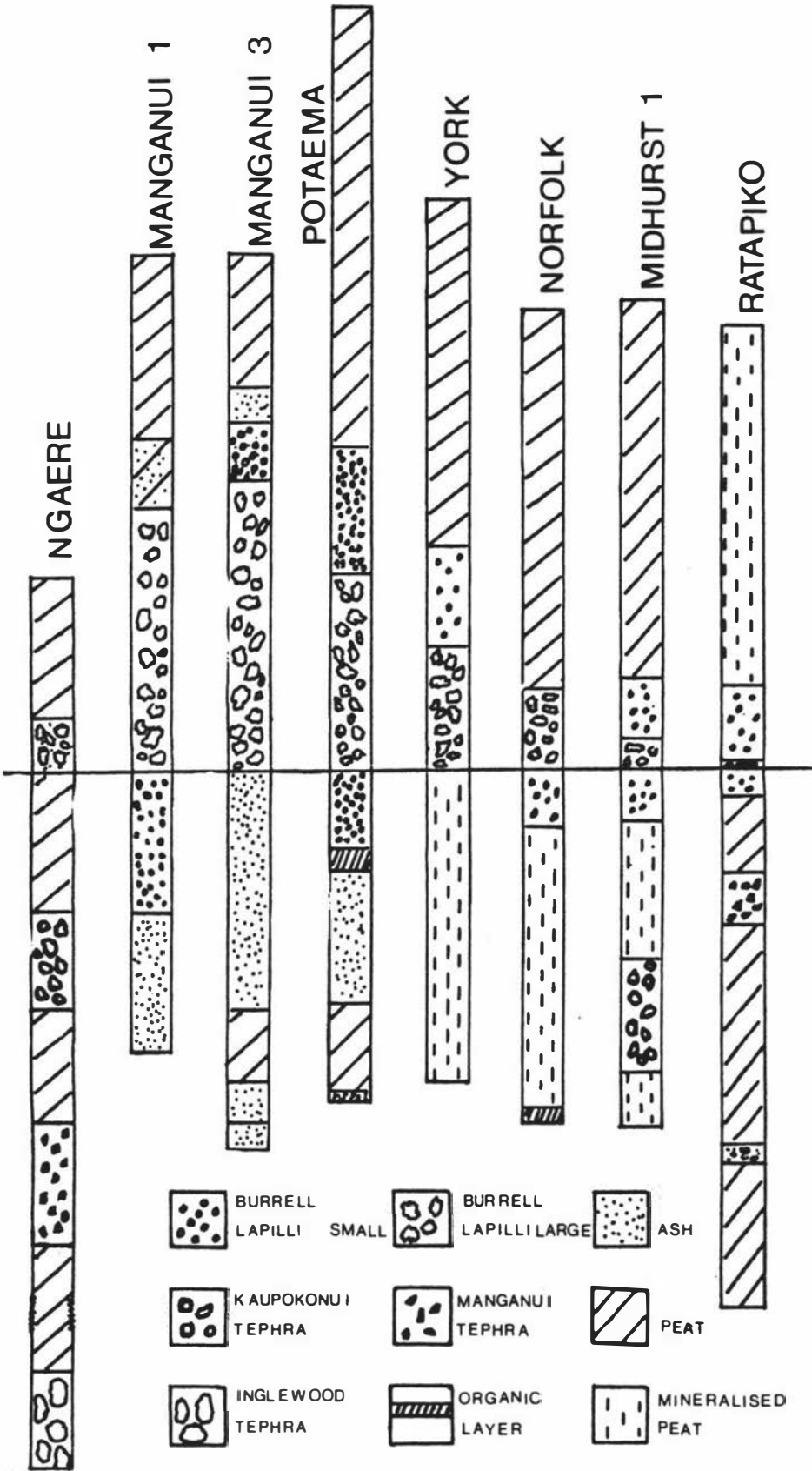


FIG.33 STRATIGRAPHY OF THE EASTERN CORES

the herbfield above the treeline, the forests of Egmont National Park and the pastures of the ring plains are very striking. Depression of the treeline in the northwest quadrant between the Hangatahua River and the Okahu Stream and the youthfulness of the vegetation between the Okahu and Oaonui streams illustrate the instability of these slopes following recent volcanic activity. Both features are due to the Maero Debris Flows (Neall 1979) and two pyroclastic flows one of which has been dated (NZ5593) at < 250 yr B.P. (Neall and Alloway 1986). The area continues to be unstable. A later event in 1922, described as a landslide and flood in the Oaonui Stream cut a 1500m long swathe through the forest (Druce 1976).

Suitable bog or swamp sites were not available in this disturbed area so two forest soil cores were collected from close to the Puniho Track. Mor soils had been recognised as potentially suitable for analysis by Iversen in 1964. A palynological study of mor soils in the Netherlands has been made by Stockmarr (1975). The sequential pollen spectra at the Puniho sites show that they were not disturbed by soil animals and that the pH was low enough to preserve pollen. It appears that these moroid soils under podocarp/hardwood forests (Taylor and Pohlen 1979) in New Zealand can be used for pollen analysis.

4.2.9 Tahurangi Ash: This is the most recent tephra and it occurs only at the Manganui bog, being identified as "peaty ashes" (83/1) and deposits of 15mm thickness in 85/1 and 54mm in 83/14. The influence of the deposition site on the depth of a deposit has been mentioned (4.2.7). Deposition of the Ash appears to have had no harmful effect on the vegetation, but at the Manganui 2 site P.Halli pollen rises due

possibly to a fertilising effect. This rise does not occur in other tree pollen from lower altitudes which only received traces of this ash. Trees of this species have established since the Burrell Lapilli (Druce 1966). A high rate of establishment is recorded for this species after the Kaharoa eruption (Nicholls 1964 and 1.7.1). Soils derived from Burrell Lapilli have been found to be deficient in nutrients (Tonkin 1970, Aitken et al 1978). Ash derived from dacite at Mount St. Helens was found to have beneficial effects (Gough et al 1981 Zobel and Antos 1985). It is therefore thought possible that Tahurangi Ash could have had a fertilising effect on P.hallii.

Traces of this ash were found during processing at Potaema in Core 83/2 where a trace had been earlier identified by Druce (1966). The presence of Pinus pollen closely associated with this ash, at the Manganui sites, confirms that it was erupted in European time and must be dated later than 1860 A.D. Table XXXIII lists details of the pollen spectra of Pinus in all three Manganui cores and results of the tests, which proved conclusively that there was no contamination in these samples (2.3.3).

TABLE XXXIII OCCURRENCE OF PINUS POLLEN AT MANGANUI BOG 1200m

Manganui 1 83/1		Manganui 2 83/14		Manganui 3 85/1		
(mm)	No: of Grains	Test	No: of Grains	Test	No: of Grains	Test
45	13	*	.	.	13	*
55	.	.	7	*	.	*
65	.	*	.	.	6	*
75	1	*	14	*	.	.
85	-	*	.	*	1	-
95	*	*	-	*		
105		*	.	.	Tahurangi	Ash
115	.	.	-	*		
125	-	-	.	.	*	*
135	peaty	ashes	-	-		
					Burrell	Lapilli
145			Tahurangi	Ash		
185	Burrell	Lapilli				
190						
195			*	*		

* = Seen on low power scan, - = No Pinus seen . = No sample

4.3 CHANGES IN VEGETATION, LAST 4000 YEARS.

4.3.1 Eastern Area

Palynological and other evidence examined here provides an overview of vegetation distribution on the eastern side of Mount Egmont and changes that followed volcanic activity over the last 4000 years. About this time the Ngaere swamp was very much as described by early European settlers (Every 1974, Standish 1984). From time to time changes in the water level, particularly after deposition of tephras, induced changes at the swamp margin and forest species tended to encroach onto the swamp. Temperate lowland forest which surrounded the areas of open water was dominated by D.cupressinum and Beilschmiedia tawa (a poor pollen producer, MacPhail 1980). (A full list of pollen taxa identified is included in Appendix 1).

Similar forest covered the lower slopes of the volcano but lahars such as that recorded at Messenger's farm frequently destroyed this forest. Vegetative debris, capable of resprouting would be carried along in the flow and may have initiated recovery. Reports from Mount St. Helens state that residual vegetative debris transported in mudflows is very important in the initial recovery stages (Means et al 1982 and del Morel 1983). Distance from the forest edge determined the role of seeds in the recovery process (Halpern and Harmon 1982) and dead trees also played an important role in furthering recovery (Frezen et al in press) At this site Pseudopanax species were important in the sample from the lahar and remained so until the shrubs were overtopped by taller species. It is not possible to tell from pollen analysis the

source of this Panax group pollen. Cyathea, mostly C.smithii became prominent later.

Sometime after the deposition of Inglewood tephra c. 3800 yr B.P. the pollen spectrum at Ratapiko swamp suggests that a lake had formed, the water impounded, possibly by lahars of the Ngatoro Formation channelled down the Manganui River. After the Manganui tephra, changes, this time in the catchment on the eastern slopes, caused a drop in water levels and the site became much drier. Similar changes occurred at the Ngaere swamp after the Manganui tephra. Some open water was always present at both sites.

Between 3000 and 2000yr B.P. the pollen record at Stratford Mountain Road has many gaps where developing soils were destroyed by tephtras and pyroclastic flows. The vegetation differed from the present subalpine scrub dominated by Brachyglottis eleagnifolia Few shrub taxa occur in the spectrum and after each event the dominant shrub species was eliminated and a new dominant arose. Dracophyllum, probably D.filifolium, was the dominant shrub about 2000 yr B.P. Gramineae pollen which had been prominent prior to this time, decreased, indicating the tussock zone may have retreated to higher altitudes.

About 1400 yr B.P. the number of subalpine shrub taxa increased. Compositae pollen reappeared after a long absence and this is the first indication of the subalpine zone dominated by B.eleagnifolia that is now present at this altitude. B.ealeagnifolia pollen declines in the uppermost sample at about the time of the Burrell Lapilli. It may have protected smaller plants from the full impact of the lapilli.

Upper montane forest, represented by Libocedrus, Cordyline sp. (C.indivisa), Griselinia and P.hallii. Only the last named has left an interpretable record. The spectrum at site 82/4 shows that these trees suffered damage after every tephra but recovery always followed and at no time is the pollen absent. In the lowland forests, a different pattern occurs D.cupressinum declines after the pyroclastic flow dated at 1980 yr B.P. but other podocarp pollen increases, a trend which is reversed after the Kaupokonui tephra. This suggests that the emergent trees suffered the most damage, as has been shown in the subalpine scrub zone.

After the deposition of the Kaupokonui tephra at Ngaere swamp, pollen of D.cupressinum increased, while P.totara and other podocarps declined. Coriaria and Leptospermum increased suggesting that again the emergent species had suffered the most damage. Destruction of the canopy allowed colonisation within the light gaps. This tephra was also deposited on the Midhurst 1 site but no changes are detectable.

There is some indication that the event/s which deposited the layered fine ashes may have caused damage to Dracophyllum in the subalpine zone but the spectrum is dominated by monolete fern spores which may be an over-representation of a species close to the site.

About 400 yr B.P. a resurgence of vegetation occurs and this may have preceded the Newall eruption in which case a change of climate could be partially responsible. Vegetation zones appear to have been much the same then as today with subalpine scrub as the local vegetation at site 82/4. The eruptive period that began with the

deposition of the Newall Ash continued with the Burrell Ash about 100 years later; damage is recorded at Potaema swamp. The Burrell Lapilli were deposited, again after c. 100 year quiescent interval. These Lapilli are widely distributed and were found at all eastern sites. The forest canopy was destroyed at Potaema bog, permitting an upsurge of Weimannia which still dominates the forests today. Other low altitude and ring plain sites suffered much less damage.

Abundant evidence has been found in all swamp pollen spectra that the deposition of tephra initiates changes at the swamp margin. This is best illustrated by the interchange of Leptospermum, Cyperaceae and marginal shrubs pollen at Potaema (Fig 14C). Under normal conditions bogs, swamps and lakes eventually become infilled by growth of mire plants. This process is speeded up by the addition of solid matter over the whole surface. At Ngaere swamp, a rise in D. dacrydioides pollen accompanies the deposition of all three older tephras, interpreted as an advance onto the swamp margin by these trees. These changes may be the most long lasting of any change brought about by volcanic activity. The process is most apparent in the field at Potema bog, where clumps of Phormium tenax are now well within the forest. It is not possible however, to make this interpretation from pollen diagrams.

At both York Road and Norfolk Road bogs a large amount of organic matter occurs below the Burrell Lapilli and there was not enough pollen for valid counts. At York Road this has been interpreted as the death of plants in situ, probably Phormium which disappears at this time. A major change in the environment is indicated by so much organic matter. Both sites also show signs of an inwash of tephra at this time, possibly

Burrell Ash.

4.3.2 Western Sites

Temperate lowland forest with a small component of swamp forest species was present at Jones' farm 3 site (132m) about the time of the Inglewood Tephra. Rhopalostylis had quite high values for an under-represented taxon but the pollen of coastal species such as Dodonaea and Dysoxylum was not found here. The base of the profile indicates recovery after the Inglewood Tephra. The most notable feature of the spectrum is the high value of Ascarina at this time c. 3800 yr B.P. Some fluctuations occur, but values remain high until it begins a slow decline about 1400 yr B.P. It is concluded that throughout this long period from c. 3800 to 1400 yr B.P. climatic conditions at this altitude (132m) would have been ideal for this species. Comparisons can be made with its present distribution (McGlone and Moar 1977 and Wardle 1979). It is rarely seen in the study area today but forests at this altitude have now been removed to establish pastoral farming. Only 5 plants have been recorded, 3 are in Pukeiti Private Scenic Reserve and 2 are on Pouakai Range, all at > 300m.

After 1400 yr B.P. pollen evidence from the Jones' farm 3 profile shows a marked decline in drought prone species D.cupressinum, Schefflera and particularly in Ascarina which disappears about 400 yr B.P. These changes are not related to volcanic activity. About the time of the Newall eruptions, all pollen values rise and taxa which have been absent from the pollen profile for a long time reappear. Weinmannia appears for the first and then rises to prominence.

This prominence is related to both a change to a wetter and cooler climate and to the availability of disturbed sites, after the widespread fires which followed the Newall eruptions. Very similar changes in pollen spectra are seen at both Jones's 1 and Pollard's farm sites.

4.3.3 Northern Sites

These undated sites do not contain any tephras deposited in situ but have some redeposited tephric layers. Three of the sites contain Dysoxylum and two have Dodonaea. Both species are under-represented in pollen spectra, Dysoxylum severely so (MacPhail and McQueen 1983). The presence of these few grains indicates that some elements of coastal forest were present between 30-60m in the past. Matarikoriko and Umutekai also have a continuing swamp forest element in their pollen spectra.

A major disturbance appears to have occurred at Matarikoriko (Fig 30A) at 405mm when M.robusta, Leptospermum and Metrosideros all of which are prominent in the profile decline. They are replaced by subcanopy species, suggesting the canopy may have been damaged. The profile at Umutekai also has a major change. Laurelia and Syzygium, prominent at the base of the profile decline steadily but the trend reverses at 305mm and they continue to increase as the site becomes wetter (Fig.31A). There is no indication in the stratigraphic column of a possible cause for these changes and they are undated.

4.4 TEPHROCHRONOLOGY

Pinus pollen was found below Tahurangi Ash in Manganui 2 core (83/14). This tephra may therefore be younger than was previously thought. Similar uncertainty surrounds the ages of other recent tephras. While the tephrochronology of the last 4000 years is soundly based on radiocarbon dating (Table XXXI) that of the last eruptive phase is largely based on limited dendrochronological studies by Druce 1966 (Table XXXII). The first event of this latest series is the Newall Ash and several radiocarbon dates are available (Neall 1979) the quoted date is 404 yr B.P. or c. 1500-1550 A.D. (Neall 1972). As this date is for charcoal below the Ash the actual date of the eruption would be a little younger. A date for European settlement has been proposed by McGlone et al (in litt.) based on the maturing of the first Pinus trees introduced, this is 1860 A.D. It seems likely that this date may be a little early for Taranaki. Disputes over Maori ownership of Taranaki land (1.8.5.) delayed major purchases until 1859 (1.9.1). The earliest record of mature Pinus trees in western Taranaki is by Burgess in 1901 (1.9.5.). Eastern Taranaki was settled later than western Taranaki (1.9.2).

Distortion of the windflow between Mount Egmont and the Pouakai Range has been discussed (1.4.3), as have long distance pollen (1.10.4.1) and updrafting of pollen from lower altitudes (1.10.4.2). All these could account for the presence of Pinus pollen, from the western coastal plains of Taranaki, at Manganui bog (1200m). Assuming 1860 A.D. to be the earliest possible date for the first occurrence of Pinus in a core, sedimentation rates can be calculated from this level to the

surface. Similarly the time represented by the sediment between the top of the Burrell Lapilli and the Pinus level can be used to derive a date for this eruption.

This data is presented in Table XXXIV. For the high altitude sites (Manganui bog 1200m) the calculated sedimentation rate has been halved. Lack of humidification, slow growth of peat and little compaction make this necessary. For the low altitude and ring plain sites the calculated sedimentation rate has been reduced by 25% to allow for the faster rate of growth. The basis for these corrections to the sedimentation rates is that 120mm of peat overlies Burrell Lapilli at Manganui bog but 307mm overlies the same tephra at Potaema bog. Prior to collecting a core, living plant material is removed from the bog surface. It is not possible to define exactly the surface of the peat. It was felt in these circumstances that the precision of using a correction factor of 2.5 was not justified, ($307/120 = 2.5$).

TABLE XXXIV DATE OF BURRELL LAPILLI BASED ON PEAT CORE DATA

Site	1st <u>Pinus</u>	Sed.Rate mm/yr	New Rate	Burrell Depth mm	Years Between	Date A.D.
Manganui 1	95	0.76	0.38	180	224	1636
Manganui 2	195	1.56	0.78	220	32	1828
Manganui 3	125	1.00	0.50	202	154	1706
Potaema	174	1.40	1.05	307	126	1734
York	125	1.00	0.75	253	171	1689
Norfolk	165	1.32	0.99	220	56	1804
Midhurst 1	205	1.64	1.23	270	53	1807
Midhurst 2	95	0.76	0.57	310	377	1483
Ngaere	125	1.00	0.75	100	-	-
Ratapiko	135	1.08	0.81	249	141	1719

In the above data the late settlement of the Midhurst 2 site gives a date prior to the radiocarbon date of 404yr B.P. for the Newall, while the use of large disc harrows has disturbed the top 150mm of the Ngaere core and the Burrell Lapilli occur in juxtaposition to European pastoral weed pollen (Fig.20D). Neither of these dates is considered acceptable. Although the range of dates calculated is large the average of Manganui dates is 1723 and of the low altitude dates 1751. All that can be claimed here is that the date of the Burrell Lapilli may be as much as 100 years later than 1655 A.D, the date derived from determining a reduction in tree ring growth by Druce (1966).

Reliable information can only be obtained from tree-ring width measurements if sites are closely paired with control sites. Correlation between changes in measurements must be established in several sections of the cores from different trees (Stokes and Smiley 1968). None of these requirements were met by the work of Druce (1966). The choice of tree species was also unfortunate since it has been established by Dunwiddie (1979) that age determinations were only poor to fair in most cores from Libocedrus. The extensive fieldwork carried out however, by Druce enabled him to identify pre-Burrell trees by their short boles and buried root flanges.

Information contained in Table 3 (Druce 1966) has apparently been overlooked. Druce identified nine Libocedrus trees from altitudes between 945-1036m as post-Burrell, the criterion being that the root flanges of these trees were not covered by Burrell Lapilli. Table XXXV is based on data from Table 3 (Druce 1966) and lists the ages of the trees in 1963. A calculation of the date of the Burrell Lapilli has been made by subtracting this age from 1963, the year in which the trees were measured.

TABLE XXXV DATE OF BURRELL LAPILLI BASED ON TREE RING COUNTS

Tree Core Number	Altitude metres	Age in 1963	Burrell Date	Age Difference
C6	975	187	1776	-39
C18	1036	181	1782	-45
C25	960	225	1738	-1
62/3	975	182	1781	-44
62/4	975	211	1752	-15
63/2	975	181	1782	-45
63/4	975	226	1737	-
63/5	945	202	1761	-23

Source Table 3 Druce (1966).

Three of the trees from the same altitude are of almost the same age. These are the youngest trees. The oldest tree has an age of 226 years (tree core 63/4). An allowance must be made for the trees to reach the 1.50m height at which they were cored, 30 years is suggested, making the age of the oldest tree 256 years in 1963 giving an establishment date of c. 1707 A.D.

Changes in the stand dynamics of Weinmannia at Potaema bog also indicate a possible date for the Burrell Lapilli. Some aspects of recovery after volcanism could be similar to recovery after fire, others to colonisation of new ground. Weinmannia is well adapted to both situations, but it does not regenerate under its own canopy. L. ericioides was found to be a nurse crop for Weinmannia, after fire in the Urewera Range, North Island. Seedlings growing in this situation were often multi-leadered but mature clumps had stems of various ages, indicating they had also resprouted from the base (Payton et al 1984). In a primary succession on deglaciated areas in the Waiho Valley, below the Franz Josef glacier in Westland National Park, seedlings of Weinmannia were found established on a site, eight years after it was free of ice. Weinmannia and M. robusta had also become established after 12 years on a loose boulder surface where other fast-growing, short-lived species had failed.

On a 50 year old site both species had penetrated the canopy of small shrubs and on a 130 year site they formed the canopy. At this last site seedlings of Weinmannia were established on the trunks of tree ferns (Wardle 1980). Epiphytic establishment, usually on Dicksonia squarrosa, was the only successful method for Weinmannia in the dense

forests of the Taupo region (Wardle 1966). This tree fern was also found to be essential for the introduction of Weinmannia into a seral community on sand dunes at Tautuku Beach, southwest Otago (Smith et al 1985). On the disturbed surface of landslips in central Westland, Stewart and Veblen (1982) found that stands of Weinmannia were often of even aged trees. These trees had established at the same time, often on landslips.

These observations assist interpretation of the post-Burrell pollen curve of Weinmannia at Potaema bog. There are two phases, the second occurs with the large rise at 195mm. Pollen from pre-Burrell trees is thought to contribute to the pollen spectra between 315-195mm. These trees would have resprouted from the base after the Burrell Lapilli. Large multi-leadered Weinmannia trees are a feature of the forest today. Seedlings established directly on the loose surface of the Burrell Lapilli from seed of these older trees would receive shelter from Leptospermum until its decline at 255mm. Although the assumption was made that all Leptospermum trees were on the swamp, the relationship between tall tree pollen and Leptospermum pollen, suggests that some trees were in the forest. Dicksonia spores appear for the first time in the profile in this sample. They would have provided sites for the epiphytic establishment of Weinmannia. At this time also large trees of D.cupressinum damaged by the lapilli finally succumbed leaving light gaps. This stage could be likened to the 130 year stage on the deglaciated area in Westland (Wardle 1980), with mature trees and epiphytic seedlings established. The large rise would be from pollen produced by the trees established directly on the Burrell Lapilli.

In the next sample all the pollen indicators of European settlement appear. A possible date is 1875 A.D. because settlement occurred later on these eastern plains than on the west. The 20mm of peat between the first large increase of Weinmannia at 195mm and the onset of European settlement represents 19 years using the adjusted sedimentation rate of 1.05mm/yr (Table XXXIV) and the 120 mm of peat between 315-195mm, 114 years. The latter agrees quite well with the 130 year for establishment on the deglaciated site at Westland (Wardle 1980). It can be concluded therefore that the Burrell Lapilli may have been deposited about 133 years prior to 1875 A.D. or about 1742 A.D. These three lines of evidence for a possible date for the deposition of the Burrell Lapilli are in general agreement, 1725-1750 A.D. seems a reasonable date.

The only core which can supply a possible date for the Burrell Ash is Manganui 3. 50mm of black sandy loam overlies the Newall Ash and underlies the Burrell Ash. The modified rate of sedimentation used for calculating the age of the Burrell Lapilli at this site (Table XXXV) is 0.5mm/yr which gives a time period of 100 years between the Newall Ash and the Burrell Ash. The date for the Newall Ash is from charcoal beneath the oven (Neall 1972) and the actual tephra will be younger than 404yr B.P. If the sedimentation rate is a good estimate then the age for the Burrell Ash would have been deposited less than 100 years after the Newall. This leaves a period of time between the Burrell Ash and the Burrell Lapilli, which could be represented by the organic layer between the two tephras. There is palynological evidence of a lapse of time within this organic layer and between the pollen spectra from the top of the Burrell Ash and the base of the Burrell Lapilli.

The occurrence of exotic Pinus pollen beneath the Tahurangi Ash indicates that this ash cannot have been deposited earlier than 1860 A.D. A time interval of about 100 years between the proposed new Burrell Lapilli date of c. 1725-1750 A.D. and an 1860 + date for the Tahurangi Ash is in agreement with the time period originally suggested by Druce (1966). The palynological evidence from the Puniho 1 and 2 sites suggests that these pyroclastic flows occurred not long before the Tahurangi Ash. Table XXXVI sets out a suggested teprochronology for the last 500 years.

TABLE XXXVI TEPHROCHRONOLOGY MOUNT EGMONT, LAST 500 YEARS.

Tephra	Date A.D.	Evidence
Tahurangi Ash	pre- 1860	Presence of <u>Pinus</u> pollen
Burrell Lapilli	1725-1750	a) Sedimentation rates in peat. b) Tree ring counts (Druce 1966). c) Stand dynamics of <u>Weinmannia</u> .
Burrell Ash	<u>c.</u> 1650	Organic layers and changes in pollen spectra between the BA and BL.
Newall Ash	1500-1550	Neall (1979)

The Waiweranui Ash and Lapilli were not identified.

CHAPTER 5

ANTHROPOGENIC CHANGES IN VEGETATION.

5.1 INTRODUCTION

Taranaki today presents a great contrast in vegetation types from the lower slopes of Mount Egmont covered with dense forests to the surrounding pasture. Forests within Egmont National Park are a source of regional pollen which could influence all pollen spectra described here. This is most evident at the Ngaere and Motunui swamp sites, which are now almost treeless but nevertheless have up to 40 pollen taxa present in the upper profile. Of the four northern sites which were sampled primarily to determine the impact of the Maori, the two closest to the coast proved disappointing. An accelerated rate of sedimentation in European time meant that all the deposits were very young. Possible fossil pollen sites remaining on both this, and the western coastal plain, are in Typha swamp or remnant swamp forest which are difficult to core. A further problem at the northern sites is the lack of identifiable recent tephras to provide dated horizons.

5.2 CHANGES DUE TO MAORI OCCUPATION

Changes in pollen spectra which can be attributed to deforestation by Polynesians have been reviewed by McGlone (1978) and later discussed by him in detail (McGlone 1983). These are; a decline in the amount of forest pollen, a rise in Pteridium spores and Gramineae pollen and a consistent presence of fine charcoal in the stratigraphic column. These

criteria will be used to define deforestation in pre-European time.

5.2.1 Eastern Sites: The high altitude sites at Manganui bog, record changes in vegetation at lower altitudes, because the spectra include pollen and spores carried by updraft. Pteridium does not grow at this site but the spores are present throughout the profiles of all three sites. There is no evidence of pre-European destruction of forest on the eastern side by Maoris. Evidence of change in pollen spectra is related to volcanic events. Pteridium spores rise after Newall Ash at site 85/1 and after Burrell Lapilli at all sites. At Stratford Mountain Road site (82/4/) there is an increase in these spores after both the Kaupokonui and Newall eruptions but there does not appear to be any other changes which could definitely be attributed to Polynesian burning of the forests.

At Potaema bog (675m), within the lowland temperate forest, Pteridium spores are absent from the spectrum below the Burrell Lapilli. They have a small rise at 295mm, but only become abundant in European time. The deeper core collected by McGlone et al (in litt.) at Potaema bog recorded the first appearance of Pteridium spores between 1500-1655 A.D. In a later sample Coriaria rose to a high 35%, which they attributed to destruction of the forest canopy by the Newall Ashes. In discussing Polynesian deforestation McGlone (1983) presents a pollen diagram of Potaema bog showing the rise in Pteridium associated with a date of 450yr B.P. and attributed by him to Maori fires. The pollen spectrum at Potaema 83/2 does not therefore agree with McGlone (1983) but is consistent with low values of Pteridium spores and lack of charcoal until European time at eastern ring plain sites

(Table XXX).

Similarly, in the York and Norfolk Road swamp profiles, Pteridium spores are always present but there is no large increase until European time. Messenger's farm site (3125yr B.P.) has no Pteridium, indicating that it was absent from the original forest and spores were not available to colonise the new laharcic surface. Absence of this species in lowland forests at this time is supported by the pollen profile at Ngaere swamp.

On the ring plain at Midhurst 1 site, Pteridium spores rise after the Kaupokonui tephra, but this is prior to Maori occupation. There are no further increases until the onset of European settlement. Pteridium spores increase after the Burrell Lapilli at Midhurst 2, but then disappear until the uppermost sample, which is in European time. Pteridium spores are again scarce in the profiles of the other two ring plain sites, Ngaere and Ratapiko swamps, until European time. There is also a lack of change in Gramineae pollen at the Midhurst and Ratapiko sites. At Ngaere, Gramineae rises at the time of the deposition of the Manganui tephra and then persists throughout the profile. In none of these sites is there any evidence of complete destruction of the forest. Deposition of tephra is followed by recovery of the forest and restoration of the previous species composition.

5.2.2 Western Sites: On the western side of Mount Egmont at both sites on the Puniho Track the curves of Pteridium closely follow those of other ground ferns and show typical recovery patterns. At these two sites the deposits accumulated largely in European time. It is not possible to be certain if the Pteridium spores present were from local or regional sources. At Jones' farm 1 site (152m) values for both Gramineae and Pteridium are very low until the forest is totally removed for European settlement. Pteridium spores appear just prior to 2750 years B.P. in Jones' 3 spectrum and have a slight rise after the Kaupokonui tephra. They remain in the pollen profile, but reach high levels only in European time. Gramineae pollen is present at the base of the profile but disappears in that section which would encompass Maori occupation. At Pollard's farm site, which is close to the limit of coastal fernland described by early settlers (1.5.1 and Day 1984), there is very little Pteridium until European settlement.

5.2.3 Northern Sites: Two of the four northern sites, Bowden Reserve and Motunui, contain Pinus and pasture weed pollen throughout the pollen profiles. At Matarikoriko, lack of time control makes it difficult to interpret the spectrum, but Pteridium spores are always present. The spectrum is independent of other ground ferns suggesting that the spores are not of local origin, but from the coast, 3km distant. This site remained in forest until European time. Two minor occurrences of charcoal (Table XXX) in the lower part of the profile also indicate fires some distance away. Above 340mm there is a rise in Knightsia, Freycinetia, Leptospermum, Coprosma and monoletic fern spores. Disturbance to the forest is indicated but it is not possible to determine a time for these changes. Further inland the Umutekai site, has

Pteridium spores present at the base and a rise in Gramineae pollen but neither is coincident with the rare occurrence of charcoal in the lower portion of this core. This site is 6.5km from the coast and has never been burned over the period represented by the core.

5.2.4 Evidence from Charcoal Data: Data presented in Table XXX (Chapter 3) shows that Maoris did not burn the forests on the eastern ring plain. On the west there is some evidence of fires. Charcoal has a persistent presence above 240mm at Jones's farm 1 and above Jones' farm 3 at 180mm. Both these depths are within the peat containing Newall Lapilli. The sites are at 152 and 137m respectively and about 18km from the summit. They are however, very close to Newall Road and the main axis for the Newall nuée ardentes. This charcoal is therefore considered to be from fires started by these volcanic events. Pollard's farm on the South Road is at 91m and 21km from the summit. Although Newall Lapilli have been identified in peat at 265mm, persistent charcoal only occurs at 125mm. European settlement is indicated at 45mm, so this charcoal is in post-Newall/ pre-European time. This is the only evidence found for pre-European fires. This site is 5km from the coast.

5.3 CHANGES DUE TO EUROPEAN SETTLEMENT.

Deforestation in European time is determined by the same three criteria as those used in examining the pollen spectra encompassing Maori occupation. There are however, additional indicators of change. Pinus pollen gives a post 1860 A.D. date (4.3.4). Pastoral farming close to a site is indicated first by windborne pollen of Plantago

usually followed by a persistent presence of Plantago,Taraxacum and more rarely Cirsium. At some sites traces of Taraxacum were found prior to more positive indications of settlement. This has been interpreted as being deposited in faeces of cattle browsing in the forests prior to clearance. A reduction in pollen of subcanopy and some shrub taxa is interpreted as due to browsing by farm stock and other introduced mammals. A decline in tall tree pollen, particularly of podocarps, results from the clearance of forests.

5.3.1 Eastern Sites: Pinus, possibly derived from shelter belt planting, occurs as single grains associated with the Taurangi Ash in all of the Manganui Bog cores (Chapter 3 and 4). Towards the top of these profiles Pinus has a much stronger presence and is associated with Taraxacum and Plantago pollen, coinciding with a decline in the pollen of all podocarps. This increased prominence represents plantation plantings. In the upper samples at all three sites, tree pollen declines, while most fern spores rise. These changes are due to clearance of forests on the ring plain. Pteridium declines at this time in Manganui 2 and 3 (83/2 and 85/1) but not at site 83/14.

At the Potaema bog, decline in pollen of tall trees is not so apparent. In the top uppermost samples pollen of the emergent D.cupressinum and M.robusta rises (Fig.14F) but there is a paucity of subcanopy pollen taxa. Weinmannia declines in this sample. The rise of these emergent trees could be the final stage in recovery after the Burrell Lapilli or may reflect the protection afforded by the formation of Egmont National Park in 1900. Even after the declaration of protected status for the forests, cattle still escaped into the

forest. Goats and opossums are still present (Mawhinney 1980). Their presence could be the cause of the absence of subcanopy species (1.9.6). At 155mm Pteridium spores reappear and continue to rise to the top of the profile. This rise is not coincident with the curves of other taxa and it must be assumed that this is regional pollen derived from settlement of the ring plain.

A feature of the pollen spectrum at York Road swamp is the changing curve of Libocedrus. Following a decline between 245-165mm there is a considerable rise, which coincides with increased charcoal and the first appearance of Pinus. While it is possible that this could represent the exotic Cupressus macrocarpa (because the pollen cannot be distinguished), it probably represents recovery after logging. Libocedrus were absent from the top stratum of forests near the York Track although the trees are present on ridges. Shrub sized Libocedrus occur near a disturbed area at Quarry Bluff. Clarkson (1981) associated these features with logging in the 1900's. Above 125mm podocarp pollen also declines to be replaced by Weinmannia. Pasture weed pollen is not prominent in this profile.

At Norfolk Road swamp however, pasture weed pollen occurs much lower in the profile (245mm) together with Pinus; above this level all are consistently present. Here, there is a general decline in all forest taxa including Weinmannia. Sub-canopy pollen is sparse and generally sporadic. Shrub pollen also declines. These changes indicate a reduction in total forested area. This reduction may not have been close to the site, which is within the Egmont National Park, but further to the east. At 85mm Gramineae pollen increases as Pteridium spores decrease,

indicating an improvement in pasture establishment.

Changes in the upper portion of the pollen spectra of all three swamps on the eastern ring plain indicate European settlement. Pollen spectra of the two Midhurst sites show that Midhurst 2, which is still surrounded by degraded forest, was settled much later than Midhurst 1. Windborne pollen of Plantago is first recorded at 225mm at Midhurst 1. Pinus and Taraxacum pollen occur later, indicating farming was then much closer to the coring site. All three pollens occur together at Midhurst 2 at 95mm depth. The pollen spectra of both sites indicate very wet forest rather than swamp because D. dacrydioides and Cyperaceae pollen are prominent. Sometime after the Burrell Lapilli was deposited Midhurst 1 became a swamp, due to blockage of drainage at the junction of the catchment with the Manganui River possibly caused by lahar aggradation. The abundance of forest taxa pollen at Midhurst 1 suggests that even after settlement some forest remained fairly close to this site. Above 105mm depth the tall tree pollen declines and the more palatable species such as Schefflera, Carpodetus and Geniostoma, disappear but Ascarina rises as competition is reduced. These changes indicate early removal of timber trees and later use of the forest for shelter and browsing by cattle.

At Ngaere and Ratapiko the upper 150mm have been presented in separate graphs, 20D and 21F respectively, because of the dominance of European changes and disturbance of tephric layers at these levels. Eltham district, in which Ngaere swamp lies, was settled from the south about 1879 (1.7.3). The juxtaposition of Burrell Lapilli and pasture weed pollen indicates some disturbance, possibly by disc harrows at this

site. The pollen is, however, sequential between 145-75mm. It was not possible to obtain valid pollen counts between 75-25mm due to large amounts of organic matter. Potamogeton pollen disappears at this time and this is probably due to improved drainage.

The initial rise of D. dacrydioides at the base of the spectrum (150mm) following drainage works is changed to a decline above 115mm to only trace levels. Pteridium is not prominent at this site which was very wet. With the Egmont National Park as a potential source of distant pollen, windborne pollen of forest tree taxa remains throughout the profile (Fig. 20D) but it is significant that the forest flora becomes impoverished by losing sub-canopy and shrub species pollen. This point can be verified by comparing Fig. 20D with Fig. 20A. It is unlikely that forest remained close to the coring site because in the upper samples Phymatodes and Metrosideros pollen has declined from previously high values. The former is a climbing fern and the latter a liane, both require trees for support in order to survive. High values of Taraxacum pollen which is not anemophilous, from 95mm upwards indicate that pastoral farming was established close to the coring site. Pinus pollen is present at 105mm indicating the establishment of a plantation in the vicinity (Fig. 36 large map in Vol. II and 3.4.4).

Settlement near Inglewood (Ratapiko swamp) began as an extension from New Plymouth about 1875 and spread southwards towards Midhurst (1.9.2). The Ratapiko core was sampled by using the whole of the 10mm slice from half of the core. When it became apparent that contamination could occur, this method was abandoned and only the centre of the other cores was then used. Taraxacum pollen is present at 495mm

(as seen in Fig. 21A and B) and this is probably due to contamination. The first valid appearance of Taraxacum and Pinus is at the 245mm level. Here Taraxacum is prominent and associated with a similar rise in Gramineae, Pteridium and the first appearance of persistent charcoal. The presence of these taxa above the redeposited tephric layer between 212-218mm indicates artificial drainage close to the actual site. After this activity both swamp and forest taxa pollen increase suggesting that the change in edaphic conditions suited both groups of species, by separating wetter and drier areas.

In Fig. 21F (Ratapiko European Time), the % data show a reduction in all forest taxa. For most species their representation is <1%. The high value of Podocarpus in the upper profile (above 150mm) is due to the poor preservation of pollen at this level making specific identifications difficult. Some of this pollen could have been remobilised during the drainage operations. The distinctive decline of Leptospermum pollen probably results from the removal of second growth. The decline coincides with a large rise in Gramineae and the replacement of Typha pollen by Cyperaceae. Some degraded forest appears to have remained for some time as indicated by Phymatodes spores and Metrosideros pollen.

5.3.2 Western Sites: On the western side of Mount Egmont, settlement was long delayed by disputes over land (1.9.1 and 1.9.4), although there had been a European presence since 1843 (1.9.1). The two Puniho sites are within Egmont National Park. At the higher Puniho 1 site (420m) only windborne Pinus and Plantago pollen are present above 65mm, while at Puniho 2 which is lower (397m), Pinus occurs at 95mm and

Taraxacum in the next sample above. Pteridium and charcoal are also present but the profile is dominated at both sites by a recovery pattern thought to be due to a volcanic event, probably a pyroclastic flow (Neall and Alloway 1986). Weinmannia is prominent in this recovery but there is a general rising trend in all taxa.

Outside Egmont National Park, Jones' farm 1 at 152m has Taraxacum at 185mm and Pinus at 165mm, both just above the section of the core with scattered Newall Lapilli. Major change in the immediate environment is indicated by the increasing presence of Typha pollen and decreasing representation of Potamogeton. This change from slow-flowing water to a Typha swamp followed increased sedimentation after erosion following forest clearance. Total clearance of the forest at the 145mm level is indicated by the small amount of pollen of all forest taxa and reduction in the number of taxa.

At Jones' farm 3 Pinus pollen occurs for the first time at 95mm but clearance of forest later is indicated at 65mm by increased values of Pteridium spores, Gramineae pollen and the greater abundance of Pinus, Taraxacum and Plantago. Typha also enters the spectrum for the first time during this period. There is a declining trend in tall tree taxa but Leptospermum, Coprosma, Coriaria and Panax group pollen rise indicating regrowth after clearance. Palatable species such as Fuchsia and Carpodetus disappear indicating browsing by cattle in the forest.

Closer to the coastal fernland described by the early settlers (1.5.1) the spectrum of the Pollard site shows that at 85mm depth Pteridium spores increase sharply but Gramineae has low values

suggesting that pasture was not established and the fires were to maintain the Pteridium sere. At 45mm depth, pollen of Pinus, Taraxacum, Plantago and Cirsium type all occur at the same time. These facts suggest that this area remained under Maori control for some time after the first Europeans settled. The rising curves of Weinmannia, Leptospermum, Geniostoma, Dicksonia and Panax group pollen indicate regrowth but the absence of Coriaria and Coprosma suggests the area close to the coring site was browsed but not cleared.

5.3.3 Northern Sites: Fresh Typha peat composes the entire deposit of the Motunui core. Pinus is present throughout, although the values decrease with depth. Charcoal is also present throughout the core and high values at 305mm and 105mm suggests the site was burned. Artificial drainage is also indicated by a very large amount of organic matter at 505mm. The % diagram gives an erroneous impression of this treeless site. Pollen of indigenous forest species must be either regional or redeposited from older sediments disturbed by new drainage patterns.

Bowden Scenic Reserve records in detail efforts to establish pastoral farming. Earlier clearance of forest is responsible for the Typha swamp indicated at the base of the profile. Marattia spores are present here but disappear from the profile after a change in drainage is indicated by the decline of Typha and a rise of Cyperaceae. Taraxacum is always prominent and D.dacrydioides declines towards the top of the profile. Tree ferns are abundant and Dicksonia prominent at the base is partially replaced by Cyathea.

The lack of dates at Matarikoriko is most unfortunate as the

pollen profile contains a significant change at the 405mm level. Rises in Knightsia, Eleocarpus, Leptospermum, Coriaria, Paratrophis and Freycinetia indicate a major disturbance prior to European time for which there is no obvious cause in the data available. Subsequently Pteridium rises before a reduction in swamp trees occurs and both Typha and Cyperaceae rise. These changes coincide with the prominence in the profile of Pinus and pasture weed pollen.

The Umutekai core preserves an intact record of fossil pollen because there is no evidence of burning and the site remains in swamp forest. Adjustment in the balance between swamp trees and lowland forest is a feature of the pollen profile. At 305mm Typha appears together with the first Plantago pollen. The latter increases as Pteridium spores and Taraxacum pollen appear. D. cupressinum and M. robusta decline at the top of the profile. Coriaria is never prominent and this is the least disturbed site outside the Egmont National Park but unfortunately it is undated.

5.3.4 Evidence from Charcoal Data: Charcoal occurs consistently in the stratigraphic column of eastern ring plain sites only in European time. Prior to this there are only small sporadic occurrences. Charcoal at the Puniho and Jones' farm sites before European time is related to recent volcanic events but the values at the latter increase greatly as settlement occurred. The two northern coastal sites have much charcoal throughout, because these sites encompass only European time. The high charcoal values which peak at 22.6 (Table XXX) in the Motunui core indicate fires at the site. Similarly Matarikoriko further inland has a high abundance value of 20.8 which must represent a fire on the site. In

contrast to these sites the values at Umutekai are always low being distant from the fires. The low value of 0.9 just prior to the first traces of pasture weed pollen may indicate the approach of land clearance towards this area, but it seems unlikely that the swamp forest here has ever been burned.

5.4 DISCUSSION

Few accounts by European settlers fail to mention the contrast between the coastal fernland and the forested slopes of Mount Egmont. Early reports also describe the danger from fires lit by Maoris which escaped from control (Greenland 1967). The importance of fern root (Pteridium rhizomes) in the Maori diet (Leach 1974) led to the necessity to perpetuate the bracken stage of succession by frequent fires (Levy 1949, Druce 1957). In attempting to interpret the effects of man's use of the Taranaki environment it is necessary to consider the vegetation before the advent of man.

5.4.1 Vegetation on the Eastern Ring Plains: Pollen spectra from the Ngaere, Midhurst 1 and Ratapiko swamps indicate that the surrounding forests were dominated by D.cupressinum, but Beilschmeidia tawa would be equally prominent. This species is a poor producer of pollen (MacPhail 1980) and the pollen was not found. It is however, an abundant hardwood in lowland and mid-lowland forests in the North Island. It has been observed at Potaema and in all the subdistricts of the Taranaki Land District (Clarkson 1981). Extant forest shows that forests in which Beilschmeidia tawa was dominant or important in the subcanopy were once widespread on the Mount Egmont ring plain (Clarkson 1981). Some

lowland forests were very wet and a swamp forest element, in particular D.dacrydioides, was present. A small remnant of this forest type still survives surrounding the Midhurst 2 site. Swamps occupied large areas of the ring plains and both the Ngaere and Eltham had some open water, prior to 3000 yr B.P. Ratapiko was probably a lake. Midhurst 1 did not become a swamp until after deposition of the Burrell Lapilli. About 1400 yr B.P. there are indications that the forest encroached onto the swamp margins. This was part of a continuing process accelerated by the prolonged dry spells in summer at that time (Chapter 6) and the deposition of solid matter after each eruption (Chapter 4).

5.4.2 Vegetation on the Western Plains: The rare occurrence of Dysoxylum and Dodonaea at the Matarikoriko (30m), Umutekai (60m) and Pollard's farm (91m) sites together with the presence of Rhopalostylis pollen indicates that semi-coastal forest occupied these sites. A small remnant of forest at Jones' farm 1 site (157m) is dominated by Melicytus but these subcanopy trees are now windshorn due to exposure. Forest nearer to the coast may also have been reduced in stature by salt spray and the prevailing wind, creating coastal scrub. The continuing presence of Pteridium at Jones's farm 3 site indicates it has been a component of regional pollen for the last 4000 years probably derived from the more open vegetation on the coast. Records of logs being found in the coastal swamps suggests that the swamp forest, found at the Jones' and Pollard's farm sites may have been more extensive in the past.

5.4.3 The Arrival of the Maori: The time is acknowledged by archaeologists to be about 800-900 yr B.P. (1.8.2). There is no evidence in the pollen record to indicate when the Maori arrived in Taranaki. When the European settlers arrived they described the coastal plains. The most detailed description gives the impression that about 1880 there was a patchwork of vegetation including fernland, overgrown Maori clearings, small stands of "heavy bush" and scrubland (Burgess 1901). Under the scrub a profusion of palms and ferns suggests some regeneration from earlier clearings. Lines of boulders, indicating garden boundaries were overgrown, presumably abandoned when seen and described by Percy Smith (1910).

The lack of evidence of persistent charcoal in pre-European sites outside the Egmont National Park indicates that clearance for new gardens was not a frequent activity of the Maori. The only tropical crop that could be grown in the cooler climates in New Zealand was the kumara (Ipomoea batatas). It required considerable effort, gravel being transported and ashes added to the gardens to improve the soil and maturation of the crop. This type of garden was maintained for many years (Best 1925). Before the introduction of steel axes, tree trunks were left standing while small branches and trash was piled and burned. This would have allowed some recovery of the forests. When steel axes were obtained the forests were felled and burned (Best 1925). Evidence from the Palliser Bay study (1.8.2) suggests that fern root became more prominent in the diet about 500 yrs ago (Leach 1981). This change is associated with a change in climate about that time. The growing and storage of kumara became much more difficult and was common only in the more northern parts of New Zealand (Davidson 1984)

Evidence of climatic change in Taranaki has been interpreted from changes in the profile at Jones' farm 3 site on the west. High levels of Ascarina pollen decline about 1400 yr B.P. together with other drought prone species and finally Ascarina disappears just prior to the Newall eruption (Fig.35). At this time there is an upsurge of Weinmannia, a species favoured by a cooler wetter climate. These aspects of the study will be discussed in greater detail in Chapter 6.

The change from kumara to fern root which had previously been used only in times of shortage, cannot have been by choice because the rhizome is known to cause severe tooth wear (Leach 1974 and Day 1984). Planes on the teeth caused by chewing fern root were more common in late pre-historic time, indicating increased use of the rhizome (Davidson 1984). Fern root was discarded when the European potato was introduced (Cameron 1964). Several dates have been suggested for this introduction. It is recorded that Marion du Fresne planted potatoes in the Bay of Islands in 1772 and Captain Cook did the same in Queen Charlotte Sound in 1773. As early as 1805 Maoris in the Bay of Islands bartered potatoes for axes. It is at this stage that large scale clearance of the forests began (Cameron 1964). Potatoes grew well only in soil which had been recently cleared from forest and then only for a few years. The trade flourished for about 70-90 years and then collapsed when Maori tribal organisation failed (Cameron 1964). It is probable that this trade was also carried on in Taranaki and accounts of widespread fires by Riemenschneider in 1846 (Greenland 1967) indicate burning for the cultivation of potatoes.

Palynological evidence presented here would appear to support

these ideas because there is so little evidence of fires in pre-European time. Several factors are involved. First deterioration of the climate to cooler and wetter than before. Second, a substitute for kumara when growth and storage of this food became difficult. Third, availability of the much hardier European potato and fourth the desirability of a food which could be bartered for axes (Best 1925, Cameron 1964). Prior to 400 yr B.P. none of these factors were in operation. Gardens were made, improved and maintained, aligned boulders being used for demarcation (Leach 1974 and Davidson 1984). Such gardens were seen (Percy Smith 1910) on the Taranaki coastlands but were overgrown. Kumara were grown within the shelter of the forest in early European time (Burgess 1901). These may have been of the improved varieties introduced later by Europeans (Best 1925).

The interpretation given above differs somewhat from the conclusions reached by McGlone (1983). He presented evidence for a much earlier date for deforestation by the Maori. His quoted sites are however, either from the South Island where kumara would never have grown or from the eastern North Island which is very prone to droughts. It has been recognised that even in the warmer districts there was no certainty of a good crop of kumara and that other sources of starch were used. These included; fernroot, the starchy pith of Cyathea medullaris and the sugary pith of the tap root of Cordyline spp. (Best 1925, Brunner 1952). The importance of these substitutes in the diet depended on climate and soil fertility. The date for Polynesian fires as indicated at Potaema bog (450yr B.P.) by McGlone (1983) agrees well with evidence from Pteridium and charcoal data at Pollard's farm site on the western side of Mount Egmont.

5.4.4 The Arrival of the European Settlers: When the Europeans arrived dense forests still covered the eastern plains and the pollen profiles show that these forests had been virtually unchanged for over 4000 years. The resilience of the vegetation had enabled it to recover after each eruptive event until about 400yr B.P. At this time Weinmannia became prominent in both western and eastern forests for the first time in the last 4000 years. Two factors are responsible for this change in species composition of the forests. First, the most recent eruptive phase of volcanism that began with the Newall nuée ardentes which provided sites on which Weinmannia could become established (Chapter 4). Second, the change to a cooler and wetter climate, which also favoured this species (Chapter 6).

Within Egmont National Park the high altitude sites at Manganui bog have regional pollen indicating clearance of the forests on the eastern ring plains in European time only. Damage at Potaema appears to be related to the introduction of mammals. The New Zealand Forest Service still carries out eradication programmes for goats (Mawhinney 1980).

At York Road bog the forest was exploited for timber. The decline in Libocedrus and subsequent recovery is due to logging after the area was declared part of the Egmont National Park in 1900 (Clarkson 1981). Timber extraction is also indicated by the rise of Weinmannia as podocarp pollen declined, suggesting that the land was not cleared for farming.

Indications are that farming approached closer and much earlier

towards the Norfolk Road swamp. At this site, coincident with the occurrence in the profile of pasture weed pollen, Weinmannia declines in common with all other tree species indicating a reduction in forest area with no recovery. Charcoal is always present at this site indicating earlier fires from some undetermined cause. Persistent charcoal does not occur at the York Road site prior to European time. This could be the reason why logging of timber took place near the York Road Track but farming became established earlier in the vicinity of the Norfolk Road site. Earlier fires near Norfolk Road may have made the task of clearing the forest much easier. At the time the Messenger's farm site which is just beyond the terminus of Norfolk Road, was sampled, the last of the cutover forest adjoining the Park boundary was being cleared.

Differences are apparent between the four eastern ring plain sites. At Ngaere conversion of the swamp to farmland required drainage. Charcoal values are low until the upper three samples. Although Pteridium is present there is no upsurge of Leptospermum, Coprosma Coriaria or Myrsine pollen which would indicate second growth after fire. It is known that drainage caused the death of the forest trees (Every 1974), so it is possible that once an area had been drained cattle were then able to control the regrowth while pastures were gradually improved. The marked decline of D. dacrydioides at this site results from the extraction of this timber and its use in the butter box industry established at Eltham (1.9.3). The industry flourished until 1913 when the supply of trees was exhausted (Standish 1984).

The Midhurst area was clothed in very wet forest where D.dacrydioides and possibly B.tawa (Clarkson 1985) were important species. This is probably why there is still a remnant of this former forest present, although much degraded. The high values of Cyperaceae that persist in the spectrum after settlement at Midhurst 1 indicate continuing waterlogging at this site. Leptospermum and Pteridium are present suggesting regrowth and it appears from the variety of forest taxa in the profile that the forest remnant (Midhurst 2) was probably much larger until quite recently.

Ratapiko was formerly a Typha swamp with open water, possibly a considerable lake surrounded by dense forests (Brooks 1892). After drainage work, recorded at 212-218mm by the redeposited tephra, destruction of the forest began. Swamp species were reduced, particularly D.dacrydioides. All small tree and shrub taxa from a floristically rich forest were almost eliminated having <1% representation. Initially this would be by browsing of cattle. As farming became established the regrowth indicated by Leptospermum and Panax group pollen together with Pteridium was removed by improved farming practices. Pinus was established early perhaps as shelter around the homesteads.

The two sites close to the Puniho Track within Egmont National Park both have large amounts of charcoal but this is not thought to be related to either Maori or European sites. The abundance of Phymatodes and Blechnum at these sites could indicate the presence of mature Beilschmeidia tawa in the vicinity. Both these species establish on the trunks of B.tawa (Knowles and Beveridge 1982). This species is known to

have survived damage at a distance of 5km after the eruption of Mount Tarawera. Stripped of all foliage and small branches it resprouted and recovered fully within 6 months (J.L. Nicholls in Knowles and Beveridge 1982). The trees must also have survived the volcanic events recorded here because these epiphytes only establish on tree trunks.

All three western sites outside the Egmont National Park record complete destruction of the forest by Europeans. The effect of this clearance is seen best at Jones' 1 when there is an abrupt increase in sedimentation and the marshy fern grove becomes a Typha swamp. Esler (1978) has described how hill country wetland communities develop after forest clearance from a slow flowing stream. At Brown's Flat at the head of the Tiritea Stream (Tararua Range), Juncus articulatus became established in the creek, thus slowing the flow and gathering silt, the process would be self-perpetuating. Typha is now established in the area. Typha is a deciduous species (Ogden and Caithness (1982). The uncompacted nature of Typha peat noted in (4.2.1) may be due to this seasonal growth pattern, leading to a rapid accumulation of litter. Although seedlings established on exposed mud at the Pukepuke Lagoon (Western Manawatu) few survived submergence and extension was achieved by the growth of rhizomes (Ogden and Caithness 1982). They also found that the most important factor in the rapid growth of Typha at the Lagoon since 1940 was due to the use of superphosphate in the catchment. Typha is highly responsive to phosphate fertilisation. Typha appears for the first time in the upper samples of the Jones's farm 3 site and at Bowden Reserve the initial clearance at the base of the profile is followed by the development of a Typha swamp.

Pollard's farm site contains the only indication of pre-European fires which could be attributed to the Maori. This site lies between two laharic mounds on which fortified pa or kumara pits were sited. A large carved boulder indicating a tribal boundary was found close to this site (Day 1984). There are indications that the Maori certainly frequented the area, but they did not burn the surrounding forest. The development of kumara pits is traced by archaeologists to the need to protect the tubers from mould. The date of this innovation is unknown (Davidson 1984). They were also frequently hidden within the forest to prevent theft (Cameron 1964).

It is unfortunate that Bowden and Motunui, the two sites closest to the northern coast which may have revealed changes due to Maori occupation, have suffered from accelerated sedimentation in European time, so that the profiles only contain very recent pollen. To-day only the Bowden site preserves any vestige of the semi-coastal forest thought to have been more common (Clarkson 1985) prior to Maori occupation. The resurgence of Marattia fern, now fairly rare, is due to the enclosure of the site as a reserve. Today the Reserve is dominated by Corynocarpus laevigatus. No pollen of this species was found here but two grains were found at Matarikoriko. Maori oral tradition states that this tree was introduced into New Zealand about 20 generations ago. It is frequently found near old Maori settlements (Best 1925). This suggests that the survival of this forest remnant close to the coast may be due to its protection by the Maori.

Removal of the forest, indicated at the base of the profile, created Typha swamp and also a need for shelter belts. The alien

streamside species Alnus was planted together with Pinus. Regrowth following clearing was dominated by Pteridium and this is still present at the site. Some time later drainage of the swamp area finally enabled the establishment of pastoral farming as indicated by a rise in the pollen of typical pasture weeds together with other herbs and grasses. Cyperaceae pollen replaced Typha as the area became better drained. The struggles of the early settlers to establish pastoral farming are shown at this site and can be compared with rapid clearance of forest at Jones' farm 1. Clearance here may have been as much as a hundred years later than at Bowden and the chainsaw and bulldozer are likely to have been used.

The Motunui site records the same sequence of swamp drainage with Typha again increasing. The major fire on the site may have been a preliminary burn prior to improving the drainage. The lower value of Gramineae in the uppermost sample may reflect the most recent influence of Europeans on the land, industrialisation. Motunui Synthetic Fuel Plant now covers a large area previously in pasture.

Matarikoriko alone, of the four northern sites, suggests fire induced fernland was present at some distance from the former pa site. The pollen profile suggests the site was forested and it is possible that semi-coastal forest was continuous between this site and that at Umutekai Road. This suggests that spores of Pteridium were not readily transferred through the trunk space within lowland forests (1.10.2.1 and 1.10.3.2.), since there is little Pteridium in the Umutekai spectrum. Fire does not appear to have destroyed the forest at either of these two sites during Maori time but it is possible that it may

have done so at Motunui and Bowden Reserve. The high charcoal values, after the first occurrence of pasture weed pollen, rise to a peak abundance value of 20.8 at 120mm depth and indicate repeated fires. The pollen profile shows that this area was very wet forest and may have been difficult to burn. The pollen profile and charcoal record of Umutekai contrasts with that of Matarikoriko. Probably settled much later than Matarikoriko, the site itself was never burnt.

The early settlers regarded the forest as a source of timber and winter browse for cattle, but mostly destroyed the forest for farming (1.9.2 to 1.9.5). This attitude was forced to change due to the need to protect the headwaters of rivers draining the steep flanks of Mount Egmont. This finally resulted in the creation of Egmont National Park in 1900. Areas of Taranaki still in forest or secondary scrub are shown in Fig. 36. Indigenous forest is almost entirely absent from the coastal plains of Taranaki. In the decade since publication of the first of these maps (N109 (4th Ed.) in 1976) some changes may have taken place. It nevertheless provides a demonstration of the change in social attitudes towards indigenous forests in the last hundred years. Inglewood and Eltham were among the first areas to be settled (1875-1879), only very small areas of forest remain. Eltham had a thriving timber industry which exploited the forest (Brown 1975, Standish 1984). In the southwest quadrant which had poorer soils and where Maori opposition to European settlement continued for some time after the Taranaki wars ended, there are larger areas of forest with straight boundaries indicating fencelines and some measure of protection.

Following destruction of the forest, erosion of the cleared area would have been accelerated by heavy and often intense rainfall (1.4.4.). Palynological evidence suggests that Typha swamps increased at several sites on the western and northern sides of the volcano in European time. On the eastern ring plains, large swamps were drained and converted to pasture. These changes in the vegetation of Taranaki are long term and are unlikely to be reversed.

Since the 1960's the conservation movement has led to an appreciation of the forest remnants which remain. The creation of reserves has afforded protection as at Bowden Reserve and the covenants in perpetuity to the Queen Elizabeth II National Trust at Matarikoriko. A reversal of the declining trend in pollen of forest taxa is shown at some sites notably Potaema and at Puniho 1 and 2, all of which are in the Egmont National Park, but also to some extent at the Pollard and Umutekai sites.

Destruction of the indigenous forests of Taranaki has had far reaching effects on the microclimate of the ring plain. Early plantings of Pinus for shelter belts is recorded in the pollen spectra of all Manganui bog cores. Heaphy cautioned against the destruction of all forest as early as 1842 and the result of its removal on the western coast was described by Burgess in 1901 (Matthews 1905).

Within about 30 years of the settlement all D. dacrydioides formerly plentiful on the ring plain, had been exploited at Eltham and within a hundred years all of the extensive lowland forests had been felled for timber. The need for timber remains. Although Pinus

plantations are not extensive in Taranaki, where pastoral farming is the preferred land use, they are indicated in the upper samples of the Manganui sites by higher values of Pinus pollen.

CHAPTER 6

CHANGES IN VEGETATION DUE TO CLIMATE.

6.1 INTRODUCTION

Sites on the western ring plain show changes in their pollen spectra which have been interpreted as a result of climatic change. Four new radiocarbon dates have been obtained for two of these cores, Jones' farm 3 and Pollard's farm, which together with the tephras provide a good chronological sequence in which to discuss climatic change. All three cores contain the Kaupokonui tephra and scattered Newall Lapilli. Evidence of change in the altitudinal range of vegetative zones has been deduced from the pollen spectra at Stratford Mountain Road and edaphic changes are interpreted from the stratigraphy of the Jones' farm 3 core and profiles of several ring plain swamps. Data from earlier palynological studies from Ahukawakawa and Potaema swamps (McGlone et al in litt.) have been collated into Table XXXVII, which lends support to the interpretations from this study.

Two species in particular show important changes in their pollen spectra at several sites. The late appearance and rise to prominence of Weinmannia has been commented on in Chapter 4 and relevant spectra are presented in Fig.34. Ascarina pollen which is rare in the study area today has very high values at Jones' farm 3 site prior to the deposition of the Kaupokonui tephra. Pollen spectra of Ascarina for western and northern sites is presented in Fig.35. Details of the tephras and radiocarbon dates shown in this diagram are listed in the

TABLE XXXVII DATA FROM AHUKAWAKAWA SWAMP AND POTAEMA BOG.*

Ahukawakawa Swamp			Potaema Bog			Comment
Depth m	Date yr B.P.	%	Depth m	Date yr B.P.	%	
0.00		*	0.00		0	Pinus
0.1		0	0.1		0	"
0.2		0	0.2		0	"
0.3		*	0.3		0	"
0.4		0				
0.5		0	0.5		0	
0.6	404	+	0.6		0	
0.7		2	0.68			Burrell Lapillii
0.8		*				"
0.9		1	0.91			"
1.0		+	1.0		0	
1.1		+	1.05-1.14			Newall Lapilli
1.2		*	1.2		0	
1.3		+	1.3		1	
1.4		1				
1.5		1	1.5		0	
1.6		+				
1.7		2				
1.8		1				
1.9		2				
2.0		1	2.0		*	
2.1		2				
2.2		2				
2.3		1				
2.4		3				
2.5		3	2.5		1	
2.6		3				
2.7		2				
2.8		1				
2.9		1				
3.0		1	3.0		1	
3.1		+				
3.2		1				
3.3		1				
3.6		-	3.6		1	
3.7		2				
4.0		2	4.0		1	
4.3	2890	1				
4.6		1	4.6		1	
4.9		2	5.0		*	
5.2		1				
5.5		1	5.7		*	
5.9		1				
6.25		+				
6.5		2				
7.2		4				
7.5		1				

* Data from McGlone et al (in litt.) and (pers. comm.)

stratigraphic tables (Volume II).

6.2 EVIDENCE FROM FOSSIL POLLEN DATA

6.2.1 Climatic Change before 4000 yr B.P.

Although this study has been designated as Late Holocene, evidence of a late glacial flora was found at the base of the core from Pollard's farm. This data will be presented although it will not be further discussed. Three new radiocarbon dates were obtained to determine the relationship of this late glacial flora to the lowland temperate forest flora found in the upper pollen spectra at the Pollard farm site.

Pollen typical of a subalpine bog dominates the base of the pollen spectrum below 465mm at the Pollard's farm site. Lagarostrobos, Dracophylum and Gaultheria are associated with Gleichenia fern spores and Restionaceae pollen (Figs. 27A and C). Myrsine, Coprosma and Coriaria pollen is also prominent and all these taxa have very similar curves declining steadily then decreasing abruptly, coincident with the deposition of an unnamed tephra at 401mm depth. Peat from the lowest sample in the core has been dated (NZ6907) at 9350 ± 730 yr B.P. Wood from just below the unnamed tephra at 410mm, identified as Dacrydium or Podocarpus (Allan 1961) has been dated (NZ7007A) at 11,900 ± 959yr B.P. This is older than the peat at the base of the core and it must be assumed that this is due to contamination of this shallow peat by younger roots. The later date agrees with the late glacial flora at this level. Pollen of swamp and lowland forests is present throughout

the core but increases markedly above 345mm. A paraconformity exists at or just above 325mm because the Kaupokonui tephra c. 1400 yr B.P. overlies the 68mm of dark peaty loam, above the unnamed tephra. Ascarina pollen is present coincident with the late glacial flora and this also suggests some contamination of the lowest peat, possibly by inwash down root channels.

6.2.2 Climatic Change since 4000yr B.P.

6.2.2.1 Western Sites: Above 345mm (Zone 3, 3.5.4) the Pollard's farm core is considered to be undisturbed. The Kaupokonui tephra is present at the base of this zone but is not well expressed. Ascarina is present as traces in most samples but has its highest value (1.9% Fig.35) at 305mm. Weinmannia appears for the first time at 125mm and then rises steadily.

Unusually high values of Ascarina pollen are recorded in the pollen spectrum of Jones' farm 3 site. This species is now rarely seen in the study area but the pollen persists in the spectrum for over 2000 years so the high values cannot be attributed to an unusual or transitory local presence. Changes in the pollen curve are synchronous with the curves of other drought sensitive taxa, namely D.cupressinum, Nestegis and Schefflera. Other taxa do not show similar changes. Fig.26C compares the gr/cm³ and % data for the six species considered to indicate changes controlled by climate. Although there are some minor differences between the two data sets, these do not alter the interpretation made. Ascarina disappears from the profile above 155mm just before European settlement. Weinmannia appears for the first time

at 175mm and persists to the top of the profile (Fig.26B and C).

Ascarina is also prominent in the Jones' farm 1 core from a slightly higher elevation (152m). The highest Ascarina value is reached at 245mm which is within the portion of the core containing scattered Newall Lapilli. The pollen spectra at this site indicate that prior to the clearance of the forest by Europeans this site was a marshy area dominated by tree ferns but essentially a forest site. The low pollen concentration throughout the profile may be related to poorer preservation conditions within the soil (Fig.25A and B). Most taxa have high values at the 305mm depth including Ascarina. Weinmannia pollen appears for the first time in the profile at 185mm (after the Newall Lapilli) and then increases (Fig.25C). The forest was destroyed by Europeans at 145mm and a Typha swamp developed. There is no Ascarina present in the Puniho 1 spectrum and only one occurrence at Puniho 2. Weinmannia dominates the pollen profile at both sites (Fig.24A and B). Both these cores are very recent.

6.2.2.2 Eastern Sites: At Manganui Bog there is only one occurrence of Ascarina pollen among the three cores but this is significant in that it is below the Newall Lapilli in core 85/1. Weinmannia occurs consistently throughout all three profiles. This pollen also occurs consistently at <1% between the 2000 year old pyroclastic flow (1980 ± 60 yr B.P.) and just above the Kaupokonui tephra c. 1400 yr B.P. in the Stratford Mountain Road site (82/4). It is of interest that Weinmannia occurs in all samples throughout this profile in trace amounts but virtually disappears at the 500mm level (g), the "layered fine ashes". There is one trace after the Newall Ashes (d). There is no

Ascarina pollen at the 85/2 site which relates only to the time of the Burrell eruptions. Weinmannia is absent from the samples below the Burrell Ash but present on the organic layer above it.

Sites at low altitudes within the Egmont National Park (Potaema, York, Norfolk) on the eastern side of the volcano have very low values for Ascarina pollen, of <1%. Only one grain of Ascarina was found at the Messenger's farm site. Weinmannia is present throughout the profiles of Potaema, York and Norfolk sites. At Potaema and Norfolk this pollen becomes much more prominent after the Burrell Lapilli. Trees of W.racemosa were present in the canopy above the coring site at York Road. Abundant pollen is produced by these trees, but it is poorly dispersed. It therefore dominates samples taken from below its canopy (McGlone 1982). On the ring plain, Weinmannia occurs for the first time at Midhurst 1 at 385mm but only becomes prominent above 165mm. It therefore follows the general pattern shown in the other sites (Fig. 34). It has lower values but a consistent presence at Midhurst 2 which is all in post-Burrell time. Both Ascarina and Weinmannia are consistently present until late European time at Ngaere and Ratapiko swamps. They have low values and show little change in the profiles.

6.2.2.3 Northern Sites: Among the northern sites, Motunui and Bowden only had one occurrence each of Ascarina. These sites are entirely modern. Fig. 30C for percentage data at the Matarikoriko site shows changes in the Ascarina curve at very similar depths to Jones' farm 3. Syzygium, Laurelia, D.cupressinum, M.robusta, Nestegis, Schefflera and podocarp pollen are all more prominent at the base of the profile and decline at the same level 455mm. This general trend is reversed at

125mm and most of these taxa rise. The pollen spectra are however, influenced by European forest clearances at this time. Sporadic occurrences and low values of subcanopy species indicate cattle may have been browsing in the forest. As this core is undated no direct correlation with the profile at Jones' farm 3 can be made. In the period between 445-205mm when the above taxa declined Knightsia, Leptospermum and Elaeocarpus become prominent, Weinmannia reappeared at 405mm and increased steadily.

Further inland the Umutekai site, also undated, shows a marked decline from the base of the profile in Laurelia and Syzygium followed by a rise at 305mm. This decline is however accompanied by a rise in D. cupressinum and M. robusta which suggests a more localised change in the edaphic conditions at the swamp. Some drying out of the site allowed the lowland forest to increase as swamp trees declined. Ascarina and Nestegis have only trace values throughout the profile. Weinmannia reappeared at 305mm and both Weinmannia and Schefflera increase at the top of the profile.

6.3 EVIDENCE OF CHANGE IN VEGETATIVE ZONES

In the pollen profile of Stratford Mountain Road site (82/4), following the emplacement of the pyroclastic flow (NZ3886A) dated at 1980 \pm 60yr B.P., Coriaria and then Dracophyllum become established but Gramineae maintained its prominence. Dracophyllum appears to have survived the deposition of the Kaupokonui tephra (1440yr B.P.) with very little change. It then largely replaces Gramineae in the profile. Just prior to 1400 yr B.P. subalpine scrub as seen at the site

today becomes established.

6.4 EVIDENCE FROM EDAPHIC CHANGES

6.4.1 Western Sites: The stratigraphy of the Jones's 3 core shows major changes which appear to be more or less coincident with the changes in climate indicated in the pollen spectrum. Black peat at the base of the core is replaced by fine sandy, peaty, yellow brown loam above 450mm depth. The upper 30mm of the peat (450-420mm) were radiocarbon dated (NZ6705) at 2750 ± 60 yr B.P. At this stage the curves of the drought-sensitive taxa are rising but above 375mm a long slow decline begins. At 210mm depth the yellow brown loam is replaced by black peat. The time is about 400 yr B.P. and there is an upsurge in pollen of all taxa including the drought sensitive species but not in Ascarina. These changes in the stratigraphic column suggest that the water table was considerably lower and that peat was not developing at this site between c. 2750 yr B.P. and 400 yr B.P. Pollen of tree species usually confined to wet areas such as D. dacrydioides, Syzygium maire and the water herb Potamogeton all disappear and reappear in the spectrum coincident with the change from peat to loam to peat.

Peaty loam is present both before and after the Kaupokonui tephra at Jones' farm 1 site. The pollen profile is that of a lowland forest and the low pollen concentration is due to poorer preservation in forest soil. The change to black peat above the Newall Lapilli is due to European clearance and development of a Typha swamp. The paraconformity below the Kaupokonui tephra in the Pollard's farm core precludes any comparison of before and after strata.

6.4.2 Eastern Sites: Few eastern sites contain the Kaupokonui tephra which provides a useful datum for the change in pollen spectra relating to climatic change as seen in the western cores. At this time Midhurst 1 was in forest and there is a striking lack of mire plant pollen from just after the Kaupokonui tephra until just prior to the deposition of the Burrell Lapilli at 405mm depth. At this time changes occur in the pollen spectrum which indicate a change to a wetter environment with the reappearance of Cyperaceae and the beginning of a slow rise in most taxa. Mineralised peat is found below 374mm depth and the rate of sedimentation is very low. Above the Burrell Lapilli 270mm of peat developed. Midhurst 2 core includes only post-Burrell time and the profile indicates a rather wet lowland forest was present throughout.

At Ngaere swamp the pollen spectra show continual change in the curves of D.cupressinum and D.dacrydioides. The latter has a small rise within each tephra layer. After the Kaupokonui tephra D.cupressinum increases while most other podocarps at first decline but then rise. This rise is coincident with a decline in D.dacrydioides and stable values for D.cupressinum. These changes would appear to indicate that forest encroached onto the swamp surface at this time as the water table fell.

6.5 DISCUSSION

The critical pollen curve is that of Ascarina representing the small tree species Ascarina lucida. Usually found in the understory of podocarp hardwood forest and preferring sheltered sites without a dense canopy cover, this species has only a restricted distribution today.

The occurrence of this pollen in fossil pollen sites has been compared to its present distribution by McGlone and Moar (1977) who concluded that the species is a good indicator of an equable climate, that is frost and drought free. Changes in Ascarina pollen curves at many sites showed it to be plentiful between 10,000 and 5000 yr B.P. It then declined but had a recovery period between the Waimihia Formation c. 3400yr B.P. and Taupo Pumice c. 1800 yrB.P. Beginning at 1700 yr B.P. it declined to the present low levels of < 1% at most sites. These conclusions are based largely on data from the Volcanic Plateau in the central North Island. Jones's farm 3 site is the first detailed fossil pollen diagram from Taranaki to cover this period. The abundance of Ascarina at this site between the Inglewood and Kaupokonui volcanic events indicates an equable climate between c. 3800 and 1400yr B.P. with some deterioration around 2750 yr B.P. After 1400yr B.P. there is a slow decline until it disappears from the spectrum just before the Newall Lapilli, (400yr B.P.). These dates are not too different from those determined by McGlone and Moar (1977). Both sets of dates are based on tephrochronology so the limits are not too precise.

Declining values of Ascarina after c. 1400 yr B.P. indicate droughts and/or frosts. Reference to the pollen profile of Jones' farm 3 shows that between 1400 and 400 yr B.P. three species rise and decline in phase with Ascarina. These are D. cupressinum, Schefflera with Nestegis a little later. D. cupressinum is not found at present in sites which experience long summer droughts, but it can however, survive severe winters (Franklin 1968) and has been known to ascend up to 600m in Westland (Wardle 1975). Schefflera is widely distributed in lowland and montane forest, growing well in gullies and along streamsides as far

south as Stewart Island (Poole and Adams 1963, Moore and Irvine 1978). Pollen of this species was found at Ahukawakawa swamp at 920m (McGlone et al in litt.). Both D.cupressinum and Schefflera were classified as "susceptible" by Ogden (1976) in his extended study of droughts in forest remnants of the Manawatu region. In the South Island, Nestegis has been considered by Moar (1984) to be representative of an inter-glacial climate because it has not yet been found in any post-glacial sites in Westland. Both N.cunninghamii and N.lanceolata were classified as "resistant" by Ogden (1976). This may be why it is slightly out of phase with D.cupressinum and Schefflera. Favourable conditions for its present day distribution (in the South Island) are moderate rainfall (1000mm/yr), relatively sunny days and a considerable difference between summer and winter temperatures. It is apparent that none of these three species is frost-tender but all of them are drought-sensitive. Thus it is concluded here that between c. 1400 and 400 yr B.P. the initial cause of the Ascarina decline was frequent longer dry spells in summer and not low temperatures.

Ascarina is reported to be nearly extinct on the Taranaki volcanoes. There are only 5 recorded individuals, two of tree height and one shrub in the Pukeiti Private Scenic Reserve and two shrubs close to the Dover Track on the Pouakai Range, all in the northwest and at >300m (McGlone et al. in litt.). Ascarina pollen found in surface samples at Ahukawakawa Swamp, which lies between Mount Egmont and the Pouakai Range at an altitude of 920m, was attributed to re-working of earlier Holocene deposits (McGlone 1982). Elevated levels of this pollen however, were found at both Ahukawakawa Swamp and Potaema Bog. Details of the values together with relevant dates have been supplied (McGlone

pers. comm. 1985) and are set out in Table XXXVII. It can be seen that periods with higher values at Ahukawakawa are comparable to similar periods at Jones' farm 3 although the actual percentages are much lower due to the higher altitude. Similarly there is a small rise at Potaema just prior to the Newall eruption (McGlone et al in litt.). They also found that Weinmannia and Elaeocarpus were most common then. Subsequently Weinmannia, Metrosideros and Nestegis had their lowest values between 1300-400 yr B.P.

A decline in canopy and subcanopy species as indicated in the pollen spectra at Jones' farm 3 would be expected to be followed by a rise of pollen types characteristic of second growth, responding to light gaps in the canopy. This does not happen here. Leptospermum pollen maintains a consistent value for a long period of time, an unusual pollen curve for this taxon. Coprosma and Coriaria pollen although present with varying values, do not show patterns associated with colonisation. This may be because these species were also under stress but is more likely to be because D.cupressinum remained alive and light gaps did not occur. Pollen rain would be reduced if the crowns of trees were damaged and it cannot be automatically assumed that a decline in pollen rain indicates death of the trees. In the Manawatu region, forest remnants have been studied after severe drought (Atkinson and Greenwood 1972). From their data they suggested that the "stag-headed" crown often seen in D.cupressinum could be due to severe drought. It is suggested that such a deterioration in crown size of D.cupressinum could have happened at Jones' farm 3 site.

It is significant that at Jones' farm 3, Laurelia pollen persists

throughout the spectrum. Atkinson and Greenwood (1972) found that species which normally live in poorly oxygenated wet sites such as D.dacrydioides, Laurelia and Syzygium were not affected by the droughts of (1969-1970), which they studied. They concluded such species must have deep roots. Of these three, only Laurelia was able to survive at the Jones' farm 3 site. This species may be the best adapted of the three for survival under changing edaphic conditions. The large plank buttresses indicate a true swamp species and it may have deeper roots than the other two species. The rising curve of Knightsia, a frequent colonizer of disturbed sites, suggests that it replaced D.dacrydioides and Syzygium when they became reduced at this site. The low values apparent when they do reappear in the spectrum would tend to support this. This last piece of evidence suggests that drought may have had a cumulative effect due to physiological stress and lowered water tables. Long term deficits in soil moisture were found to be a better indicator of stress than the "number of rainless days" criterion usually applied as a measure (Jane and Green 1983).

Early settlers extracted many logs of Lagarostrobos colensoi from Ngaere swamp but no living specimens were seen (Every 1974). Evaporation from the swamp surface would be high during a drought. If the soil water was not replenished by winter rainfall then peat levels would be compacted and edaphic conditions might not suit a bog species like Lagarostrobos. After 400yr B.P. the wetter and cooler climate would raise the water table but if there was no viable seed the plants would not re-establish.

If prolonged dry spells were responsible for the changes in the

Ascarina curve at Jones' farm 3 site, it would be expected that evidence of change would be found at other sites and different altitudes. Compositae pollen representing B. elaeagnifolia enters the profile of the Stratford Mountain Road site (82/4) about 1400yr B.P. The leaves of this species are thick and leathery with a dense cream coloured tomentum on the lower surface. Features which are almost identical to those of Olearia colensoi. Clarkson (1981) regarded these two species as "ecological equivalents". These adaptations would normally be found in plants living in dry conditions but both B. elaeagnifolia and O. colensoi occur at high altitudes, frequently cloud covered. It has been suggested (Wardle 1965b) that in this situation such features would enable the plants to survive short but intense periods of drought and also to exploit short spells of high light intensity between cloudy periods. Prolonged dry spells might therefore favour B. elaeagnifolia over Chionochloa rubra and enable the former to extend its maximum altitudinal range. This tussock is favoured by "sour" soil, heavy rainfall and cloudy skies (Godley 1975). These changes in the pollen spectrum are therefore interpreted as indicating an upward extension of the subalpine scrub zone and a retreat upslope of the tussock zone.

Evidence from the upper montane forests is limited in this study but Ahukawakawa Swamp (920m) is within the present altitudinal limits of the upper montane forest. Palynological evidence from this site indicates considerable variation in the representation of Libocedrus and Weinmannia pollen and a negative relationship between the two (McGlone et al in litt.). Between 1400-400 yr B.P. Libocedrus had a very high average value of 32 % while Weinmannia, Metrosideros, Nestegis and tree ferns fell to their lowest levels. Ascarina was also less

common than previously. After 400yr B.P. there is a marked decline in Libocedrus and a strong increase in Weinmannia. These changes suggest that conditions favoured an increase in Libocedrus between 1400 - 400 yr B.P. in the forests surrounding the swamp. Periods free of cloud coincident with long dry spells would permit greater growth of this species and an upward extension of its altitudinal range.

About 400yr B.P. Weinmannia appears for the first time in all western sites. Fig.35 shows that it became more prominent at all sites at lower altitudes and this is also the case at Midhurst 1 and 2 not shown in Fig.35. In Chapter 4 some of this change was attributed to the availability of disturbed sites. These were plentiful on the western side following the Newall eruptions (4.2.5). On the eastern side, the forest canopy was removed by the Burrell Lapilli which would allow some colonisation but the pollen spectra do not suggest large areas of bare land (4.2.7). The present distribution of Weinmannia on Mount Egmont below 750m is as a prominent component of a lower montane forest in which D.cupressinum and M.robusta are emergent. Above 750m these large trees are gradually replaced by P.ferruginea, Myrsine salicina, Griselinia and P.hallii. Above 900m Weinmannia dominates a type of forest called "Goblin Forest" by Cockayne (1928) and Clarkson (1977, 1981). The multi-stemmed trees are dwarfed, the trunks covered with abundant epiphytic lichens, liverworts and the pendulous moss Weymouthia. Similar forests of which a Weinmannia sp is a component, found at high altitudes on volcanic islands in eastern Polynesia are described as "cloud" or "mossy" forests. The former is the better term since it describes the controlling factor in such forests (Radovsky et al 1984). High humidity is maintained not only by

rainfall but by clouds which form during the heat of the day (Neill 1969). The Weinmannietum on the Eastern Cordillera (Colombia) is also a "very wet montane forest" (Van Geel and Van der Hammen 1972). Transpiration is reduced in these zones of high humidity, affecting both vigour and tree height (Odum 1971). Leaves of Weinmannia racemosa were considered by Clarkson (1981) to parallel the leaf structure characteristic of high altitude forests and to be adapted to tolerate conditions of mist, fog and high rainfall. These are the conditions he found to govern distribution of this species on Kaitake (1985).

It is hypothesised here that between c. 1400 and prior to 400 yr B.P. not only were there frequent prolonged dry spells but also the base of the afternoon cloud on Mount Egmont formed at higher levels. The coincidence of a higher cloud base with drier weather might be expected on meteorological grounds. The altitude of the cloud base is dependent on temperature and humidity of the air. Under these conditions the Weinmannia dominated "cloud forest" may have been able to extend its range upwards.

Fog has been found to be of ecological importance in the upland regions of the Kaimai Ranges (North Island). Its effect is very similar to that described above for "cloud forest". Because of this and the higher rainfall at high altitudes, Jane and Green (1984) found it difficult to extrapolate the severity of droughts at low altitudes to the uplands. Early work on the Tararua Ranges (North Island) showed that it is primarily low temperatures which limit growth at high altitudes (Zotov 1938). These findings would support upslope extension of

vegetation zones during periods of drought since higher light intensity under clear skies would promote growth.

Weinmannia pollen, although plentiful is not widely dispersed (McGlone 1982). If Weinmannia forest were at higher altitudes prior to 400yr B.P. this might explain the lack of pollen in the previous 1000 years at the lower altitude sites. The decline of Ascarina to low levels at 400yr B.P. was due to a wetter and frostier climate. These conditions would have assisted Weinmannia to colonise the newly devastated slopes and to extend downslope. Today the trees can be found down to sea level in some areas on the western coastal plain (Clarkson 1981).

The destruction caused by the Newall eruption has been described by Druce (1966). Fires lit by the nuée ardentes spread over a very wide area. Drought-stressed forest would be more vulnerable and this may have assisted the spread of fires (1.6.1). The impact of the Burrell Lapilli was perceived by Druce (1966) and Clarkson (1981) as devastating vegetation on the eastern slopes of Mount Egmont, but the pollen spectra do not support this. The random nature of change in the pollen curves of the subalpine shrubs at the Manganui Bog sites is interpreted as competitive responses by individual plants to a damaged canopy and not succession on bare ground (4.2.7). The patterns of change vary from taxa to taxa both within the spectra and between sites although the sites are close together. Destruction of the canopy by Burrell Lapilli at Potaema bog is followed by a similar competitive response. The recovery and rise to prominence of Weinmannia at this site has been investigated in detail (4.4). The increase of this species

was considered by Clarkson (1977 and 1981) to be indirectly related to the depth of Burrell Lapilli. There was only one exception to this indirect relationship and this was at Lake Dive. On the west the Weinmannia pollen increase coincides with the Newall eruptions. Disturbed sites here are also a significant factor in the prominence of this species (4.2.8).

Weinmannia is however, normally part of a succession to podocarp hardwood forest. It's persistent presence over the last 400 years could be influenced by the variability the climate in that period. Many accounts of climatic change within the last 400 years have been published. The precise dates vary depending largely on the topography and geographical position of the sites. Reviews have been made by Molloy (1969), later by Wardle (1979) and most thoroughly by Burrows and Greenland (1979). They considered evidence from meteorological data and such climatic indicators as glacier retreats, changing treelines, lake levels and distributions of tree species. They concluded that the apparent variations could all be explained by latitudinal alterations in positions of pressure systems and changes in the rate of circulation. The variability of the modern climate cannot be denied and this may be another reason for the success of Weinmannia. High intensity rainfalls for example cause debris flows on the steep slopes providing sites on which this species can establish (Stewart and Veblen 1982). The lowered treeline on the northwestern slopes of Mount Egmont and the indistinct boundaries of the vegetative zones (Clarkson 1977, 1981) are evidence of the interaction between volcanism and climatic change on Mount Egmont.

The evidence presented here indicates that between 4000 and 1400yr B.P. an equable climate existed in western Taranaki. Ascarina thrived at an altitude of 132m in the lowland forests. About 1400yr B.P. a deterioration of the climate is indicated, droughts become either more frequent, more severe or both. During this period swamps on the eastern ring plain became drier and lowland forest encroached onto the bog surface. It is possible that the vegetation zones on Mount Egmont were distributed higher up the mountain, particularly the Weinmannia dominated cloud forest. About 400yr B.P. rainfall became more evenly distributed and frosts more frequent. This change in climate and the availability of exposed sites for colonisation has led to the dominance of this species in the forests of Egmont National Park. It is believed that the variability of the modern climate may contribute to maintaining the disturbed sites on the western flanks and thereby the continuing prominence of this species.

CHAPTER 7

CONCLUSIONS AND SUMMARY.

7.1 CONCLUSIONS

7.1.1 Past Vegetation of Western Taranaki.

Temperate lowland forest dominated by D.cupressinum has covered the eastern ring plains for the last 4000 years. Within this forest there were large swamps surrounded by D.dacrydioides and in the wetter parts by Laurelia novae-zelandiae and Syzygium maire. The forest canopy was destroyed by volcanic events which deposited the Inglewood, Manganui and Kaupokonui tephras but the resilience of the indigenous forest ensured recovery and the species composition was restored after each event.

Two large swamps on this plain were investigated. Ngaere swamp near Eltham had areas of open water but very little Typha or Phormium. Leptospermum was important and a sedge/shrubland was present at the swamp margin. Ratapiko swamp, in the Inglewood district, was a Typha swamp. After deposition of lahars of the Ngatoro Formation the swamp was flooded, possibly a lake was present, but the area of Typha also increased. Following the Manganui volcanic event, drainage improved and the site became much drier. At Midhurst which is at a higher altitude than the other swamps the area remained in rather wet lowland forest in which D.dacrydioides and Cyperaceae were important until European time. Probably because these forests were so wet a small

remnant of this forest has survived.

On the western plains Pteridium was always present over the last 4000 years, indicating open scrubland near the coast. Further inland the small remnants of swamp forest investigated indicate that this type of forest, with a semi-coastal element has been present over the last 4000 years. Reports of large logs found in swamps in the area suggest it was formerly more extensive. On a terrace of the Waitara River to the north, semi-coastal forest with swamp trees was present. It extended inland at least as far as Umutekai Road. At both these sites, adjustment between swamp and lowland forest, in which both D.cupressium and M.robusta were co-dominants, occurred from time to time.

On Mount Egmont, subalpine scrub as seen at 1080m today, dates from just prior to 1400yr B.P. Before this Dracophyllum, Coriaria and Gramineae covered the area. About 2000 yr B.P. the tussock zone may have extended further downslope. Many events are recorded in the period between 4000 and 1400yr B.P. some of which removed any buried soils which may have been present. It is concluded that at times the slopes were devastated and little vegetation was present. Younger profiles from several low altitude sites, have a significant rise about 400yr B.P. of Weinmannia pollen. A species not previously important at any site in the last 4000 years.

7.1.2 Changes in Vegetation due to Climate.

The pollen spectrum of Ascarina at the Jones' farm 3 site indicates that between 4000 and 1400yr B.P. the climate in western Taranaki was equable, being frost and drought free. Between 1400 and 400yr B.P. droughts became a feature of the climate. These may have been either more frequent, more severe or both. This is indicated by the decline of Ascarina during this period. Coincident declines in other drought sensitive species and changes in the stratigraphic column of this site support this interpretation. Further support comes from similar changes in Ascarina pollen spectra by McGlone et al (in litt.) from palynological studies at Potaema bog and Ahukawakawa swamp.

Supporting evidence for the prevalence of droughts includes encroachment of lowland forest onto the Ngaere swamp surface about 1400yr B.P. It is further suggested that recurring drought and non-replenishment of ground water may have caused the extinction of Lagarostrobos colensoi. There is an indication at the Stratford Mountain Road (site 82/4) of change in the altitudes of the vegetational zones. Between 1400yr and 400yr B.P. there was a general upward movement of the zones due to increased photosynthesis under higher light intensity during periods of drought. Changes in the subalpine zone at this time have already been mentioned. In the upper montane forests surrounding Ahukawakawa swamp at 920m Libocedrus became more abundant between 1400-450yr B.P. (McGlone et al in litt.). Under a regime of more frequent droughts the base level of the afternoon cloud which forms on Mount Egmont would be higher. Under these conditions the Weinmannia dominated cloud forest would also extend upslope. This would

explain the absence of this pollen from lowland sites on the west prior to 400yr B.P.

After 400yr B.P. Ascarina has low levels at all sites, probably due to frosts. Weinmannia appears for the first time at the western sites and rises to prominence. At sites where it was already present, it increased. This species is still dominant in the forests within Egmont National Park today. Both this change to a cooler wetter climate and the availability of newly exposed sites after recent volcanic episodes have contributed to the expansion of this species. Pronounced variability in the modern climate and the resulting disturbance of the slopes of the volcano contribute to its continuing presence.

7.1.3 Changes in Vegetation due to Volcanic Activity.

Sampling at 10mm vertical intervals was not always fine enough to include the initial stage of recovery. At some lowland sites a return to full pollen production may have happened within a few years. Slow peat growth at high altitude sites and compaction of peat and older tephras at low altitudes compounded the problem. Definition between peat and tephra is never exact and sampling very close to tephra entrains inorganic matter which influences the concentration of pollen. In swamp forest samples, clumping of pollen grains occurred. The problem was overcome by repeated rinsing and decanting. A procedure which was possible due to the control established by the addition of a known quantity of Lycopodium spores. Clumping was a useful indicator however, of the presence of a tephra when it could not be visually

identified. Despite these difficulties, pollen analysis appears to be a valid technique to elucidate the effects of volcanic activity on vegetation in the past.

Deposition of tephra has quite different effects on the bog/swamp environment to those that occur in a forest. The expression of a tephra deposited into a cushion bog, such as Manganui, has variable depth depending on whether the coring site was a cushion or a pool. The greatest thickness of Tahurangi Ash was deposited into a pool (site 83/14). Site characteristics also affect subsequent recovery. At Manganui bog Anisotome aromatica was an important pioneer species, particularly on lapilli.

Subdivision of forest taxa into life form groups assisted interpretation. Of these the epiphyte/liane group conveyed the presence of standing trees, close to the site as distinct from regional pollen. Unusually high values of Blechnum and Phymatodes at the Puniho track sites indicated the presence of Beilschmeidia tawa (a poor pollen producer) when it could not be discerned from the pollen profile. Damage to forest was assumed when post-tephra values were lower than pre-tephra values. For Coriaria a large post-tephra value indicated opening up of the canopy. A subsequent rise in post-tephra values of most taxa has been interpreted as recovery, often accompanied by a decline in Coriaria. Abundant evidence of the pioneering role of this species has been found. With older tephras, recovery patterns and the Coriaria rise are seen within the tephra layer due to compaction.

Long term infilling of bogs and swamps, that normally occurs by

plant growth, is accelerated by the addition of tephra. Species at the swamp margin advance onto the drier area. This is shown at Ngaere swamp where D. dacrydioides increased within the Inglewood, Manganui and Kaupokonui tephra layers. Water levels in ring plain swamps are affected by lahars channelled down rivers. Those in the Manganui River after the Inglewood Tephra caused flooding at Ratapiko. Drainage at this swamp improved after the Manganui tephra and the site became drier. Both events caused major change in species composition at the site.

Damage from lateral cloud deposits of ash, which are not hot, were found to change the species composition by burial (Newall Ashes at Manganui, Burrell Ash at Potaema), but recovery was fairly rapid. Damage by lapilli, removes the forest canopy and is recognised by an upsurge of most taxa, of which Coriaria is an important member, followed by competition. This is recognised by discontinuity in the general trend of the curves. It is envisaged that the removal of aerial parts of plants does not kill the root system. Recovery then depends on resprouting and not solely on seed establishment, although this may occur at the same time. Evidence from soil studies on Burrell soils indicates that adventitious roots penetrated the tephra after the Burrell Lapilli event. Organic debris within the tephra supplied nutrients lacking in the tephra.

Of the older tephtras deposited prior to 1400yr B.P. only general trends can be seen as the pollen record has been compressed. The widely distributed pumiceous lapilli of the Inglewood Tephra caused damage both at Ngaere swamp on the east and at Jones' farm on the west. Lithic

lapilli deposited by the eruption from Fantham's Peak, known as the Manganui, caused less damage at Ngaere than the Inglewood. No change was detectable following deposition of this tephra at Ratapiko. (Manganui tephra was found also at Messenger's farm and Stratford Mountain Road but pollen records are not present). The much younger Kaupokonui tephra (1400 yr B.P.) is less compacted. Coriaria rises both within and above the tephra indicating damage. Although this tephra was deposited at Midhurst and all the western sites, little damage is apparent and it is concluded that these sites lie outside the main axis of deposition. No isopach map is available for this tephra.

The most severe damage to occur is not adequately recorded at the sites examined because sites within the path of the Newall nuée ardentes were destroyed either by the blast or the debris and pyroclastic flows that have occurred since. Widespread fires followed the eruption and these could have been enhanced if drought conditions existed at the time. These northwestern slopes continue to be unstable and Weinmannia is the most successful colonist. Sites from the Puniho Track are dominated by rising curves of this species. Both contain abundant charcoal which could be associated with recent pyroclastic flows.

Eruption of Burrell Ash may have been a similar event to the Newall eruption but on the eastern slopes only cool lateral cloud deposits of ash were emplaced. At Potaema, Cyperaceae, Blechnum and several herbs were temporarily removed from the pollen profile after the fall of this ash. Complete removal of the canopy by Burrell Lapilli is indicated at both Manganui and Potaema bog. Damage

however, declines with the size of lapilli outside the area beneath the main axis of deposition. This has been shown to be aligned with Stratford Mountain Road. The greatest depths of Burrell Lapilli found in this study are along this line.

Size appears to be the controlling factor in the amount of damage caused. Considering the age of the record and the wide distribution, the Inglewood Tephra appears to have been the most destructive event, of those for which there is a pollen record, on the eastern side in the last 4000 years.

7.1.4 Tephrochronology.

Pinus pollen found in and below the Tahurangi Ash indicates it must be younger than 1860 A.D. This date was used to determine a possible date for the Burrell Lapilli. Calculations made from three sets of data; tree-ring counts on post-Burrell Lapilli Libocedrus (Druce 1966), peat core length and stand dynamics of Weinmannia. All agree on a 1725-1750 A.D. date. An organic layer present at Manganui (83/14), Stratford Mountain Road (85/2) and Potaema (83/2) between the Burrell Ash and Burrell Lapilli indicates a lapse of time between the deposition of these two tephras. A revised tephrochronology based on the above is given in Table XXXV (Chapter 4).

7.1.5 Changes in vegetation due to Maori Occupation.

No evidence has been found of deforestation on the eastern ring plains which could be attributed to Maori occupation. On the western plains, charcoal and a pre-European rise of Pteridium are an indication of Maori fires, which occur only near the Pollard's farm site. The actual site, which is known to have been frequented by Maoris, from artifacts found nearby, was not burned until European time. Lack of suitable fossil pollen sites near the coast however, is an indication of anthropogenic activity in that area. Bowden Scenic Reserve, dominated by Corynocarpus laevigatus may have been protected by the Maori for the food it supplied. Two pollen grains of this species were found in samples from Matarikoriko site, which is close to a former Maori pa. Both sites were only burned in European time. The lack of evidence of pre 400yr B.P. fires on the western plain supports the conclusion that Pteridium rhizomes were not so important in the Maori diet prior 400yr B.P. A change to a wetter and cooler climate about 400yr B.P. resulted in poorer growth and unreliable crops of kumara. Overgrown garden boundaries of aligned boulders on the western coastal plain indicate that horticulture had been practiced in earlier times. Storage problems were also increased by the wetter weather. The introduction of the European potato, perhaps as early as 1800 A.D., replaced "fernroot" in the diet but led to increased clearance of forests to grow potato crops for barter and sale.

7.1.6 Changes in Vegetation due to European Settlement.

Dense forest covered the eastern ring plains, the area around Inglewood and the lower slopes of Mount Egmont when the first European settlers arrived. On the west, fernland and scrub are said to have extended to the approximate alignment of South Road. Of all the sites examined only Motunui is likely to have been burned before this time. At every site some alien Pinus pollen has been found together with Plantago and Taraxacum. At sites within the Egmont National Park this may be regional but alien weeds tend to establish along roadsides and paths so this may not be so. Outside Egmont National Park, all sites except Umutekai contain abundant charcoal, a rise in Pteridium spores and Gramineae pollen. Compared to the lower profiles they have smaller values of tree pollen, fewer subcanopy species and few epiphytes and lianes. Coriaria is usually prominent coincident with the rise in charcoal values. Ngaere swamp lacks evidence of secondary growth, this may be because it was converted to pasture by drainage and browsing by cattle.

Browsing by cattle is indicated by a decline in palatable species and sometimes Taraxacum pollen deposited in faeces. The approach of farming towards a site is first indicated by windborne pollen of Pinus and Plantago. Only later is Taraxacum consistently present. Other mammals were also introduced by Europeans. Of these goats, hares, stoats and opossums are all present within Egmont National Park. There is little in the pollen spectra to indicate damage by these mammals. The establishment of the butter box industry at Eltham is indicated by the decline of D. dacrydioides at Ngaere swamp. This occurs at Bowden

Reserve also. Early settlers had a struggle to bring the forest regrowth under control as seen at Bowden Reserve. Later sites were rapidly cleared probably with the use of chainsaws and bulldozers as well as fire. Following clearance, erosion, increased sedimentation and eutrophication from fertilisers, new Typha swamps have developed. Artificial drainage of the ring plain swamps has created pastures. European farming activity greatly increased the proportion of mire plants at Midhurst 1. All these changes have been accomplished in the last 150 years.

On the credit side, attitudes to indigenous forests have changed. Egmont National Park was created in 1900 and new reserves are being made. Some indication of this is seen in the southwest area of Taranaki where fencelines enclose forest remnants. It must be concluded that the greatest changes in the vegetation of Taranaki have been made by European settlers.

7.2 SUMMARY

The study area in western Taranaki was delimited by deposition of recent tephras. Sites were confined to eastern and western slopes and the northern coastal plain. Teprochronology has been used for dating the stratigraphic columns, but four new radiocarbon dates were also obtained. A wide range of environments was sampled including swamp forest, Typha swamps and forest soils. A metre length of PVC pipe was driven into the site and retrieved. Cores of up to 750mm were obtained. Sampling was at 10mm vertical intervals but depths were adjusted to sample close to tephra layers. Standard processing methods were used. A

known quantity of alien Lycopodium spores was added to each sample and grains/cm³ data were obtained and used together with percentage data for interpretation. Two computer programs were compiled to analyse the large volumes of data and to produce pollen diagrams.

The Inglewood, Manganui, Kaupokonui, Newall and Burrell tephras were identified. Some information was also gained about the 2000 yr pyroclastic flow, "layered fine ashes" and recent pyroclastic flows near the Puniho Track. The Waiweranui and Puniho 1 and 2 (Druce 1966) tephras were not identified. A method was developed to overcome the problem of pollen clumping in samples with a high lignin content and weathered tephra. Tests to investigate possible contamination of Manganui bog samples were carried out when Pinus pollen was found in Tahurangi Ash. The tests proved there was no contamination.

A revised tephrochronology of the last 400 years is presented. Tahurangi Ash is younger than 1860 A.D. Possible dates for the Burrell Lapilli are between 1725-1750 A.D. established from tree ring counts of Libocedrus, peat core data and stand dynamics of Weinmannia. The presence of an organic layer with significant changes in pollen spectra indicates a lapse of time between Burrell Ash and Burrell Lapilli. This has been estimated from peat core data as < 100 years. Both the Tahurangi Ash and the Burrell Lapilli are 100 years younger than previously thought.

Change in vegetation due to volcanic activity was the primary interest. Each site (Chapter 3) and each tephra (Chapter 4) has been discussed. The fossil record is compressed for the older tephras and

only general trends could be interpreted. A long record of volcanic events was found at Stratford Mountain Road but continuing disturbance had removed many records. Details of the immediate effects of the Burrell Lapilli were interpreted at Potaema and to a lesser extent at Manganui bog. The resilience of the indigenous vegetation is abundantly demonstrated at all sites. This has ensured that despite repeated deposition of tephra over the last 4000 years, lowland forests have remained fairly stable until the last 400 years. Adjustment of water levels following tephra deposition into lowland swamps is indicated. Lahars channelled down rivers altered drainage patterns at lowland swamps. One lahar was examined. In the succession on the new surface Pseudopanax and Cyathea were important.

No changes in the forests on the eastern plains could be attributed to Maoris. On the west, evidence of pre-European fires and a rise in Pteridium was found at only one site. Lack of suitable sites nearer the coast was a disadvantage. All sites investigated have evidence of European clearance and settlement. High altitude sites receiving regional pollen contain a record of clearance on the ring plain. Removal of the indigenous forest in western Taranaki took approximately 150 years. Forest protected in the Egmont National Park since 1900 provided sites for this study. Lowland sites were in places uneconomic to drain. Forest clearance has created new Typha swamps. Drainage of ring plain swamps has created pasture. Early settlers experienced difficulty in controlling regrowth. This is not so apparent at more recently cleared sites. The present extent of the indigenous forest and scrub in western Taranaki is shown on a full scale map (Volume II).

Changes in the pollen spectrum of Ascarina, an indicator of equable climate, show that the climate of western Taranaki was frost and drought free between 4000 and 1400 yr B.P. After 1400 yr B.P. a deterioration to a drought prone climate occurred and lasted for about 1000 years. During this period ring plain swamps appear to have become drier and vegetation zones on Mount Egmont moved upslope. About 400 yr B.P. rainfall became more evenly distributed and frosts more frequent and or more severe. At this time Weinmannia appeared for the first time at some sites and increased in prominence at all sites. It is very common in the Mount Egmont forests today. This persistence of a seral species is attributed to the variability of the modern climate and the continuing availability of newly exposed ground due partly to climate, partly to recent pyroclastic flows in this vicinity.

The greatest change in the vegetation of western Taranaki is not however, due to volcanic activity, climatic change or Maori occupation but is due to European settlement in the last 150 years.

APPENDIX 1 BOTANICAL NOTES

The following notes explain the procedures adopted with reference to the naming of plants in the various chapters of this thesis. Family names (Hutchinson 1973) have been used here because they are still in current use and occur in most of the references used. At the first appearance of a plant in the text (Chapter 1) the most commonly used name is given first followed by the Latin name in brackets. Common names may be either Maori, European or a combination of both. Subsequently only common names are used except in (1.7.2.) when it was considered this could be confusing. In chapters 2-7 latin names have been used throughout. Common names are taken from Poole and Adams (1963).

LIST OF COMMON NAMES.

Common Name	Latin Name
Hange hange	<i>Geniostoma ligustrifolia</i>
inanka	<i>Dracophyllum filifolium</i>
kaikamako	<i>Pennantia corymbosa</i>
kaikawaka	<i>Libocedrus bidwillii</i>
kamahi	<i>Weinmannia racemosa</i>
kanuka	<i>Leptospermum scoparium</i>
karaka	<i>Corynocarpus laevigatus</i>
kohekohe	<i>Dysoxylon spectabile</i>
kumara	<i>Ipomoea batatas</i>
mahoe	<i>Meliccytus ramiflorus</i>
makomako	<i>Aristotelia serrata</i>
mangaero	<i>Litsea calicaris</i>
manuka	<i>Leptospermum ericoides</i>
mapou	<i>Myrsine australis</i>
matai	<i>Prumnopitys taxifolia</i>
nikau	<i>Rhopalostylis sapida</i>
pate	<i>Schefflera digitata</i>
poroporo	<i>Solanum aviculare</i>
puhututkawa	<i>Metrosideros excelsa</i>
pukatea	<i>Laurelia novae-zelandiae</i>
putaputaweka	<i>Carpodetus serratus</i>
puriri	<i>Vitex lucens</i>
rangiiora	<i>Brachyglottis repanda</i>
rata	<i>Metrosideros</i> spp.
raukawa	<i>Pseudopanax edgerleyi</i>
raurekau	<i>Coprosma grandifolia</i>
rimu	<i>Dacrydium cupressinum</i>
tawa	<i>Beilschmiedia tawa</i>
ti	<i>Cordyline australis</i>
titoki	<i>Alectryon excelsus</i>
toittoi	<i>Cortaderia fulvida</i>
toro	<i>Myrsine salicina</i>
totara	<i>Podocarpus totara</i>
beech	<i>Nothofagus</i> spp.
bracken	<i>Pteridium aquilinum</i>

broadleaf	<i>Griselinia littoralis</i>
flax	<i>Phormium tenax</i>
fivefinger	<i>Pseudopanax arboreus</i>
fuchsia	<i>Fuchsia excorticata</i>
Hall's totara	<i>Podocarpus hallii</i>
leatherwood	<i>Brachyglottis elagnifolia</i>
mountain tauhinu	<i>Cassinia vauvilliersii</i>
mountain toatoa	<i>Phyllocladus glaucus</i>
mountain tutu	<i>Coriaria plumosa</i>
niggerhead	<i>Carex secta</i>
pink pine	<i>Halocarpus biformis</i>
red tussock	<i>Chionochloa rubra</i>
shining broadleaf	<i>Griselinia lucida</i>
silver beech	<i>Nothofagus menziesii</i>
silver pine	<i>Lagarostrobos colensoi</i>
swamp maire	<i>Syzygium maire</i>
tree rata	<i>Metrosideros robusta</i>
wineberry	<i>Aristotelia serrata</i>

LIST OF NAME CHANGES SINCE 1961-1982

New Name	Discarded Name
<i>Brachyglottis elagnifolia</i>	<i>Senecio elagnifolius</i>
<i>Chionochloa rubra</i>	<i>Danthonia raoulia</i> var. <i>rubra</i>
<i>Coprosma grandifolia</i>	<i>Coprosma australis</i>
<i>Cortaderia fulvida</i>	<i>Arundo fulvida</i>
<i>Dacrycarpus dacrydioides</i>	<i>Podocarpus dacrydioides</i>
<i>Empodisma minus</i>	<i>Caloraphus minor</i>
<i>Freycinetia baueriana</i>	<i>Freycinetia banksii</i>
var. <i>banksii</i>	
<i>Geniostoma rupestre</i>	<i>Geniostoma ligustrifolium</i>
var. <i>crassum</i>	
<i>Halocarpus bidwillii</i>	<i>Dacrydium bidwillii</i>
<i>Halocarpus biformis</i>	<i>Dacrydium biforme</i>
<i>Lagarostrobos colensoi</i>	<i>Dacrydium colensoi</i>
<i>Leucopogon fraserii</i>	<i>Cyathodes fraserii</i>
<i>Nestegis</i>	<i>Olea</i>
<i>Phyllocladus asplenifolius</i>	<i>Phyllocladus alpinus</i>
var. <i>alpinus</i>	
<i>Prumnopitys ferruginea</i>	<i>Podocarpus ferrugineus</i>
<i>Prumnopitys taxifolia</i>	<i>Podocarpus spicatus</i>
<i>Pseudopanax simplex</i>	<i>Pseudopanax simplex</i>
var. <i>sinclairii</i>	
<i>Syzygium maire</i>	<i>Eugenia maire</i>

LIST OF POLLEN TAXA IDENTIFIED

Code	Key	Name
ACA	H	Acaena
ALE	T	Alectryon
ALN	T	Alnus
ANA	F	Anarthopteris
ANI	H	Anisotme
ASC	T	Ascarina
AST	H	Astelia
BLE	F	Blechnum
CAP	T	Carpodetus
CAR	H	Carex
CAS	S	Cassinia
CAY	H	Caryophyllaceae
CHE	H	Chenopodiaceae
CIR	O	Cirsium type
COD	T	Cordyline
COM	S	Compositae
CON	T	Corynocarpus
COP	S	Coprosma
COR	S	Coriaria
CRU	H	Cruciferae
CUP	O	Cupressus (exotic)
CYA	F	Cyathea smithii type
CYD	F	Cyathea dealbata
CYM	F	Cyathea medullaris
CYO	S	Cyathodes
CYP	M	Cyperaceae
DAC	O	Dactylanthus
DAP	T	Dacrycarpus dacrydioides
DCP	T	Dacrydium cupressinum
DIC	F	Dicksonia
DOD	T	Dodonaea
DRA	S	Dracophyllum
DYS	T	Dysoxylon
ELA	T	Elaeocarpus
ELY	O	Elytranthe
EPI	H	Epilobium
EUP	H	Euphrasia
FRE	O	Freycinetia
FUC	T	Fuchsia
GAL	H	Galium
GAU	S	Gautheria
GEN	S	Geniostoma
GET	H	Gentiana
GLE	F	Gleichenia
GRA	H	Gramineae
GRI	T	Griselinia
GUN	H	Gunnera
HAL	H	Haloragis
HBI	S	Halocarpus bidwillii type
HEB	S	Hebe

HED	T	Hedycarya
HIS	F	Histiopteris
HYM	F	Hymenophyllum
KNI	T	Knightia
LAG	S	Lagerostrobos colensoi type
LAU	T	Laurelia
LEP	T	Leptospermum
LIB	T	Libocedrus
LOP	S	Lophomyrtus type
LYB	O	Lycopodium billardierii
LYC	O	Lycopodium
MAC	S	Macropiper
MAL	T	Malvaceae
MAR	F	Marratia
MEI	S	Melicope
MEL	T	Melicytus
MER	T	Metrosideros robusta
MET	O	Metrosideros
MOL	F	Monolete fern spores
MON	H	Monocotyledon
MRI	M	Myriophyllum
MTR	T	Myrtaceae
MUE	O	Muehlenbeckia
MYO	T	Myoporum
MYR	S	Myrsine
NES	T	Nestegis
NOF	T	Nothofagus fusca group
NOM	T	Nothofagus menziesii
PAN	S	Panax group
PAR	S	Paratrophis
PAS	O	Parsonsia
PEN	T	Pennantia
PCO	S	Pseudopanax colensoi
PFE	T	Prumnopitys ferrugineae
PHA	T	Podocarpus hallii
PHL	T	Phyllocladus
PHO	M	Phormium
PHY	O	Phymatodes
PIN	O	Pinus (exotic)
PIT	T	Pittosporum
PLA	O	Plantago
POD	T	Podocarpus
POT	M	Potamageton
PRA	H	Pratia
PSE	T	Pseudowintera
PTA	T	Prumnopitys taxifolia
PTE	F	Pteridium
PTO	T	Podocarpus totara
PYR	F	Pyrrrosia
QUI	T	Quintinia
RES	M	Restionaceae
RHO	T	Rhopalostylis
RIP	O	Ripogonum
RUB	O	Rubus

RUN	H	Rununculus
SHE	T	Schefflera
SOP	T	Sophora
STE	H	Stellaria
SYZ	T	Syzygium maire
TAR	O	Taraxacum
TEP	O	Tetrapathaea
TET	S	Tetrad
TUP	O	Tupeia
TYP	M	Typha
ULE	O	Ulex europaeus (exotic)
UMB	H	Umbelliferae
WEI	T	Weinmannia

Three letter code used in computer programs for pollen taxa.

Life form code T = Tree, S = Shrub, H = Herb, F = Fern, M = Mire plant

O = Other = Exotic, Epiphytes, Lianes, Parasites and Distant pollen.

REFERENCES

- Allan, H.H. 1961 Flora of New Zealand Volume I
Government Printer, Wellington.
- Clarkson, B.D. 1980 Vegetation in Ed. J.S. Tullett Egmont National Park
Egmont National Park Board, New Plymouth.
- Druce, A.P. 1976 The Vegetation in Ed. Fullarton Egmont National Park
Egmont National Park Board, New Plymouth
- Eagle, A. 1982 Eagle's Trees and Shrubs of New Zealand,
Second Series. Collins, Auckland.
- Edgar, E. 1971 Nomina Nova Plantarum Novae Zelandiae 1960-1969
Gymnospermae and Angiospermae.
New Zealand Journal of Botany 9: 322-330
- 1983 Nomina Nova III 1977-1982
New Zealand Journal of Botany 21: 421-441
- and Connor, H.E. 1978 Nomina Nova II 1970-1976
New Zealand Journal of Botany 16: 103-118
- Hutchinson, J. 1973 The Families of Flowering Plants
Clarendon Press, Oxford.
- Moore, L.B. and Edgar, E. 1976 Flora of New Zealand Volume II
Government Printer, Wellington.
- Poole, A.L. and Adams, N.H. 1963 Trees and Shrubs of New Zealand.
Government Printer, Wellington.

BIBLIOGRAPHY

- Aitken, J.F. Campbell, I.B. Wilde, R.H. 1978: Soils of Stratford County, North Island, New Zealand. N.Z. Soil Survey Report 42.
- Allen, M.F. MacMahon, J.A. Andersen, D.C. 1984 Reestablishment of Endogonaceae on Mount St. Helens: survival of residuals Mycologia 76: 1031-1038
- Antos, J.A. Zobel, D.B. 1982: Snowpack modification of volcanic tephra effects on forest understory plants near Mount St. Helens. Ecology 63: 1969-1972
- 1985a: Plant form, developmental plasticity and survival following burial by volcanic tephra. Canadian Journal of Botany 63: 2080-2090
- 1985b: Upward movement of underground plant parts into deposits of tephra from Mount St. Helens. Canadian Journal of Botany 63: 2091-2096
- 1985c: Recovery of understories buried by tephra from Mount St. Helens. Vegetatio 64: 103-111
- Atkinson, I.A.E. 1974: Tongariro National Park In Ray Knox (ed.) New Zealand Nature Heritage 6: 2371-2377
- Atkinson, I.A.E. and Greenwood, R.M. 1972: Effects of the 1969-70 drought on two remnants of indigenous lowland forest in the Manawatu District. Proceedings of the Ecological Society 19: 34-42
- Bates, C.D. Coxon, P. Gibbard, P.L. 1978: A new method for the preparation of clay-rich sediment samples for palynological investigation. New Phytologist 81: 459-463
- Benninghoff, W.S. 1962: Calculations of pollen and spore density in sediments by addition of exotic pollen in known quantities. Pollen spores 4: 332
- Best Eldson 1925 Maori Agriculture. Government Printer, Wellington.
- Birks, H.J.B. and Birks, Hilary H. 1980: Quaternary Palaeoecology Edward Arnold, London.
- Blong, R.J. 1984: Volcanic hazards. A sourcebook on the effects of eruptions. Academic Press, Australia
- Bond, G. 1958: Root nodules of Coriaria. Nature 182: 474
- Brauns, F.E. 1952: The chemistry of lignin. Academic Press Incorporated, New York

- Brooks, E.S. 1892: Frontier life in Taranaki. Published by H. Brett, Auckland
- Brown, R.W. 1975: Te Moa, 100 years history of Inglewood 1875-1975. Published by Inglewood Borough & County Councils
- Brunner, T. 1852: Expedition to the Middle of the Middle Island. 1846-48
In J. Pascoe (ed.) Pegasus Press, Christchurch.
- Buchanan, J. 1869: Notes on the Botany of Mount Egmont and Neighbourhood February 1867. Journal of the Linnean Society (Botany) 10: 57-62
- Burgess, J. 1901: Shelter trees in Cape Egmont District.
In H.J. Matthews Tree culture in New Zealand. 1905
Government Printer, Wellington
- Burke, W.D. 1963: A note on the occurrence of nodules in the New Zealand species of Coriaria. New Zealand Journal of Botany 1: 377-380
- 1964: A study of the vegetation of part of Mount Tarawera, Rotorua. MSc Thesis Botany Victoria University of Wellington, New Zealand.
- 1974: Regeneration of Podocarps on Mount Tarawera.
New Zealand Journal of Botany 12: 219-222
- Burrell, A.W. 1931: In W.R.B. Oliver An ancient Maori oven on Mount Egmont. Journal of the Polynesian Society 40: 73-80
- Burrows, C.J. Greenland, D.E. 1979: An analysis of the evidence for climatic change in New Zealand in the last thousand years: from diverse phenomena and from instrumental records. Journal of the Royal Society of New Zealand 9: 321-373
- Cameron, R.J. 1964: Destruction of the indigenous forests for Maori agriculture during the nineteenth century. New Zealand Journal of Forestry 9: 98-109
- Campbell, E.O. 1975: Peat deposits of northern New Zealand as based on identification of plant fragments in the peat. Proceedings of the New Zealand Ecological Society 22: 57-60
- Carpenter, S.E. Trappe, J.M. Hunt G.A. 1982: Observations on fungal succession on recent volcanic deposits of Mount St. Helens In J.F. Evett (ed.) Proceedings of the Oregon academy of Science 19: 36-44

- Cassels, R. 1979: Early prehistoric wooden artifacts from the Waitore Site (N1 36/16) near Patea, Taranaki. New Zealand Journal of Archaeology 1: 85-108
- Clarkson, B.D. 1977: Vegetational change along an altitudinal gradient, Mount Egmont, New Zealand MSc Thesis University of Waikato, New Zealand.
- 1980: Present day vegetation In J.S. Tullett (ed.) Egmont National Park
- 1981: Vegetation studies in the Taranaki land district. Ph.D Thesis University of Waikato, New Zealand
- 1985: The vegetation of the Kaitake Range, Egmont National Park, New Zealand. New Zealand Journal of Botany 23: 15-31
- Clarkson, B.R. Clarkson, B.D. 1983: Mt. Tarawera, Rates of changes in the vegetation of the high domes. New Zealand Journal of Ecology 6: 107-119
- Cockayne, L. 1919: New Zealand Plants and their story. 2nd Ed. Government Printer, Wellington
- 1928: The vegetation of New Zealand (2nd Ed.) Englemann, Leipzig.
- Coulter, J.D. 1966: Dry spells in New Zealand as a factor in plant ecology. Proceedings of the New Zealand Ecological Society 13: 4-9
- 1967: Mountain Climate. Proceedings of the New Zealand Ecological Society 14: 40-57
- Cushing, E.J. 1967: Evidence for differential pollen preservation in Late Quaternary sediments in Minnesota. Review of Palaeobotany, Palynology 4: 87-101
- Cranwell, L.M. 1939: Southern beech pollens. Record Auckland Institute and Museum 21: 75-196
- 1940: Pollen grains of New Zealand conifers. New Zealand Journal of Science and Technology 22: B 1-17
- 1942: New Zealand pollen studies 1. Key to the pollen grains of families and genera in the native flora. In Records of the Auckland Institute and Museum 2: 280-308
- 1953: New Zealand pollen studies - The Monocotyledons. Bulletin Auckland Institute and Museum 3

- Cranwell, L.M. von Post, L. 1936 Post-Pleistocene pollen diagrams from the Southern Hemisphere I New Zealand. Geografiska Annaler Stockholm 3-4: 308-347
- Dale M.B. Walker D. 1970: Information analysis of pollen diagrams 1. Pollen et Spores 12: 21-37
- Daniel, M.J. 1974: Rats and mice. In (ed.) Ray Knox New Zealand Nature Heritage 6: 2350-2356
- Davidson, J. 1984: The prehistory of New Zealand. Longman Paul, Auckland.
- Davis, M.B. 1963: On the theory of pollen analysis. American Journal of Science 261: 897-912
- 1966: Determination of absolute pollen frequency. Ecology 47: 310-31
- Davis, M.B. Goodlett, J.C. 1960: Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont. Ecology 41: 346-357
- Day, K. 1984: Warea School and District Centennial 1884-1984. Published by Warea Jubilee Committee
- del Moral, R. 1983: Initial recovery of sub-alpine vegetation on Mount St. Helens, Washington. The American Midland Naturalist 109: 72-80
- Dickson, J.H. 1969: The effects of the eruption of 1961 on the vegetation of Tristan da Cunha. Pt VI. Transactions of the Royal Society of London B 249: 403-424
- Dieffenbach, E. 1843: Travels in New Zealand, with contributions to the geography, botany and natural history of that country Vol 1 published by John Murray, London
- Dimbleby, G.W. 1957: Pollen analysis of terrestrial soils. New Phytologist 56: 12-28
- 1961a: Soil pollen analysis. Journal of Soil Science 12: 1-11
- 1961b: Transported material in the soil profile. Journal of Soil Science 12: 12-23
- 1985: The palynology of Archaeological sites. Academic Press London
- Dobson, A.T. 1979: Mire types of New Zealand. Proceedings of the International Symposium, Classification of Peat and Peatlands. Quoted in Gibson, N. and Kirkpatrick, J.B. 1985.
- Dodson, J.R. 1972: Computer programs for the pollen analyst. Pollen et Spores 14: 455-465

- 1976: Modern pollen spectra from the Chatham Islands New Zealand. New Zealand Journal of Botany 14: 341-347
- Druce, A.P. 1957: Botanical survey of an experimental catchment Taita, New Zealand. Department of Scientific and Industrial Research, Bulletin 124
- 1966: Tree-ring dating of recent volcanic ash and lapilli, Mount Egmont. New Zealand Journal of Botany 4: 3-41
- 1974: Some notes on the flora of Mount Egmont. Newsletter of the Auckland Botanical Society 31st year 3: 1-4
- 1976a: The vegetation. In J.H. Fullerton (ed.) Egmont National Park 3rd Ed.
- 1976b: Egmont botanical studies, Seminar on Science in National Parks. 53-57. National Parks Authority, Wellington
- 1986: Indigenous higher plants (Psilopsids, Lycopods, Quillworts, Ferns, Gymnosperms, Flowering plants) on Mt Egmont/Mt Taranaki, Sea level to the Summit. (Unpublished ms) Botany Division D.S.I.R. Wellington.
- Dunwiddie, P.W. 1979: Dendrochronological studies of indigenous New Zealand trees. New Zealand Journal of Botany 17: 251-266
- Eggleger, W.A. 1948: Plant communities in the vicinity of the El Paricutin, Mexico after 2 1/2 years of eruption. Ecology 29: 415-436
- Egunjobi, J.K. 1969a: Dry matter accumulation in secondary successions involving Gorse Ulex europaeus L. and associated shrubs and trees. New Zealand Journal of Science 12: 175-193
- 1969b: Primary productivity and nutrient cycling in terrestrial ecosystems. A review with particular reference to New Zealand. Tuatara 17: 49-77
- Erdtman, G. 1952: Pollen morphology and Plant taxonomy. Almgvist and Wilsell
- Esler, A.E. 1978: Botany of the Manawatu District, New Zealand. Government Printer, Wellington.
- Every, P.E. 1974: Rawhitiroa, collections and recollections of a pioneer's daughter. P.E. Every, Broad Bay, Dunedin.

- Faegri, K. Ottestad, P. 1948: Statistical problems in pollen analysis. Universitetet I Bergen Arbok Naturvitenskapelig rekke Nr.3
- Faegri, K. Iversen, J. 1975: Textbook of pollen analysis 3rd Ed. Munksgaard
- Federal Coordinating Office 1980: Mount St Helens Technical Network Bulletins 1, 8, 9, 12 and 15
- Franks, A.M. 1984: Soils of Eltham County and the Tephrochronology of central Taranaki. Unpublished Ph.D thesis Massey University Palmerston North, New Zealand
- Frenzen, P.M. Franklin, J.F. 1985: Establishment of Conifers from seed on tephra deposited by the 1981 eruption of Mount St.Helens, Washington. The American Midland Naturalist 114: 84-97
- Frenzen, P.K. Rigney, L.P. Krasny, M.E.: Plant succession in relation to enviromental factors on a thirty-three year old mudflow surface at Kautz Creek, Mount Rainer National Park, Washington. In print.
- Fridriksson, S. 1975: Surtsey. Evolution of life on a volcanic island. Butterworths, London
- Fullarton, J.H. 1976: (ed) Egmont National Park 3rd Ed. Egmont National Park Board, New Plymouth
- Garnier, B.J. 1958: The climate of New Zealand, a geographic survey. Arnold, London.
- Gibson, N. Kirkpatrick, J.B. 1985: A comparison of cushion plant communities of New Zealand and Tasmania. New Zealand Journal of Botany 23: 549-566
- Godwin, H. 1968: The development of Quaternary palynology in the British Isles. Review of Palaeobotany and Palynology 6: 9-20
- Gough, L.P. Swenson, R.C. Lichte, F.E. Peard, J.L. Tuttle H.L. Harms, T.F. Smith, K.S. 1981: Ashfall effects on the chemistry of wheat and the Ritzville soil series, Eastern Washington. In (eds.) P.W. Lipman and Mullineaux: 716-782
- Grant, P.J. 1963: Forests and recent climatic history of the Huriarau Range, Urewera Region, North Island. Transactions of the Royal Society of New Zealand 2: 143-172

- Grant-Taylor, T.L. 1964: Volcanic history of Western Taranaki.
New Zealand Journal of Geology and Geophysics 7: 78-86
- Grant-Taylor, T.L. Rafter, T.A. 1963: New Zealand natural radiocarbon measurements I-V Radiocarbon 5: 118-162
- Greenland, W. 1967: Riemenschneider of Warea.
A.H. and A.W. Reed, Wellington
- Griggs, R.F. 1922: The Valley of Ten Thousand Smokes.
National Geographic Society
- Halpern, C.B. Harmon, M.E. 1982: Early plant succession on the Muddy River mudflow, Mount St. Helens, Washington.
The American Midland Naturalist 110: 97-106
- Hamilton, W.M. Baumgart, I.L. 1959: White Island. Department of Scientific and Industrial Research Bulletin 127
- Harris, G.P. Morrison, T.M. 1958: Fixation of N-15 by excised nodules of Coriaria arborea. Nature 182: 1812
- Harris, W.F. 1955: A manual of spores of New Zealand Pteridiophyta. Department of Scientific and Industrial Research Bulletin 116, Government Printer, Wellington
- 1956a: Pollens of Nothofagus. New Zealand Journal of Science and Technology 37B: 635-638
- 1956b: Pollen characteristics of Nothofagus. New Zealand Journal of Science and Technology 37B: 731-765
- 1968: Peat classification by pedological methods applied to peats of western Wellington. New Zealand Department of Scientific and Industrial Research Bulletin 189
- Harris, W.F. and Norris, G. 1972: Ecologic significance of recurrent groups of pollen and spores in Quaternary sequences of New Zealand.
Palaeogeography, Palaeoclimatology, Palaeoecology 11: 107-124
- Havinga, A.J. 1964: Investigation into the differential corrosion susceptibility of pollen and spores. Pollen et spores 6: 621-635
- 1974: Problems in the interpretation of pollen diagrams of mineral soils. Geologie en Mijnbouw 53: 449-453

- Hay, R.F. 1967: Sheet 7 Taranaki (1st Ed) 'Geological map of New Zealand 1:250,000'. Department of Scientific and Industrial Research, New Zealand
- Heaphy, C. 1842: Narrative of a residence in various parts of New Zealand. Smith Elder and Co. 65 Cornhill
- Heslop-Harrison, J. 1976: The adaptive significance of the exine. In (eds) I.K. Ferguson and J. Muller. The evolutionary significance of the exine. Academic Press
- Hill, E. 1969: There was a Maori Land League in Taranaki. Wellington Historic Association Pamphlet
- Holloway, J.T. 1954: Forests and climates in the South Island of New Zealand. Transactions of the Royal Society of New Zealand 82: 329-410
- 1964: The forests of the South Island, the status of the climatic change hypothesis. New Zealand Geographer
- Howard, W.E. 1966: Control of introduced Mammals in New Zealand. Department of Scientific and Industrial Research Information Service
- Howorth, R.; Frogatt, P.; Vucetich, C.G.; Collen, J.D. 1981: (eds.) Proc. Tephra Workshop June 30th - July 1st. Wellington (1980). Published by Geology Department of Victoria University of Wellington
- Hursthouse, C. 1849: An account of the settlement of New Plymouth. Smith Elder & Co Cornhill
- Hutchinson, J. 1973: The families of flowering plants. (3rd Ed) Clarendon Press, Oxford.
- Jane, G.T. Green, T.G.A. 1984: Ecological aspects of climate patterns within the Kaimai Ranges, North Island, New Zealand. New Zealand Journal of Ecology 7: 183-196
- Johnston, H.W. 1969: The solubilization of 'Insoluble' phosphates versus the action of some organic acids on iron sands and aluminium phosphates. New Zealand Journal of Science 2: 215-218
- Jorgensen, S. 1967: A method of absolute pollen counting. New Phytologist 66: 489-493
- Kieffer, S.W. 1981: Fluid Dynamics of the May 18 blast at Mount St. Helens. In (eds.) P.W. Lipman and D.R. Mullineaux: 379-400

- Knowles, B. Beveridge, A.E. 1982: Biological flora of New Zealand 9. Beilschmeidia tawa (A.Cunn) Benth. et Hook F. ex Kirk. New Zealand Journal of Botany 20: 37-54
- Lawlor, I. 1980: Radiocarbon dates from Kohika swamp pa (N68/104), Bay of Plenty. New Zealand Archaeological Association Newsletter 23: 265-267
- Lawrence, D.B. 1938: Trees on the March. Mazma Annual 20: 49-54
- Leach, B.F. 1981: The prehistory of the Waiarapa. Journal of the Royal Society of New Zealand 11: 11-33
- Leach, B.F. Leach, H.M. 1979: Prehistoric man in Palliser Bay (eds.) National Museum of New Zealand Bulletin 21
- Leach, H.M. 1974: Pre-European. The first 500 years. In Ray Knox (ed.) New Zealand Nature Heritage 1: 15-122 and 164-169
- Lee, K.E. 1959: The earthworm fauna of New Zealand. Department of Scientific and Industrial Research of New Zealand Bulletin 130
- Lees, C.M. 1981: Some Aranuan (postglacial) deposits in the Southern Ruahine Range, North Island, New Zealand. Investigated by palynological methods. Unpublished MSc Thesis Massey University Palmerston North
- 1986: Late Quaternary palynology of the southern Ruahine Range North Island, New Zealand. New Zealand Journal of Botany 24: 315-329
- Levy, E.B. 1949: The conversion of rain forest to grassland in New Zealand. Tuatara 11: 37-51
- Lintott, W.H. 1963: A peat profile from Kettlehole Bog, Cass. Unpublished thesis University of Canterbury New Zealand
- Lintott, W.H. Burrows, C.J. 1973: A pollen diagram and macrofossils from Kettlehole Bog, Cass, South Island New Zealand. New Zealand Journal of Botany 11: 269-282
- Lipman, P.W. Mullineaux, D.R. 1981: The 1980 eruptions of Mount St. Helens. Geological Survey Professional paper 1250. United States Printing Office, Washington D.C.
- Livingstone, D.A. 1968: Some Inter-stadial and Post-glacial diagrams from Eastern Canada. Ecological monographs 38: 87-125
- Loomis, B.F. 1926: Pictorial history of the Lassen Volcano. Published by B.F.L. Loomis Anderson Valley Press, California

- MacPhail, M.K. 1979: Two additional Australian pollen types in New Zealand. New Zealand Journal of Botany 17: 221-223
- 1980: Fossil and modern Beilschmiedia pollen in New Zealand. New Zealand Journal of Botany 18: 453-457
- MacPhail, M.K. Mildenhall, D.C. 1980: Dactylanthus taylorii in North-west Nelson, New Zealand. New Zealand Journal of Botany 18: 149-152
- MacPhail, M.K. McQueen, D.R. 1983: The value of New Zealand pollen and spores as indicators of Cenozoic vegetation and climates. Tuatara 26: 37-57
- Mair, G.M. 1979: Maori occupation of the Wairarapa during the protohistoric period. In (eds.) B.F. Leach and H.M. Leach (1979)
- Marcus, M.G. Moore, R.D. 1983: Snowpack structure and climate Mount Egmont, New Zealand. Weather and Climate 3: 42-51
- Mark, A.F. Adams, N.M. 1979: New Zealand Alpine Plants (revised) A.H. and A.W. Reed, Wellington
- Matthews, H.J. 1905: (ed.) Tree culture in New Zealand. Government Printer, Wellington
- Matthews J. 1969: (ed.) The assessment of a method for the determination of absolute pollen frequencies. New Phytologist 68: 161-166
- McFadgen, G.G. 1981: Teph^hras in Archaeology. In Howarth et al
- McGlone, M.S. 1973: Late Otiran/Early Aranua vegetation in the Tongariro area, central North Island, New Zealand. New Zealand Journal of Botany 11: 283-290
- 1978a: Pollen wall structure of the New Zealand species of Epacris (Epacridaceae) New Zealand Journal of Botany 16: 83-89
- 1978b: Pollen wall structure of the New Zealand species of Styphelieae (Epacridaceae). New Zealand Journal of Botany 16: 91-101
- 1978c: Forest destruction by Early Polynesians, Lake Poukawa, Hawkes Bay, New Zealand. Journal of the Royal Society of New Zealand 8: 275-281
- 1980: Post-glacial vegetation change in coastal Southland. New Zealand Ecological Society 3: 153-154
- 1981: Forest fire following Holocene tephra fall. In (eds) R.Howorth

- 1982: Modern pollen rain, Egmont National Park, New Zealand. New Zealand Journal of Botany 20: 253-262
- 1983a: Holocene pollen diagrams, Lake Rotorua, North Island, New Zealand. Journal of the Royal Society of New Zealand 13: 53-65
- 1983b: Polynesian deforestation of New Zealand. A preliminary synthesis. Archaeology Oceania 18: 11-25
- McGlone, M.S. Moar, N.T. 1977: The Ascarina decline and post-glacial climatic change. New Zealand Journal of Botany 15: 485-489
- McGlone, M.S. Topping, W.W. 1977: Aranuiian (post-glacial) pollen diagrams from the Tongariro region, North Island, New Zealand. New Zealand Journal of Botany 15: 749-760
- McGlone, M.S. Nelson, C.S. Hume, T.M. 1978: Palynology, age and environmental significance of some peat beds in the Upper Hinuera Formation, South Auckland, New Zealand. Journal of the Royal Society of New Zealand 8: 385-393
- McGlone, M.S. Topping, W.W. 1983: Late Quarternary vegetation, Tongariro region, central North Island. New Zealand Journal of Botany 21: 53-76
- McGlone, M.S. Bathgate, J.L. 1983: Vegetation and climate history of the Longwood range, South Island, New Zealand New Zealand Journal of Botany 21: 293-315
- McGlone, M.S. Neall, V.E. Pillans, B.J. 1984: Inaha Terrace deposits, a Late Quaternary terrestrial record in South Taranaki, New Zealand. New Zealand Journal of Geology and Geophysics 27: 35-49
- McGlone, M.S. Howarth, R. Pullar, W.A. 1984: Late Pleistocene stratigraphy, vegetation and climate of the Bay of Plenty and Gisborne regions, New Zealand. New Zealand Journal of Geology and Geophysics 27: 327-350
- McGlone, M.S. Neall, V.E. Clarkson, B.D.: Late Holocene vegetation history of the Taranaki Volcanoes New Zealand (in litt.)
- McGlone, M.S. Neall, V.E.: The late Pleistocene and Early Holocene vegetation of Taranaki, New Zealand (in litt.)
- McIntyre, D.J. 1963: Pollen morphology of New Zealand of Myrtaceae Transactions of the Royal Society of New Zealand 2: 83-107
- McKelvey, P.J. 1953: Forest colonisation after recent volcanicity at West Taupo. New Zealand Journal of Forestry 6: 435-488

1955: A note on the forest edge at Te Whaiti.
New Zealand Journal of Forestry 8: 77-80

McLintock, A.H. 1959: A descriptive atlas of New Zealand.
Government Printer, Wellington.

Mawhinney, K.A. 1980: Introduced animals. In (ed.) J.S. Tullett
Egmont National Park

Means, J.E. McKee, W.A. Moir, W.H. Franklin, J.F. 1982: Mount
St. Helens: One Year Later. In Keller, S.A.C. (ed.)
Proceedings of a symposium 17-18 May 1981 Eastern Washington
University Cheney, WA Eastern Washington University
Press.

Means, J.E. Winjum, J.K. 1983: Road to recovery after
eruption of Mt.St.Helens.In Using our resources.
Yearbook of Agriculture, Washington D.C. Department of
Agriculture 1983 204-251

Mehringer, Jr. J Blinman, E. Petersen, K.L. 1977: Pollen influx
and volcanic ash. Science 198: 257-261

Mildenhall, D.C. 1973: Acacia in New Zealand. Quaternary
sequences. IX INQUA Congress New Zealand. Abstract

1976: Exotic pollen rain on the Chatham Islands during
the Late Pleistocene. New Zealand Journal of Geology and
Geophysics 19: 327-333

Miller, C.F. 1966: Operation Ceniza-Arena: The retention of
fallout particles from Volcano Irazu (Costa Rica) by
plants and people Part I Standford Research Institute
SRI project Number Mu-4890

Moar, N.T. 1952: A botanical survey of a peat area between
Raumati South and Paraparaumu. New Zealand Journal
of Science and Technology A33: 78-89

1953: Vegetation and peat of a small mire at
Plimmerton, North Island, New Zealand New Zealand Journal
of Science and Technology A34: 479-486

1954: Peat profiles Whareroa Block, Paekakariki,
New Zealand. New Zealand Journal of Science and
Technology 36: 221-231

1960a: Studies in pollen morphology 1. The New
Zealand species of Hydrocotyle Linn. New Zealand
Journal of Science and Technology 3: 51-60

1960b: Studies in pollen morphology 2. The pollen of the New Zealand species and two Australian species of Callitriche L. New Zealand Journal of Science and Technology 3: 415-421

1966: Plant fragments from Kettlehole Bog, Cass. New Zealand Journal of Botany 4: 596-598

1967: Contributions to the Quaternary history of the New Zealand flora 5. Pollen diagrams from No Man's Land Bog, Northern Ruahines. New Zealand Journal of Botany 5: 399-439

1969a: Pollen analysis of a surface sample from Antipodes Island. New Zealand Journal of Botany 7: 419-423

1969b: Possible long distance transport of pollen to New Zealand New Zealand Journal of Botany 7: 424-425

1970: Recent pollen spectra from three locations in the South Island, New Zealand. New Zealand Journal of Botany 8: 210-221

1974: Peat. In (ed.) Ray Knox New Zealand Heritage 4: 1617-1619

1981: In D.C. Mildenhall (ed.). Bibliography of Australasian Palynology and Palaeobotany - 1981. Palynological and Palaeobotanical Association of Australasia

1982: Chronostratigraphy and the New Zealand Post-glacial. In (eds.) J Mangerud, H.J.B. Birks and K.D. Jager Striae Uppsala 16: 10-16

1984: Nestegis (Oleaceae) pollen in coastal sites in Westland. New Zealand Journal of Botany 22: 169-171

Moar, N.T. Gage, M. 1973: Interglacial deposits in Joyces Stream (S74) Waimakariri Valley, Canterbury. New Zealand Journal of Geology and Geophysics 16: 321-331

Moar, N.T. Myers, J.V. 1978: A note on pollen dispersal in Canterbury, New Zealand. New Zealand Journal of Botany 6: 413-415

Moar, N.T. Suggate, R.P. 1979: Contributions to the Quaternary history of the New Zealand flora 8. Interglacial and glacial vegetation in Westport District, South Island. New Zealand Journal of Botany 17: 361-387

Moore, P.D. Bellamy, D.J. 1974: Peatlands. Paul Elek Scientific Books Limited, London

Moore, P.D. Webb, J.A. 1978: An illustrated guide to pollen analysis. Hodder and Stoughton, London

- Mosimann, J.E. 1965: Statistical Methods for the pollen analyst. Multinomial and negative multinomial techniques. In (eds.) B.G. Kummel and D.M. Raup. Handbook of palaeontological techniques Freeman. San Francisco
- Molloy, B.P.J. 1969: Evidence for post-glacial climatic changes in New Zealand Journal of Hydrology (New Zealand) 8: 56-63
- Morrison, T.M. Harris, G.P. 1958: Root nodules in non-leguminous plants. Proceedings of the New Zealand Ecological Society 6: 23-24
- Myers, J.V. 1973: A note on the dispersal of Nothofagus pollen in Canterbury, New Zealand. New Zealand Journal of Botany 11: 311-316
- Neall, V.E. 1972: Tephronchronology and tephrostratigraphy of West Taranaki (N108-109) New Zealand. New Zealand Journal of Geology and Geophysics 15: 507-557
- 1973: Some aspects of Western Taranaki Geology and Pedology Ph.D. Thesis Victoria University, Wellington, New Zealand
- 1974: The volcanic history of Taranaki. Egmont National Park Board, New Plymouth
- 1976: Volcanology of Egmont National Park. In (ed) J.H. Fullarton
- 1979: Sheets p19, p20, p21, New Plymouth, Egmont and Manaia (1st Ed.) "Geological map of New Zealand 1:50,000" 3 maps and notes. New Zealand Department of Scientific and Industrial Research, Wellington
- 1980: Volcanology of Egmont National Park. In (ed.) J.S. Tullett, Egmont National Park, Egmont
- 1981a: A comparative study of Holocene tephrochronology of Mount Egmont, New Zealand with four andesite stratovolcanoes in the Cascade Ranges, Western United States. In (eds) R. Howorth et al
- 1981b: Elucidation of the late Quaternary tephrostratigraphy in Taranaki, New Zealand. In eds. Howorth,
- 1981c: Potential hazards from future eruptions of Egmont volcano, Taranaki, New Zealand. Report submitted to National Civil Defence Committee on Volcanic Hazards, June 1981
- 1982: Yellow-Brown loams of Taranaki. In (ed.) V.E. Neall Soil Groups of New Zealand. New Zealand Society of Soil Science, Part 6

- Neall, V.E. Jansen, H.S. 1984: Anomalous radiocarbon dates from Mount Egmont In Programme and abstracts, Geological Society of New Zealand Annual Conference, Victoria University of Wellington. Geological Society of New Zealand Miscellaneous Publication 31A.
- Neall, V.E. Alloway, B.V. 1986a: Quaternary volcanoclastics and volcanic hazards of Taranaki International Volcanological Congress, New Zealand 1986. New Zealand Geographical Survey Record 12
- Neall, V.E. Stewart, R.B. Smith, I.E.M. 1986b: History and petrology of the Taranaki Volcanoes. In (ed.) I.E.M. Smith Late Cenozoic Volcanism in New Zealand. Royal Society of New Zealand Bulletin 23: 251-263
- New Zealand Meteorological Service In J.S. Tullett (ed) 1980: Egmont National Park.
- Nicholls, J.L. 1956: The historical ecology of the indigenous forest of the Taranaki Upland. New Zealand Journal of Forestry 7: 17-34
- 1959: The volcanic eruptions of Mount Tarawera and Lake Rotomahana and effects on surrounding forests. New Zealand Journal of Forestry 8: 133-142
- 1964: Vulcanicity and indigenous vegetation in the Rotorua District. Proceedings of the New Zealand Ecological Society 11: 58-65
- 1982: In Knowles, B. Beveridge, A.E. 1982:
- Ogden, J. 1976: Notes on the influence of drought on the bush remnants of the Manawatu Lowlands. Proceeding of the New Zealand Ecological Society 23: 92-98
- Ogden, J. Caithness, T.A. 1982: The history and present vegetation of the macrophyte swamp at Pukepuke Lagoon. New Zealand Journal of Ecology 15: 108-120
- Oliver, W.R.B. 1931: An ancient Maori oven on Mount Egmont. Journal of the Polynesian Society of New Zealand 40: 73-80
- Payton, I.J. Allen, R.B. Knowlton, J.E. 1984: A post-fires succession in the Northern Urewera forest, North Island, New Zealand. New Zealand Journal of Botany 22: 207-221
- Pearl, I.A. 1967: The chemistry of lignin Edward Arnold, London
- Percy Smith, S. 1910: History and traditions of the Maoris of the West Coast of the North Island, New Zealand before 1840. Published by Avery

- Pocknall, D.T. 1978: Relative pollen representation in relation to vegetational composition, Westland, New Zealand. New Zealand Journal of Botany 16: 379-386
- 1980: Modern pollen rain and Aranuian vegetation from Lady Lake, north Westland, New Zealand. New Zealand Journal of Botany 18: 275-284
- 1981a: Pollen morphology of the New Zealand species of Dacrydium Solander, Podocarpus L'Heritier and Dacrycarpus Endlichner Podocarpaceae. New Zealand Journal of Botany 19: 67-95
- 1981b: Pollen morphology of Phyllocladus L.C.Et A.Rich. New Zealand Journal of Botany 19: 259-266
- 1981c: Pollen morphology of the New Zealand species of Libocedrus Enlicher (Cupressaceae) Agathis Salisbury (Araucariaceae). New Zealand Journal of Botany 19: 267-272
- 1982a: Modern pollen rain on Stewart Island, New Zealand New Zealand Journal of Botany 20: 191
- 1982b: Modern pollen spectra from mountain localities in the South Island, New Zealand. New Zealand Journal of Botany 20: 361-371
- Pullar, W.A. and Birrell, K.S. 1973: Age and distribution of Late Quaternary pyroclastic and associated cover deposits of the Rotorua and Taupo area, North Island, New Zealand. New Zealand Soil Survey Report 1.
- Radwan, M.A. Campbell, D.L. 1981: Mount St. Helens Ash and Mud: Chemical properties and effects on germination and establishment of trees and wildlife browse. United States Department of Agriculture, Forest Service Pacific Northwest. Forest and Range Research Station Research Paper PNW-294
- Raeside, J.D. 1948: Some post-glacial climatic changes in Canterbury and their effect on soil formation. Transactions of the Royal Society of New Zealand 77: 153-171
- Raine, J.I. 1974: Pollen sedimentation in relation to the Quaternary vegetation history of the Snowy mountains of New South Wales. Ph.D. Thesis Australian National University
- Rawson, D.H. 1980: Maori history and the Park. In (ed.) J.S. Tullett Egmont National Park
- Rosenbaum, J.G. Waitt Jr, R.B. 1981: Summary of the eye witness accounts of the May 18 eruption. In (eds.) P.W. Lipman and D.R. Mullineaux 1981 53-67

- Rutherford, J. Skinner, W.H. 1969: The establishment of the New Plymouth settlement 1841-1843. Thomas Avery & Sons Ltd
- Sakai, A. Wardle, P. 1978: Freezing resistance of New Zealand trees and shrubs. New Zealand Journal of Ecology 1: 51-61
- Salas, M.R. 1983: Long distance pollen transport over the Tasman Sea. Evidence from MacQuarrie Island. New Zealand Journal of Botany 21: 285-291
- Sangster, A.G. Dale, H.M. 1961: A preliminary study of differential pollen grain preservation. Canadian Journal of Botany 39: 35-43
- Scanlan, A.B. 1961: Egmont, The Story of a Mountain. A.H. and A.W. Reed, Wellington, New Zealand
- Seffern, W.H.J. 1896: Chronicles of the garden of New Zealand, known as Taranaki. Published by W.H.J. Seffern
- Shaw, J. 1971: The chemistry of sporopollenin In (eds) J Brooks Proceedings of Symposium held at the Geology Department, Imperial College, London Academic Press
- Skeet, H.M. 1901: Mount Egmont and the Pouakai Range. Dept of Lands and Survey Annual Report (1900-1901) 136-137
- Skinner, W. 1975: Survey of country areas In (ed.) R.W. Brown Te Moa
- Smith, S.M. Allen, B.M. Daly, B.K. 1985: Soil relationships on a sequence of sand dunes, Tautuku Beach, South-east Otago, New Zealand. Journal of the Royal Society of New Zealand 15: 295-512
- Standish, R. 1984: Eltham, One hundred years. Eltham Centennial Committee
- Stockmarr, J. 1971: Tablets with spores used in Absolute pollen pollen analysis. Pollen Spores 13: 615-621
- 1975: Retrogressive forest development, as reflected in a mor pollen diagram from Mantingerbos, Drenthe, The Netherlands Palaeohistoria 17: 38-51
- Stokes, M.A. Smiley, T.L. 1968: An introduction to tree-ring dating. Chicago University Press
- Stronge, J.S. 1973: The history of Egmont county (ms), Arawhata Road, Opunake, New Zealand.
- Suggate, R.P. Moar, N.T. 1970: Revision of the chronology of the Late Otira Glacial New Zealand Journal of Geology and Geophysics 13: 742-746

- 1974: The Otiran/Aranuian Boundary. New Zealand Journal of Botany 12: 235-237
- Syers, J.K. Springett, J.E. 1983: Earthworm ecology in grassland soils. In (ed.) J.E. Satchell earthworm ecology from Darwin to Vermiculture. Chapman and Hall, London
- Tauber, H. 1965: Differential pollen dispersion and the interpretation of pollen diagrams. Geological Survey of Denmark ser III Number 89
- 1967: Differential pollen dispersion and filtration In (eds.) E.J. Cushing and H.E. Wright Jr. Quaternary Palaeoecology 16: of the Proceedings of VII Congress of the International Association for Quaternary Research. Yale University Press
- Taylor, N.H. Pohlen, I.J. 1979: Soil Survey Method. Soil Survey Bulletin 25. Department of Industrial and Scientific Research, Government Printer, Wellington
- Thomas, A.P.W. 1888: Report on the eruption of Tarawera and Rotomahana, New Zealand. Government Printer, Wellington
- Thompson Webb III 1974: Corresponding patterns of pollen and vegetation in Lower Michigan: a comparison of quantitative data. Ecology 55: 17-18
- Thomson, G.H. 1917: A ramble on Egmont. Otago Daily Times 6 January, 1917
- Thomson, N.A. 1982: Potash requirements of the Stratford sandy loam as affected by rainfall. In (ed.) V.E. Neall Soil groups of New Zealand Part 6 Yellow-brown loams. New Zealand Society of Soil Science: 92-94
- Tomlinson, A. 1980: The frequency of high intensity rainfalls in New Zealand, Part 1. Water and Soil Publication 19
- Tonkin, P.J. 1970: The soils of the southeastern sector of Egmont National Park. Earth Science Journal 4: 36-57
- Topping, W.W. 1972: The Burrell eruptives, Mount Egmont. New Zealand Journal of Geology and Geophysics 15: 476-490
- 1974: 1480 A.D. Maori oven from Mount Egmont, New Zealand. New Zealand Journal of Science 17: 119-122
- Tullett, J.S. 1980: (ed) Egmont National Park. Egmont National Park Board, New Plymouth
- Turner, E.P. 1928: A brief account of the re-establishment of vegetation on Tarawera mountain since the eruption of 1886. Transactions of the New Zealand Institute 59: 60-66

- Turner, M.A. Neall, V.E. 1978: Survey of magnesium content of the soils and pastures and incidence of grass tetany in three selected areas of Taranaki. New Zealand Journal of Agricultural Research 21: 583-592
- von Post, L. 1944: The prospect for pollen analysis in the study of the Earth's climatic history. New Phytologist 45: 193-217
- Vucetich, C.G. Pullar, W.A. 1964: Ash beds and soils in Rotorua District. Proceedings of the New Zealand Ecological Society 11: 65-71
- Waite, J.R.B. 1981: Devasting Pyroclastic density flow and attendant ash fall of May 18th. Stratigraphy and sedimentology of the deposits. In Lipman and Mullineaux 1981
- Walker, D. Milne, P. Guppy, P. Williams, J. 1968: The computer assisted storage and retrieval of pollen morphological data. Pollen et Spores 10: 251-262
- Wardle, P. 1963: The regeneration gap in New Zealand Gymnosperms. New Zealand Journal of Botany 1: 301-315
- 1965 Significance of xeromorphic features in humid sub-alpine environments in New Zealand. New Zealand Journal of Botany 3: 342-34
- 1966: Biological flora of New Zealand 1. Weinmannia racemosa Linn.F. (Cunoniaceae) Kamahi, New Zealand Journal of Botany 4: 114 -131
- 1975: Vascular plants of Westland National Park (New Zealand) and Neighbouring lowland and coastal areas. New Zealand Journal of Botany 13: 497-545
- 1979a: Forest and Climatic Change. The status of the "Holloway theory" Annual Journal of the Royal New Zealand Institute 133-144
- 1979b: Plants and landscape in Westland National Park. National Parks Scientific Series Number 3. National Parks Authority, Wellington.
- 1980: Primary succession in Westland National Park and its vicinity, New Zealand. New Zealand Journal of Botany 18: 221-232
- Wardle, P. Field, T.R.O. Spain, A.V. 1971: Biological flora of New Zealand 5. Olearia colensoi Hook.f. (Compositae) Leatherwood, Tupari. New Zealand Journal of Botany, 9: 186-214
- Wellman, H.W. 1962: Holocene of the North Island of New Zealand: a coastal reconnaissance. Transactions of the Royal Society of New Zealand 1: 29-99

- Wells, B. 1878: The History of Taranaki. Edmonson and Avery
New Plymouth
- Winner, E.W. Casadevall, T.J. 1981: Fir trees as thermometers during the May 1981 eruption. In (eds.) Lipman and Mullineaux 1981
- Wodehouse, R.P. 1935: Pollen grains. McGraw Hill Book Company,
New York
- Wood, R.G. 1959: From Plymouth to New Plymouth. A.H. and A.W. Reed, Wellington
- Yamaguchi, D.K. 1983: New tree-ring dates for recent eruptions of Mount St.Helens. Quaternary Research 20: 246-250
- 1985: Tree-ring evidence for a two year interval between recent prehistoric explosive eruptions of Mount St.Helens. Geology 13: 554-557
- Zobel, D.B. Antos. J.A. 1982: Adventitious rooting of eight conifers into a volcanic deposit. National Research Council of Canada Notes 717-719
- 1985: Response to conifer elongation to tephra from Mount St.Helens. Forest Ecology and Management 12: 83-91
- Zotov, V.D. 1938: Some correlations between vegetation and climate in New Zealand. New Zealand Journal of Scientific Technology 19: 474-488