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SOME ARANUIAN (POSTGLACIAL) ORGANIC DEPOSITS IN THE SOUTH EASTERN RUAHINE RANGE, NORTH ISLAND, NEW ZEALAND, INVESTIGATED BY PALYNOLOGICAL METHODS.

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

CYNTHIA M. LEES

1981

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ABSTRACT

Palynological methods have been used to investigate Aranuian organic deposits in the south eastern Ruahine Range. The relevant literature was reviewed. Six profiles from five sites ranging in altitude from 80 to 1050 metres and from 13,300 years B.P. to present were sampled and the pollen analysed. Investigation of the palaeoecology of each site included the geomorphology, stratigraphy, present vegetation and pollen rain where relevant. The pollen data as percentages of several pollen sums was presented in pollen diagrams, statistically analysed and an interpretation suggested.

An investigation of pollen rain in the Kahuterawa Valley in the Tararua Range and on Mount Ruapehu was made to obtain information on present podocarp-broadleaf forests and about *Weinmannia racemosa* in particular. The results indicated a succession of dominants, including *W. racemosa* over a period of up to 1000 years. This information was used in interpreting the pollen spectra of the fossil sites.

All sites were reviewed as part of an Aranuian series. It was concluded that a climatic change from a drier cooler climate to a warmer moister one occurred between 13,300 ± and 10,650 (provisional date only). A more equable climate than at present possibly occurred between 3200 ± and 3770 ± with fewer frosts and droughts. These findings are in general agreement with those of palynologists at sites in other parts of New Zealand. Other aspects of climatic change erosional history, plant-land relationships and species representation have been discussed. The decline of *W. racemosa* at the West Tamaki site was part of a natural stage in the life cycle and not caused by the browsing of the opossum.

PREFACE

This is the first time that an investigation of organic deposits by palynological methods has been undertaken at Massey University. Personally, I am grateful for the opportunity that has been given me to follow an interest I have had for many years and the work has given me much satisfaction and pleasure. The investigation would not have been possible without the help, interest and co-operation of three Departments.

I would like particularly to thank Professor K.W. Thomson for his permission to submit such an investigation as a fit subject for a masterate thesis in Geography. Professor B.P. Springett and Professor R.G. Thomas generously supplied the necessary equipment and chemicals. Professor J.K. Syers kindly allowed the use of laboratory space and facilities during vacations.

For so willingly giving of their time and knowledge in many helpful discussions and advice, I would like to thank my supervisor Dr J.P Skipworth of the Botany and Zoology Department and my assistant supervisor Dr M.J. Shepherd of the Geography Department. During Dr Shepherd's absence overseas Dr J.L. McArthur of the Geography Department arranged essential field trips and gave much appreciated advice and encouragement.

Without the help and enthusiasm of Dr V.E. Neall and Mr M. Marden of the Soil Science Department the investigation would not have been possible, they suggested suitable sites some of which were already dated. The technical staff of all these Departments cheerfully tackled the practical problems of equipment and supplies and I thank them for their assistance. The Curator of the Massey Herbarium Dr M.B. Forde graciously consented to the removal of pollen samples from the herbarium specimens. The reference slide collection will remain at Massey.

Much support from outside the campus came from D.S.I.R. Dr E.J. Godley, Director of the Botany Division, Lincoln kindly gave permission for a six weeks study period in 1980 in the Palynological Laboratory under the direction of Dr N.T. Moar. All the staff of this laboratory were most helpful and enthusiastic. Two further visits were made during 1981 when valuable advice was received on the handling and presentation of data. The curator of the National Herbarium at Lincoln, Miss B.H. Macmillan kindly identified many specimens and allowed me to collect pollen from the herbarium specimens. Other identifications were made by Dr E. Edgar and Dr D.R. Given. All the identifications of the fossil wood specimens were made by Dr R.N. Patel. I am grateful to all these people for their generous interest and support. Dr E.O. Campbell of Massey gave up valuable time to identify the fossil plant remains found at the Delaware site and shared her knowledge of bog plants, this timely help was much appreciated.

During the last three months two visits have been made to the Geological Survey Department, Lower Hutt. Discussions with Dr J.I. Raine were most useful and he very kindly instructed me in the use of their excellent photographic equipment which enabled the photographs of the modern and fossil pollen to be included in this thesis.

Thanks are also expressed to the staff of the Massey Printery for the production of many diagrams and to the Central Photographic Unit for their continued interest in the production of the photographs. Lastly, but by no means least, I would like to thank Mrs Fay Wicherts for her patience and support during the final weeks as she coped so skilfully with the typing of this thesis.

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CHAPTER 1

AIMS

The following aims were defined:

1) To investigate aspects of the palaeoecology of the South Eastern Ruahine Range during the post-glacial period by investigating different sources of fossil pollen and modern pollen rain at a range of sites at different altitudes and of different ages.

2) To extend a knowledge of the Podocarp-Broadleaf forests of the present to interpret the vegetation of the past.

OBJECTIVES

The aims defined above were translated into the following objectives:

1) Preparation of a reference pollen slide collection from authoritatively identified botanical specimens. (The nucleus of such a collection was completed in 1980.)

2) Sampling of deposits at the selected sites in a regular sequence to obtain a record of the pollen trapped at that site.

3) Obtaining, where possible, radio carbon dates for the deposit.

4) Production of diagrams based on the analysis of the pollen counted on the microscope slides, prepared from each sample. These were expected to yield information in the following areas:

i) Climate, deduced from the vegetation on the site as indicated by the pollen.

ii) Possible climatic change as reflected in changes in vegetation, derived from variation in the proportions of different pollen types.

5) Examination of the geomorphology and the stratigraphy of the sites with a view to the evolution and development of the site in relation to the landform itself and possibly the climate at the time of formation.

6) Comparison of the interpretations of the data with that from other fossil pollen sites:

i) In the Ruahine Ranges.

ii) In the North Island.

iii) In New Zealand, in general terms.

7) Investigation of the life cycle of kamahi. (The apparent decline of the kamahi, *Weinmannia racemosa*, in the West Tamaki catchment is thought to be due either to browsing by the introduced opossum, *Trichosurus vulpecula* or to a natural stage in a cyclic life cycle. It was thought that pollen analysis might be able to clarify this problem.) Cunningham (1977).

THE STUDY AREA AND SITES

The Southern Ruahines are delimited by the Pohangina River on the west and north, the Tamaki River on the east and the Manawatu River and Gorge to the south, the study area lies to the east of the Main Divide. The sites were found and suggested by Dr V.E. Neall and Mr M. Mardon of the Soil Science Department of Massey University.

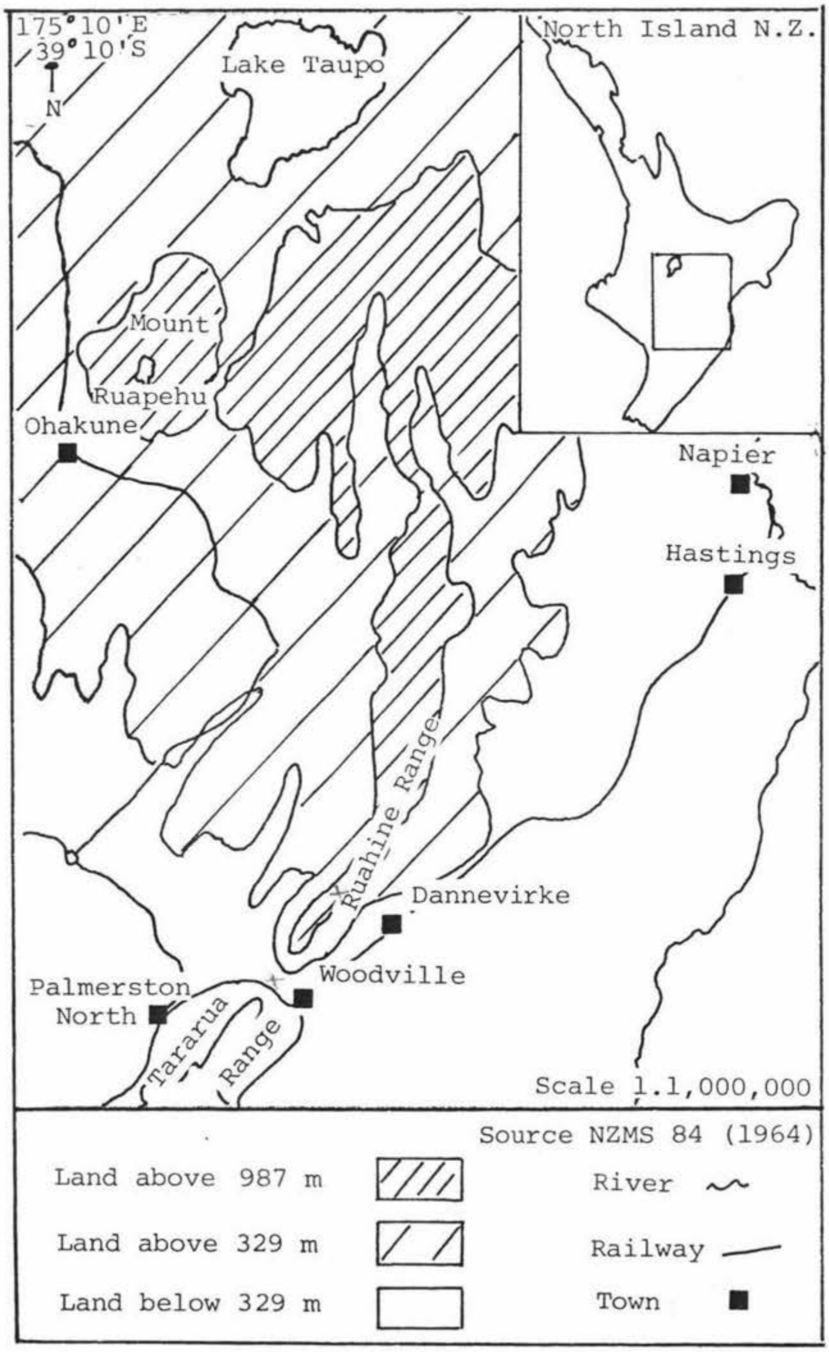
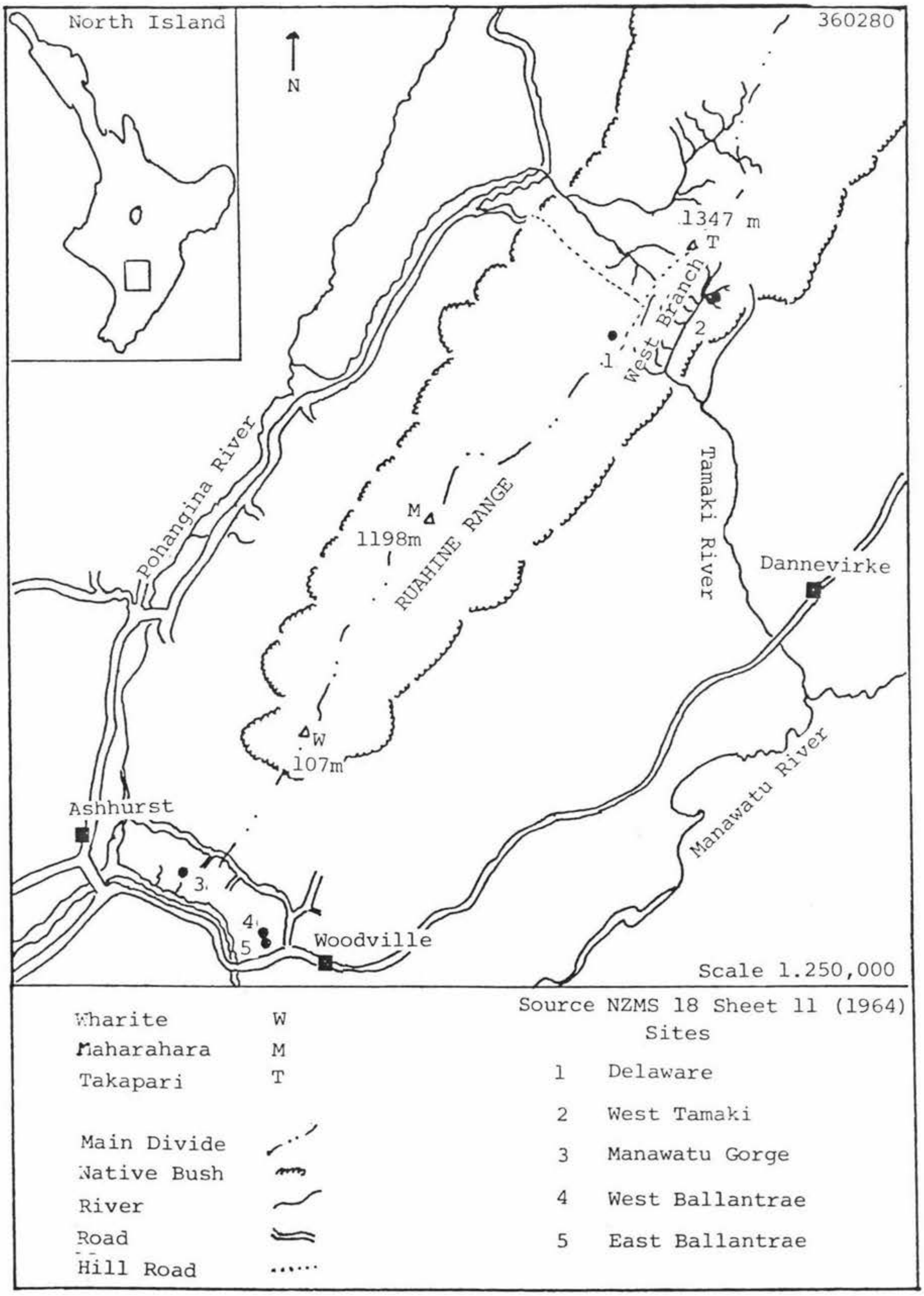


Figure 1.1 Location of study areas in the North Island , New Zealand.

Figure 1.2 Location of study sites in the S.E.Ruahine Range.



Source NZMS 18 Sheet 11 (1964)

Sites

1	Delaware
2	West Tamaki
3	Manawatu Gorge
4	West Ballantrae
5	East Ballantrae

Two of the sites, the Delaware and the West Tamaki were described by Hubbard (1978) and Hubbard and Neall (1980) Figure 1.1 shows the location of the study area with reference to the North Island of New Zealand. Figure 1.2 shows the location of the sites within the study area.

Table 1 Fossil pollen sites in the S.E. Ruahine Range

CML 80/1	Delaware Ridge Road	Altitude	1050 m	348266
CML 80/2	Whiteywood fan, W. Tamaki River	"	500 m	268353
CML 81/3	West Ballantrae Nr. Woodville	"	100 m	333239
CML 81/5	Manawatu Gorge	"	300 m	329241
CML 81/9	East Ballantrae Nr. Woodville	"	80 m	333239

All map references are given for NZMS 18 Dannevirke Sheet 11.

Altitudinal data approximate from the same map.

Table 2. Radio carbon dates for fossil pollen sites Ruahine Ranges

Site	Ref No.	NZ 14C No.	Age	Species
Delaware Ridge[a]	T23/f19	NZ 5274 B	8400 ± 130	*Compositae*
West Tamaki		NZ 4547 C	770 ± 60	*Pittosporum*
Manawatu Gorge[a]	T24/f15	NZ 5231 C	3770 ± 90	*D. cupressinum*
West Ballantrae		NZ 4651 B	13,300 ± 200	*Conifer*
East Ballantrae	T24B/f17	Provisional	10,650 ± 150	*Leptospermum*

[a] Wood dated for this thesis

PART 1

LITERATURE REVIEW

CHAPTER 2

HISTORICAL

'Little of the Earth's topography is older than the Tertiary and most no older than the Pleistocene.' (Thornbury, 1954.27)

Geomorphology

Pleistocene geomorphology began with the observations of Le Charpentier and Agassiz in the mountain passes of Switzerland (West, 1977). It was some time before interest was aroused in Europe and America but eventually many studies of glacial and periglacial landforms were made. Authoritative texts are Flint (1971) and French (1976). Papers on these and allied landforms, such as coastal phenomena, dominated British geomorphology for many years. An entire issue of the Transactions of the Institute of British Geographers was devoted to 'The vertical displacement of shorelines in Highland Britain' (1966).

Later it was realised that the effects of Pleistocene climatic changes were global and that evidence for this could be found far from areas of glaciation. Bloom, who had previously investigated peat deposits submerged by the Flandrian transgression on the coast of N.W. America, found similar submerged peats on the atolls of the Eastern Caroline Islands in the Pacific Ocean (Bloom, 1967; and Bloom 1970). Erosion of Holocene beach ridges were investigated by Thom (1974) on the coast of Australia and Chappell (1974) studied the uplifted coral terraces formed at different sea levels on the Huon Penisular in New Guinea. In southern Africa, arid and semi-arid phases were distinguished by the radio carbon dating of cave deposits, in Ngamiland, (Cooke, 1975).

Three new techniques led to great advances and an upsurge of interest. These were the extension of time scales by improved radio isotope analyses including the determination of ratios, the development of oceanography and deep drilling of ocean cores and the discovery of residual magnetism led to a palaeomagnetic time scale which applied all over the world and thus enabled correlations to be made (Goudie, 1977).

The definition of the Pliocene Pleistocene boundary was clarified by Ericson *et al*. (1963) using *Globigerina* assemblages in deep sea cores. Emilani (1966) deduced a palaeotemperature curve based on the 0^{18} : 0^{16} in calcitic tests of *Foraminifera*. His interpretation of the causes of the observed changes was later modified by Shackleton (1967). Several curves of sea level changes have been made (Bloom *et al*, 1974) (Chappell, 1974), but the first was Fairbridge (1961) based on glacial advances and retreats. Both Chappell (1974) and Bloom (1971) had considered the relationship between glacioeustatic and isostatic changes in sea level. A more theoretical geophysical approach to this complex problem was adopted by Walcott (1972a). He defined the concept of a model earth which would exhibit both elastic surface movements and long term relaxation in response to changes in the loading of ice.

New Zealand studies began with statements by Speight on glaciation in New Zealand in 1910. The evidence at that time seems to have been mostly biological, based on the study of logs in peat bogs. The geomorphological approach followed. Gage (1958) discussed the late Pleistocene glaciations in the Waimakariri valley in Canterbury. Other papers presented by Gage (1961a, 1961b) included studies on the New Zealand glaciations and a special study of the Ross glaciation. Burrows and Lucas (1967) used lichenometry to derive the ages of moraines of the Mueller and Tasman glaciers. The first chronology of the Pleistocene in New Zealand was made by Gage and Suggate (1958), this was later amended by Suggate (1965). Suggate and Moar (1970) using evidence from pollen analysis of a site in the Grey River revised the chronology of the late Otira Glacial. They were able to show that the major retreat of the glaciers began in the South Island about 14,000 years B.P. Thus defining the beginning of the postglacial period which is the subject of this thesis.

Pleistocene Climate

The transformation of data derived from such diverse sites, sources and techniques to produce a map of the world climate during the Pleistocene was made possible by the development of a computer programme by members of the CLIMAP Project (Climap, 1976; Gates, 1976). The map simulates the world climate in July 18,000 years B.P. On this map a depression of the sea temperature around New Zealand of about 6°C is shown (CLIMAP 1976, 1134).

Examination of the recorded temperatures in the Tasman Sea and the movement of westerly weather across New Zealand has shown that there is the possibility of a connection between sea temperature and weather patterns (Trenberth, 1973).

A depression of 6^{o}C of the mean annual temperature during the Pleistocene in New Zealand was suggested by Willett (1950). He based his assessment on a comparison of the levels of the present snowline and the levels of cirque floors, on this basis the Pleistocene snowline would have been 1067 metres lower. Soons (1979) reviewed the evidence and comments by several authors (Gage, 1965; Soons, 1963; Wardle, 1970) which indicated that the climate was probably less severe than Willett had suggested. By using the 'limit of glaciation' as suggested by Flint (1971) she was able to propose a depression of only 4.5^{o}C in the mean annual temperature and of the snowline of only between 850 and 830 metres, at the maximum of the Otira glaciation.

Reconstructed snowlines in other areas of Pleistocene glaciation tend to agree with the probable 0^{o}C isotherm for the warmest month. This is not the case in New Zealand. Compared with the continental areas of the northern hemisphere, New Zealand could be regarded as an oceanic group Soons suggested, therefore the climate would tend to be less severe. The expectation that climatic events in the northern hemisphere would be closely paralleled in the southern hemisphere does not appear to be justified according to Pittock (1978). He cited differences in the configuration of land and sea, storage of ice and the ensuing feedbacks, mainly due to differences in albedo and suggested that time lags could be as great as two thousand years. Trenberth (1977) has given a comprehensive survey of climate and climatic change from the New Zealand perspective, with special emphasis on the causes of climatic change both in the long and short term.

Biostratigraphy

Dorf (1959) stated that fossil plants are proven to be the most widespread and dependable indicator of ancient climates of the earth because plants are very sensitive to their environment. The general facies of the total assembly gives the only safe and reliable basis for reconstructing past climates. West (1977) justifies the use of biostratigraphy on the assumption that the ecological responses of an individual to the environment will have remained unchanged during the period under review and therefore a change in species assemblage indicates a change in the environment. This was the basis for the definition of interstadials and interglacials by Jessen and Milthers in 1928 and for the interpretation of pollen diagrams produced from pollen analysis. Godwin (1940a) allocated pollen zones to changes in the pollen sprectra which had been frequently observed in N.W. Europe.

Harris (1964) attempted to transfer similar zones to the New Zealand studies of fossil pollen sites based on the work of Cranwell and von Post (1936). He suggested a period of maximum warmth corresponding to the European hypsithermal between 6500-

2500 B.P., following a general warming from about 18,000 B.P. McGlone and Topping (1973) working on peats in the Tongariro region were able to use tephra layers previously investigated by Vucetich and Pullar (1973) to date the pollen profile. They suggested that for this North Island site, 13,800 B.P. was the youngest date for the climatic amelioration following the Otiran Glaciation which marks the onset of the post-glacial or Aranuian period. Further work in the same area enabled them to discern three major pollen zones related to climatic change (McGlone and Topping 1977). These are:

1) 14,000-10,000 yr B.P. *Podocarpus spicatus* forest was dominant. Annual temperatures may have been only 2-3°C lower than present, but the climate was substantially drier.

2) 10,000-5000 yr B.P. *Dacrydium cupressinum* forest was dominant and the climate much wetter and milder than at present.

3) 5,000 yr B.P. - present. Return to *Podocarpus spicatus* dominant forest, increase of *Nothofagus*, and a general trend away from the mild climates of (2) to a more drought and frost-prone climate.

CHAPTER 3

PRINCIPLES AND METHODS OF POLLEN ANALYSIS

'Pollen analysis is the principal technique used to reconstruct Quaternary environments' (Birks and Birks 1980, 156)

Historical

Qualitative descriptions of vegetation and pollen floras were made during the nineteenth century. Quantitative analysis dates from a classical paper by Lennart von Post prepared in 1916, according to Birks and Birks (1980). In the Vega lecture delivered by von Post in 1944 he commented that 'Pollen analysis in its present form, or as it should be properly called, pollen statistics,...... was designed mainly as a means of determining geological time'. He went on to say 'Nevertheless the inescapable basis of this chronological apparatus is the establishment of the historical course of the development of the vegetation, as this appears in the pollen diagrams'. (von Post, 1946, 196-197).

With the development of radio isotopic analysis and the palaeomagnetic time scale the role of pollen analysis has in fact changed from being a geological tool to a palaeoecological one as envisaged by von Post. Faegri and Iversen (1975) outlined the techniques now widely used for the extraction of pollen from a variety of substrates. The methods used for the preparation of pollen for reference slides and from field samples in this thesis are based on those in use at the Palynology laboratory, Botany

Division, D.S.I.R. Lincoln. They were supplied by McGlone and Shand and follow the general principles described by Faegri and Iversen. Early reference texts still in use are by Wodehouse (1934) and Erdtman (1952). Moore and Webb (1978), although a text of British pollen, has excellent plates which were used in some identifications.

New Zealand palynology

The first workers in this field were Cranwell and von Post (1936) and later Cranwell (1938, 1939, 1940). Some of W.F. Harris's papers are quoted elsewhere but he also produced a text on Pteridophyte spores (1955). Further morphological pollen grain studies were contributed by Cranwell (1942, 1953), Harris (1956a, 1956b), Moar (1960 a & b), McIntyre (1963), McGlone (1978a, 1978b), MacPhail and Mildenhall (1980) and Pocknall (1981).

Knowledge of the postglacial climate rests very heavily on palynological evidence. The pollen of the small tree *Ascarina* appears to have a use as a climatic indicator. The pollen of this species is usually well preserved. Formerly abundant in both the North and South Islands it now has a very restricted distribution. The ecology of this species indicates it is probably drought and frost tender (McGlone and Moar 1977).

Apart from studies in peat bogs, some of which are referred to in chapters 4 and 5, there have been investigations into deposits in organic layers preserved and exposed in quarries, stream banks and road cuttings such as that by Moar and Suggate (1978).

Pollen rain studies (Clarke 1951) and Licitis (1953) were concerned with medical aspects of pollen airfall. The pollen in moss polsters from different forest communities at three localities in the South Island was analysed by Moar (1970). Myers (1978) used traps to investigate the dispersal of pollen from *Nothofagus* species in Canterbury. This study was further reported on by Moar and Myers (1978). Relative pollen representation using moss polsters was examined by Pocknall (1978) but he found only a limited application for this concept. The same author (1980) compared modern pollen rain with the pollen found in sediments from Lady Lake, Westland.

Recent advances

The quantitative aspects of pollen analysis were critically examined by Davis (1963). Emphasising the need for some measure to evaluate the relationship of modern pollen rain to the vegetation present, she suggested the R value whereby the percentage of pollen of a species was divided by the percentage of that species in the vegetation. Tauber (1965) found that the deposition of pollen was related to three components of dispersal; rain-out, canopy and trunk space. He was able to make some predictions about the respective values of each. Moore and Webb (1978) and also Birks and Birks (1980) reported on Mosimann's (1965) method for the statistical analysis of proportional representation of pollen in the samples of a profile. The method used in this thesis was taken from Moore and Webb (1978, 85-87).

A critical examination of pollen rain in a deciduous forest was made by Andersen (1967) and he later extended these studies to seasonal and annual deposition (Andersen 1974). Extracting pollen from soils and its sequential deposition was stated by Moore and Webb to be possible in mor soils. It was on the basis of this statement that it was decided to use soil samples from one site on Ruapehu. The validity of this technique appears to have been established by Wright *et al*, (1967) while investigating pollen rain in Iran. They found they could get comparable results from pollen in moss polsters and surface soil samples, providing the local vegetation, usually a herb, was noted as this tended to be over represented.

The use of modern pollen rain in moss polsters and from soil samples to derive a pattern of succession in species composition in a forest as used in this thesis does not appear in the literature examined.

CHAPTER 4

POST GLACIAL CLIMATE AND VEGETATION IN NEW ZEALAND

'Fluctuations of temperature and of humidity have left their record in layered sediments, in pollen deposition and in the growth rings of trees. In soils, in peat bogs and in areas of living forest evidence of change may be found'. (Harris, 1950)

Evidence from macrofossils

Although the first interest in climatic change due to glaciation was awakened by the biological evidence (Speight 1910), it was not until the 1960s that papers began to appear showing an interest again in organic material preserved as evidence. Molloy *et al.* (1963) studied the distribution of subfossils in the South Island. These included surface logs, buried wood and charcoal also windthrow dimples and palaeosols. They regarded these as abundant evidence of former forests which had been destroyed by fire but were unable to decide if climatic change had contributed. Molloy and Cox (1972) investigated buried wood at a site in the Rakaia valley and determined that the area had been covered with a *Nothofagus* dominated forest for the last 5000 years. Forest also grew on the coastal fringe of Canterbury from 9400 years to 700 years ago according to evidence of buried wood and charcoal found by Cox and Mead (1964) when they investigated soils of that area. Leaves of *Nothofagus menziesii* found by Wardle and McKellar (1978) in till-like sediments at Milford Sound have been dated at 7940 years and Johnson obtained a date of between 6000 and 3000 years B.P. for small plant fragments and logs, mainly of podocarps, preserved on an offshore shelf at Lake Manapouri (1978).

In the North Island evidence of different distributions of vegetation from those of the present have also been found. McGlone *et al.* (1978) investigated peat deposits in the Hinuera formation of South Auckland. They interpreted the vegetation and the formation of the swamp as indicating a cool and/or drought prone climate, but with high intensity rainstorms probably occurring also during the period from 20,000 to 18,000 years B.P. Sedimentation slowed dramatically between 18,000 and 17,000 yrs B.P. and ceased altogether between 14,000 and 12,000 indicating a change in climate. The dating of deposits by tephra layers is possible in the North Island, this technique was used by Campbell *et al.*(1973) for peat deposits in the Rangitaiki plains and the Maketu basins, to date plant fragments and pollen. Papers by McGlone and Topping (1973, 1977) using tephrochronology have already been mentioned. Macrofossils can also be useful when it is not possible to identify pollen down to a specific level as in Lintott's study of Kettlehole Bog at Cass (1963), reported by Moar (1966).

Evidence from microfossils

Some of these studies have included pollen analysis. This technique permits an interpretation of change over time which isolated macrofossils do not. The interpretation of the evidence needs care. Lintott and Burrows (1973) suggested that warming had occurred about 10,000 years B.P. Suggate and Moar (1974) refuted this claim and regarded the changes as local in origin because they did not correlate with those found by Moar at a site only 6 km away (Moar 1971). They also commented that a lack of climatic change in New Zealand contrasts with the oscillations found in N.W. Europe during the Allerød interstadial. Reporting on the results of pollen analysis of a large number of sites in the South Island, Moar (1980) was able to show that grassland had persisted in central South Island from 26,000 to 12,000 years B.P. During this period there were several retreats of the glaciers. Moar explained that either there was insufficient time or an unsuitable climate did not permit the expected transition to shrubland but he also stressed that the absence of a change in vegetation could not be taken as evidence of an unchanging climate.

Evidence of regional differences in the pollen spectra have been found. Moar (1979) records that in the Westport area rapid amelioration of the climate was indicated by the presence of podocarp forest in the Late Otiran. This supported evidence found earlier (Moar 1970, and 1973b), which suggests that there were climatic differences on either side of the Main Divide just as there are today. Working in the north of the South Island, Dodson (1978) investigated sediments from the Dew Lakes of the Bryant Range in Nelson. His pollen analyses and radiocarbon dates indicated that *Nothofagus* podocarp forest had been present in the area for the last 10,500 years B.P. There was a continuous rise in *Nothofagus* pollen. Pollen of *Podocarpus ferrugineus* and *Dacrydium cupressinum* was present in relatively constant amounts but the *Nothofagus* rise was accompanied by a decrease in other *Podocarpus* species and shrub taxa. He comments that this sequence appears to agree with the analyses published (Moar 1961, 1967) for the Ruahine Range of the North Island.

The present forests of New Zealand

'Quaternary palaeoecology must, by necessity, use the present to model the past'. (Birks in Birks and West, 1972). Cockayne (1928) was the first of several workers to investigate the relationship of the present vegetation of New Zealand to climate. He correlated vegetation belts with the duration of winter snow but did not offer an explanation of this idea. In selecting temperature, Zotov (1938), regarded warmth in summer as a limiting factor. His diagram of vegetational belts in the mountains of New Zealand and the Subantartic islands was later used by Willett (1950) in his paper on New Zealand Pleistocene snowlines and climate. The possibility that summer warmth only controlled the actual tree limit and the distribution of some species was suggested by Wardle (1964), he also evaluated the effect of local factors of climate and soil in influencing the altitudinal distribution of some species and discussed the east west distribution.

In 1954 Holloway published a paper which aroused a great deal of controversy. He had observed forests in the South Island where the vegetational belts were reversed and also many areas with relatively few, very large, overmature podocarps and no apparent regeneration. He suggested that a period of severe cold comparable to that which had been recorded for Europe had occurred in New Zealand about A.D. 1300. The idea is thought to have arisen from a paper by Raeside (1948) on soils in Canterbury. That other explanations were possible such as a mosaic or cyclical regeneration pattern was suggested by Cameron (1954) but this was rejected by Holloway (1954b). Several other workers (Grant 1963, McKelvey 1953, Nicholls, 1956) found such a climatic change valid in explaining certain difficulties they found when studying the podocarp broadleaf forests. Some evidence for a regeneration gap was found by Wardle (1963b) when he studied ages of three species at six locations in the South Island, but he cautioned that he did not consider he had sufficient evidence to form a definite conclusion.

Bray (1971) made a thorough research into the literature on the geophysical mechanisms of the solarclimate relationship and the effects of volcanism on the patterns of vegetation throughout the world. He found that the extensive cooling after the thirteenth century was the result of lowered solar activity. He quoted Raeside's (1948) paper as a New Zealand example. In discussing synchroneity, however, he found considerable variation in time of cooling in the Southern hemisphere. He attributed this to specific variability, local climates and in part, to the accuracy of the botanical chronologic techniques.

The controversy was continued by Cumberland in a very extensive discussion entitled '"Climatic change" or Cultural Interference' in the book 'Land and Livelihood' (McCaskill 1962). He attributed the destruction of the former forests to cultural interference, specifically man's use of fire. A bibliography of all papers relevant to ecologically significant changes in climate was made by Fleming (1963) but he did not draw any conclusions about such changes in the postglacial period in New Zealand. Molloy thoroughly investigated the many papers written on this theme of postglacial climatic change particularly the 'climatic optimum' and 'the little ice age' for which there is conclusive evidence in northern Europe (Molloy 1969). He also was unable to find any convincing proof of change except for a general rise in temperature about 10,000 years B.P. The latest work by McGlone and Topping (1977) is quoted in Chapter 2 page 11.

The present climate of New Zealand

The classic text on New Zealand climate is that of Garnier (1958). Coulter (1975) has presented the climate in the light of recent knowledge gained from studies of the upper air and large scale global wave patterns. Trenberth (1973) showed that the persistent S.W. regime which dominated the N.Z. weather in the autumn and winter of 1972 occurred when anticyclones formed over Australia failed to move out over the N.Z. area, or if they did so, were very weak. During this period the surface temperatures of the Tasman sea were above normal. Salinger and Gunn (1975) reported a recent climatic warming around N.Z. but no significant change in rainfall. They suggested that a movement of the subtropical high pressure ridge would give increased westerlies and climatic deterioration whilst a southward movement would give weak westerlies and warming. Trenberth (1977) supported the recent warming and quoted as proof that the trend was shown by rural as well as urban centres. Hessell (1980) investigated the records both physically and statistically and concluded that the changes could be explained in the cities by urbanisation and in the rural stations, which were mostly forest plantations, by the increased shelter provided by tree growth. It appears that, even with detailed records, restraint must be exercised in interpreting the data.

Coulter (1973b) described the vagaries of mountain weather due to the lowered temperature and increased air movement. There have been several studies of mountain weather but most are for the South Island and none of them refer to any of the study areas of this thesis.

Neall and Thompson (1978), however, did study three weather patterns in the Manawatu, particularly in the vicinity of the Gorge. The Tararua and Ruahine ranges are lower in this area. Kingma (1962) stated that the fault pattern in the Manawatu Gorge area suggests the Ruahine greywacke block is overriding the Manawatu block, hence the lower topography and the superimposed Manawatu River. Neall and Thompson found that due to this lowering the normal west to east rainfall pattern is changed and more rain falls on the Woodville and Eketahuna lowlands to the east of the ranges than would be expected. They also found that moist air was often overlain by dry air above or even an inversion located at about 800 - 700 mb. Condensation of atmospheric moisture would normally form below such a layer when the moist westerly air stream was forced to rise by the mountain range, this hill fog is simply stratiform cloud enveloping high ground (Barry and Chorley, 1968).

Zotov (1938) recorded his observation of fairly persistent fog present on 200 days of the year in the Tararuas and remarked that this was true also for the Ruahines. He further associated the treeline with the level of this fog. Wardle (1965) drew attention to the apparent enigma of plants in humid situations which have xeromorphic features. He particularly singled out the leatherwood *Olearia colensoi* and concluded that these adaptations help the plant to make the most of the intense insolation and not to lose this heat when fog reduces the radiant energy supply. This shrub forms extensive areas of cover in the S.E. Ruahines.

Wardle and Campbell (1976) surveyed postglacial pollen diagrams from inland regions of the S.I. and noted the anomalous position of *Dacrydium* (probably *D. bidwillii*). Their experiments proved that this species is more frost-hardy than two other treeline species, *Phyllocladus* and *Nothofagus solandri var. cliffordioides*. They therefore concluded that in the early postglacial, as well as the temperatures being generally lower, there were probably more severe temperature inversions. Moar (1961) has recorded treeline variation associated with *D. biforme* and McGlone and Topping (1977) comment that prior to 10,000 yrs B.P. *D. bidwillii* was the main pioneering species on new tephra layers in the Tongariro region and that since that time *Leptospermum* fulfills this role. Finally McGlone and Moar (1977) comment on the abundance of *Ascarina lucida* between 10,000 yrs B.P. and 5000 yrs B.P. and its decline since then and they attribute this to a more frostprone and droughtprone climate.

The point is made that mean annual temperatures as recorded by instrumentation may not give as clear an indication of climate as the vegetation.

'Trust not authority; pay no heed to books, but go to the plants themselve.' 'Sound advice given to the author by the late Mr R. Brown' quoted by L. Cockayne in his book 'New Zealand plants and their story (1910, 4th Ed. 1967).

CHAPTER 5

THE STUDY AREA. SOUTH EASTERN RUAHINE RANGES

Geomorphology

The physiology, structure and geology of the Ruahines were described by Kingma (1957b, 1962). The points emphasised are the ruggedness of the range bordered by many faults, these parallel faults show dextral transcurrent movement as well as normal or reverse faulting. The wedge shaped horst is intricately faulted at the southern extremity and the Ruahine greywacke becomes progessively less deformed and less indurated eastwards. Marden (1977) has investigated the relationship of geology to erosion in the West Tamaki catchment of the S.E. Ruahines and has associated rock falls and slides with bedrock features, while slumps occur in loose colluvial material associated with recent fault scars. The presence of faults on the steep eastern faces of the range and the steep attitudes of the bedding planes are regarded as the most important features which contribute to the general instability of the area. In a later review (1981) he stated that all forms of slope failure identified within the S.E. Ruahines are often found in association with faults.

In describing the geology of the Dannevirke sub-division which includes all the fossil pollen sites described in this thesis, Lillie (1953) presented a picture of ancient and persistent fault movement occurring up to the present day. Two large active faults, the Ruahine and the Mohaka, extend north north east through the study area. The West Tamaki River valley is a fault line valley. Two sites, the East and West Ballantrae lie on either side of the splintered Mohaka fault in the Woodville area. Figure 6.1 shows the sites in relation to the geology of the study area.

Erosion

Concern over the apparent increase in erosion has led to intensive study of the West Tamaki catchment by the Soil Science Department of Massey University, the Aokautere Science Centre, the Manawatu Catchment Board and the Forest Service. These studies are briefly recorded in two booklets (Neall 1977, 1981). The current rate of erosion has been calculated by Stephens (1977) as $3000m^3/ km^3/$ yr. An increase of $1000m^2/km^2/yr$ occurred between 1946-1974 as measured on two sets of aerial photographs. There appears to be a consensus of opinion that the combination of an unstable geologic setting and intense rainstorms are the main cause of erosion in this area.

Coulter (1975) comments that very heavy and widespread rain and destructive gales over large areas are caused by severe storms originating in cyclonic centres in the vicinity of New Zealand. Marden (1981) states that intense cyclonic storms may produce daily rainfalls of 300mm, the average rainfall for the area being 2000 - 3000mm per year. Rainfall data for the range is very limited. At Wharite, altitude 914 metres, 160mm in 24 hours was the maximum recorded up to 1978 (NZ Met. Ser., 1979). Hubbard and Neall (1980) have described the erosional effect of Cyclone Alison in March 1975 in the West Tamaki catchment. Grant (1963, 1965, 1977b, 1979) has indicated that there have been five periods of increased erosion in the Ruahine ranges, the first starting about A.D. 1270 and the fifth and present one commencing about 1940. During these periods, erosion of hill and mountain slopes increases, vegetation is destroyed and channels become wider, straighter and they also steepen and aggrade. Grant's hypothesis is based on an increase in erosion as a result of a change in the pattern of storm rainfall probably caused by a sustained increase in the frequency of major rainstorms, (Grant 1981). The long lasting effects of gales, gales with icing and cloudbursts on the vegetation of the North Island forests were also observed, (Elder 1963).

Vegetation

Colenso was the first European to cross the Ruahine Range in 1845, he recorded the presence of many species and noted forms of erosion which impressed him. He described how trees which had fallen halfway down a collapsed cliff continued to grow and mentioned with horror having to navigate a pass in the forest where 'It was as if an avalanche of half the mountain's side had suddenly slipped into the distant gulph below', (Colenso 1884, 17). Initial concern was expressed when the widespread destruction of the vegetation became obvious following the introduction of browsing animals. The exposed dead limbs of kamahi, *Wainmannia racemosa* were the most conspicuous signs and this species was known to be a favourite food tree of the introduced oppossum, *Trichosurus vulpecula*. Opossums were first introduced into the Pohangina Valley in 1893, colonisation of the range was considered to be complete by the Forest Service in 1953, (Cuddihy, 1977). James and Beaumont (1971) reporting on a survey of vegetation undertaken in 1969/70 state that descriptions of forest composition and structure made prior to World War II (Druce and Greenwood, reported by Elder, 1965) were no long recognisable, and even the more recent ones of Elder himself (1965) and Cunningham (1966) had become out of date. They themselves regarded the forest as so unstable that a botanical report would be useless and they only assessed the processes which were occurring and their relevance to watershed condition.

They set up twenty permanently marked transects in the Pohangina catchment and established sampling and plot measurement procedures which would permit reassessment every five years. Cuddihy (1977) established 514 permanent reference sample plots at 100m intervals along 132 altitudinal transects. All these studies were made by the Forest Service. Although the S.E. Ruahines act as a water supply area for cities and towns over a wide area, an additional concern is the possibility of large scale erosion causing aggradation of the streams with consequent flooding and damage to highly productive farmland, (Cuddihy 1977). These reports contain lists of species in various areas as well as assessing damage. Nicholls (1970) has also prepared notes to accompany the vegetation map of the Ruahines (Forest Service. MS 6, No.13). (Figure 6.2).

Palaeoecology

Peat bogs on the Mokai Patea in the Western Ruahines were investigated by Moar (1956), he concluded that peat formation had formerly been more active. Later, three sites on the Mokai Patea and two on the Whanahuia range were sampled by Moar (1961). These show a general decline in *Podocarpus* and a rise in *Nothofagus*. Moar associated a change in the *Dacrydioid* curve with changes in the position of the treeline, during the period between the Taupo and Waimihia eruptions. This correlated with *Dacrydium biforme* wood found in the peat and in the soils above indicating the presence of that species 152 metres above its present limit some 200 - 3000 years ago. Pollen preserved in the peat of No Man's Land Bog in the Northern Ruahines (Moar 1967) did not show this feature. All these sites contain tephra deposits which permit correlations between the widely separated sites, and all the sites lie above 1200 metres. In this paper Moar cautioned that with such high altitude sites the interpretation of pollen diagrams may be confused due to the upward drift of pollen from lower altitudes. Several species have lower altitudunal limits in the S.E. Ruahines, (Elder 1965).

Relevance of the present studies

The knowledge of the postglacial period in New Zealand has largely been derived from biostratigraphy, on land the organic material is mostly of plant material. The wide use of radiocarbon dating in both islands plus the use of tephrochronology in the North Island has enabled the information to be referred to a time scale of possible events over the last 14,000 years.

In the North Island comparatively few sites have been investigated and nothing at all is known of the palaeoecology of the S.E. Ruahine Range which is the subject of this study. The problem of erosion has been highlighed by many studies in this area, particularly in the West Tamaki catchment. The pollen diagrams of 3 sites reveal both the re-vegetation of the disturbed ground and the type of forest surrounding the site. Site CML 80/2 records approximately 700 years of plant cover in one area of the West Tamaki valley. Two other sites lie one on each side of a fault line, East and West Ballantrae, and contribute useful information on the movement of this fault in this geologically unstable area, where erosion appears to be closely associated with fault scars.

The dates available indicate a time span from 13,300 ± 200 yrs B.P. to the present. The altitudinal range of the sites is from 81 metres at East Ballantrae to 1050 metres at the Delaware Ridge. This site lies in the sub-alpine scrub of *Olearia colensoi*, that is above the present treeline. The study therefore spans the altitudinal extent of the podocarp-hardwood forest in the region.

The extension of the study into the Kahuterawa valley and the slopes of Mount Ruapehu for pollen rain and soil samples has permitted a new understanding of the ecology of these forests and in particular the life cycle of kamahi, *Weinmannia racemosa*. These studies have particular relevance to the observed state of this species in the West Tamaki valley. Many observers see a link between the browsing of the oppossum, the decline of the kamahi and the acceleration of erosion. Another point of view suggests that the decline is a normal stage in the life cycle of the kamahi, (Strand 1977).

This study has been able to contribute biogeographical evidence to supplement that gained from studies in many other disciplines in the S.E. Ruahines. Such studies may have relevance to other areas with erosion problems.

SUMMARY PART 1.

The theme for this literature review has proceeded from the historical background of Pleistocene geomorphology and climatology in the northern background to New Zealand studies and the part played by biostratigraphy in defining postglacial changes. Pollen analysis has been described as a valuable biostratigraphical method which has greatly enhanced knowledge of postglacial and climatic changes in New Zealand, interpretation being based on knowledge of present climatic regimes and distribution of vegetation. The geology, geomorphology, climate, vegetation and anthropomorphic effects and their inter-relationships as observed in the study area, the S.E. Ruahine Range, completed the theme.

Synopsis

The effects of the Pleistocene climatic changes on the world's topography have been studied using a broad spectrum of techniques ranging from simple observations to computer analyse of complex data. While there is general agreement in the timing of events absolute synchroneity between the two hemispheres is neither expected nor proven.

The mid-oceanic location of New Zealand may have reduced the severity of glacial cold periods but there is abundant evidence of both geomorphological and biological change. In the postglacial period, that is the last 14,000 years, in New Zealand, there is also evidence of climatic change but the 'climatic optimum' and the 'little ice age' so well documented in northern Europe have not yet been substantiated by conclusive evidence in New Zealand.

Palynological techniques are particularly well suited to this aspect of biogeography as they can provide a sequential record of vegetational change which reflects climatic change. The continuing search for and study of sites containing organic material which can be investigated and sometimes dated, is justified in that the information collected can be correlated with other dated sites to build up a more accurate record of past events.

While knowledge of the present is necessary for interpreting the past, knowledge of the past may provide a long term view of climatic and vegetational change which can increase understanding of the present. In the S.E. Ruahines the geology and climate have apparently interacted to produce severe erosion at present, and this may be a threat to productive farmland. The purpose of this study has been to investigate some aspects of the palaeoecology of one area. It is hoped that this knowledge may contribute to a greater understanding of the erosion problem.

PART 2

THE INVESTIGATION

CHAPTER 6

PALAEOPALYNOLOGY

Field work

Five sites were sampled. These were suggested by Dr V.E. Neall and Mr M. Mardon of the Soil Science Department of Massey University. Two of these were originally discovered by Hubbard (1978) and subsequently described by Hubbard and Neall (1980). These are the Delaware Ridge Road site and West Tamaki River site.

All sites were open faced exposed sites. Channel samples were collected by first cleaning the face of the deposit to expose an uncontaminated surface. The profile was marked off in the required intervals and the entire block removed. From within this block a representative sample was removed as a field sample. Precautionary measures were taken to prevent contamination between samples and from any modern material. The Delaware deposit was also sampled by point sampling whereby only the top 1 cm out of a 5 cm block was collected.

All field sites were visited at least twice. This permitted a thorough survey of the vegetation at different times of the year, further study of the geomorphology and of any changes which had occurred, so that a more complete picture of the deposition conditions could be built up.

Laboratory work

A small representative sample was removed from the field sample. Each sample was treated with warm KOH, then HF followed by bleaching, acetolysis and staining with Basic Fuchsin. Details of the preparation appear in Appendix 1. The pollen was then mounted, duplicate slides being prepared. The technically better slide was labelled 1 and used for the first count. An Olympus microscope and high power (x400) were used. Traverses of the slide were made starting at a specified point on the stage micrometer scale and the slide moved up one scale unit after each traverse. After formal counting was completed the slide was then scanned at low power to discover any pollen types missed. A record was kept of grains which would have been identifiable had reference material been available. Preservation of the pollen grains was better at some sites than others, some difficulties were encountered with organic debris that even prolonged bleaching could not remove.

Presentation of data

Pollen diagrams were prepared from the information obtained. The stratigraphy of the profile together with information on dates appears at the left of the diagram. The percentage of each pollen type occurring in the specified pollen sum is then graphed alongside the sample which is indicated by a scale of depth at the far left. Where a marked change in species representation is apparent and proved to be significant when tested by statistical analysis (Mosimann 1965) zones may be indicated.

Validity of the data

The skill of pollen analysis can only be acquired by the actual investigation of sites, this skill had to be attained during the studies for this thesis. The following steps were taken therefore to test and verify the information obtained.

1) Some slides were counted twice.

2) Duplicate slides were counted.

3) Duplicate profiles were sampled.

4) Sampling methods were compared.

5) Repeated counts with different pollen sums were made.

6) Surface samples where collected where relevant.

7) Published literature on pollen morphology of N.Z. Grains was used to supplement the limited reference collection.

8) A visit was made in July 1981 to the Botany Department of D.S.I.R., Lincoln to consult palynologists Dr N.T. Moar and Dr M.S. McGlone. Their advice about re-counting was followed.

9) A subsidary study was designed to obtain knowledge of the pollen rain of North Island podocarp-broadleaf forests because no published information could be found. This study and the results obtained are described in Chapter 7.

10) Statistical analysis was used to determine the significance of observed changes in pollen representation.

Despite all these procedures it has to be admitted that some information has been lost due to the small size of the reference collection, only 125 species. It must be true for example that *Libocedrus* was present at the Delaware sites but could not be identified.

Statistical analysis of data

The method used is that of Mosimann (1965) as illustrated in Moore and Webb (1978. 86). An estimation is made of the true proportion (p) of a pollen type within the pollen sum by the ratio x/n, where x = the number of grains of the pollen type and n = pollen sum. Where n is fairly large, (greater than 150) the confidence interval at the 95% confidence level is calculated thus; the estimated proportion for the pollen grain (p)

$$= \frac{\hat{p} + \left[\frac{(1.96)^2}{2n}\right] \pm 1.96 \ [\hat{p}\ (1 - \hat{p})/n] + [(1.96)^2/4n^2]}{1 + [(1.96)^2/n]}$$

If there is any overlap between confidence intervals then this indicates that $\hat{p}$ could have come from the same population.

Statistical investigation of the validity of the method of pollen analysis used in this thesis

The pollen type used in this example is *N. fusca* type. CML 80/1 sample 0 - 5 cm $\hat{p} = 0.169$ and $n = 320$ (number of woody grains). The estimated proportion for the pollen grain (p) *N. fusca* type

$$= \frac{0.169 + \left[\frac{(3.84)}{640}\right] \pm 1.96 \ [0.169 \ (0.831)/320] + [(3.84)/409600]}{1 + [3.84/320]}$$

and the Confidence Interval = 0.215 - 0.133. at 95% confidence level. For sample 85 - 90 cm where $\hat{p}$ is 0.045 the C.I. = 0.079 - 0.031. These intervals do not overlap so the $\hat{p}$ of each sample must come from a different population, clearly there has been an increase in the pollen of *N. fusca* type deposited at this site over the last 8400 years, which is significant at the 95% level.

For CML 81/6 for *N. fusca* type.

sample 1 cm $\hat{p} = 0.203$ C.I. = 0.251 - 0.162

sample 81 cm $\hat{p} = 0.033$ C.I. = 0.038 - 0.029

It can now be stated that:

1) There is a significant difference in the two populations represented by the pollen in the uppermost and lowest valid samples at both sites.

2) The populations of the uppermost and lowest valid samples from the two profiles, however, are the same since the confidence intervals overlap in both cases.

Therefore it can now be stated that there is no significant difference in the data as sampled from these two profiles at the 95% level of confidence.

Using these calculated intervals as guidelines and inspection of the data as given in Tables 3 and 4, it can be seen that for *N. fusca* type pollen the difference between any adjacent pair of samples within either profile is never more than five percent except for sample CML 81/1 35 cm. Furthermore comparison of samples at the same level of each profile shows that the difference is always less than five percent and in some cases is less than one percent. In pollen grain numbers this is 5 grains or less.

Table 5 gives comparative data from counting 500 grains per slide for the following cases:

1) Counting the same slide twice (at different times).

2) Counting duplicate slides.

3) Counting similar samples from two profiles sampled by different methods

Table 3 Summary of pollen percentages CML 80/1 Delaware Ridge Road

Species	0-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60	-65	-70	-75	-80	-85	-90	-100
Dacrycarpus	1.3	2.6	+	3.0	+	1.9	+		+	1.9	2.0	2.1	2.6	2.9	1.4	2.9	2.9	3.4	5.2
D.cupressinum	21.9	29.2	33.3	28.2	27.2	24.5	22.6	25.8	29.3	19.0	23.5	22.6	25.4	17.9	25.2	17.5	15.3	18.8	7.1
Dacrydioid	6.3	4.1	6.3	5.0	7.8	6.5	2.8	7.3	5.2	6.1	6.8	5.8	5.8	5.2	5.5	4.5	6.4	4.2	1.3
Podocarpus	33.1	30.6	25.1	32.7	33.2	28.8	35.2	39.0	34.2	35.9	35.1	32.3	48.4	33.2	39.9	38.5	40.1	51.4	54.4
N. Fusca Type	16.9	17.9	14.5	16.3	19.1	15.2	19.6	13.2	13.8	14.2	13.9	11.0	13.5	12.7	12.9	10.8	8.6	4.5	4.5
N. menziesii	1.9	1.2	+	+	3.3	1.9	1.4	2.0	1.2	3.6	1.4	1.5	1.2	2.3	+	1.0	1.3	+	1.1
Weinmannia	+	2.0	1.1	3.0	+	3.1	+	+	3.2	+	3.4	1.5	0.9	1.7	2.0	1.6	2.9	2.0	1.9
Ascarina	+		2.3	1.8	1.7	2.5	1.7	3.1	2.6	3.0	1.4	2.1	2.1	6.3	4.0	4.1	1.9	+	+
Leptospermum						2.8	S				+	+	+	+					
Olearia	10.3	7.5	9.1	4.5	4.2	5.6	4.5	3.9	2.9	1.9	1.4	1.2	+	1.4	+	2.9	3.5	1.7	+
Compositae	2.5	2.0	2.0	+		1.2	+	2.0	+	1.1	+	1.8	+	2.6	1.2	3.5	3.2	1.4	2.2
Coprosma	+	+	2.3	1.2	1.4	1.8	1.1	+	1.4	1.1	2.3	2.7	1.2	1.7		3.5	2.6	2.0	2.2
Myrsine	+		+	+	+	+	1.4	+	+	1.4	1.1	4.0	2.1	5.2	4.6	2.6	+	2.3	5.5
Phyllocladus	+	+				+	+	1.1	+	+	+	+	1.2	1.7	1.2	+	1.3	1.1	+
Nestegis			+	+			1.4	1.7	2.0	+	+	1.8	+	1.7	1.4	1.0	1.6	+	1.1
Quintinia			+			+	+			3.0	2.0	5.8	+	3.8	3.5	1.9	2.9	2.3	1.9
Pseudopanax											+		+				1.6	+	+
Pseudowintera		+				+				+				+		+		+	
Tetrad	+	+	+			+		+			+	+	+	+		1.0	1.9	+	
Metrosideros	+	+	+	2.4	+	1.2	+		1.7	2.5	1.4	+	+	+	1.7	+	+		1.7
Muehlenbeckia			+		+		+	+		+									+
Knightia	+																		
Fuchsia				S													+		
Rubus		+	+	+	+	+		+	+	+			+		+	+			+
Malvaceae	+					S	S			+	+	+	+			+	1.0	1.1	+
Coriaria		+	+								+	2.1	+	+			2.9	1.1	2.5
Elaeocarpus	+							+					+						+
Total Woody	320	347	351	339	364	318	358	357	348	363	353	328	356	347	369	310	314	358	364
% / 500 grains																			
% Woody	64.0	69.4	70.2	67.8	72.8	63.6	71.6	71.4	69.6	72.6	70.6	65.6	71.2	69.4	73.8	62.0	62.8	71.6	72.8
% Spores	10.6	10.8	9.4	7.2	6.4	13.0	9.4	9.8	7.8	6.2	8.6	11.0	9.4	9.0	9.0	19.0	16.4	15.0	6.0
% Grass & herbs	23.4	17.0	18.8	22.4	16.4	20.4	16.8	16.4	20.4	19.2	19.0	21.0	17.8	20.4	15.2	16.2	17.6	11.4	[illegible]
% Aquatic														0.2	-	0.2	0.4	0.2	-
% Unidentified	2.0	2.8	1.6	2.6	2.4	3.0	2.2	2.4	2.2	2.0	1.8	1.6	1.6	1.0	2.0	2.6	2.8	1.8	[illegible]

Pollen sum = % Woody from Total count 500 grains

Table 4 Summary of pollen percentages CML 81/6 Delaware Ridge Road

	1 cm	6	11	16	21	26	31	36	41	46	51	56	61	66	71	76	81	86
Dacrycarpus	+		1.8	1.4	+	+	1.3	+	1.0	2.4	2.7	+	2.7	2.1	1.5	1.8	3.0	4.8
D. cupressinum	29.4	28.7	27.8	32.5	34.7	33.2	27.4	32.5	29.7	34.5	30.5	28.5	33.4	29.8	32.8	30.8	32.3	23.2
Dacrydioid	2.5	1.0	3.0	6.6	6.3	5.5	3.1	3.7	2.0	3.1	2.4	2.3	2.1	2.4	2.1	+	1.1	+
Podocarpus	27.9	28.7	36.5	24.7	28.0	27.0	27.0	32.5	36.6	38.1	40.9	42.7	35.5	40.6	38.2	44.8	51.1	42.4
N. Fusca Type	20.3	17.6	18.1	15.0	14.2	14.7	14.8	17.7	14.1	9.2	11.9	12.3	11.2	11.4	9.5	7.9	3.3	10.7
N. menziesii	+	+	+	+	+	+	+	+	+		+		+	+	+	+	+	+
Weinmannia		1.4		1.1	+	+	+	+	+		+	+	+	+				
Ascarina	1.6	2.4		3.4	1.8	3.4	+	1.1	1.4	1.2	+	2.9	1.8	2.1	2.4	1.5	s	1.3
Leptospermum			+		+	+	+					+	+	+				
Olearia	11.1	8.7	4.8	6.9	3.1	5.2	3.4	3.4	2.9	1.8	1.2	1.6	2.7	1.5	+	1.2	1.1	2.3
Compositae	+	1.0	+	+	1.2	1.2	+	1.4	1.6	+	1.2	+	1.2	1.5	+	+	1.3	1.9
Coprosma	2.5	1.0	+	+	+	1.2	1.8	+	+	+	+	+	+	+	1.5	+	+	+
Myrsine	1.6	1.7	+		3.8	1.8	5.0	2.6	1.6	1.5	1.5	1.6	2.4	1.8	3.6	2.4	1.7	4.9
Phyllocladus		+	+	+	+	+	+	+	1.4	+		1.0	+	+		+	+	+
Nestegis	+		+		+	+	2.5	+	1.4	2.1	+	+		+	+		+	+
Quintinia									1.4	+	+	+	+	1.5	1.2	+	+	+
Pseudopanax	+	+			+		+	+	1.0	+		+		+	+		+	+
Pseudowintera								+	s		0.3					+	s	+
Tetrad			+	+		+	+	+	s	+	+	+	+	+	+	+		
Metrosideros	+	2.8	1.5		+	+	1.3	+	1.6	+	+	+	+	+	+	+	+	[illegible]
Muehlenbeckia		1.0					+	+	1.0			+	+	+			+	+
Knightia	+		+	1.1	+	+					+					+		
Fuchsia		s							s									
Rubus		+	+		+	+	1.3	+		+	+	+	+					+
Malvaceae		+			s	+	s			s		s	s	+	+	+	+	2.0
Coriaria			1.2	+	+		+	+	+	+			+	+				
Elaeocarpus				+	+	+	+	+	+	+	+	+				+		+
Total Woody	316	289	331	350	320	325	317	351	306	328	328	309	338	342	338	328	[illegible]	[illegible]
% Grains																		
% Woody	63.2	57.8	66.2	70.0	64.0	65.0	63.4	70.2	61.2	65.6	65.6	61.8	67.6	68.4	67.6	65.6	72.4	[illegible]
% Spores	8.0	11.4	4.0	10.4	9.8	12.0	11.6	12.0	10.6	9.6	8.8	9.0	11.8	10.8	12.6	12.8	[illegible]	[illegible]
%Grass & herbs	27.8	28.8	28.4	19.2	25.2	21.8	23.2	16.6	26.6	23.8	24.4	27.8	19.2	18.8	18.4	19.8	[illegible]	23.4
% Aquatic											0.2							
% Unidentified	1.0	2.0	1.4	0.4	1.0	1.2	1.8	1.2	1.6	1.0	1.0	1.4	1.4	2.0	1.4	1.8	[illegible]	[illegible]

Pollen sum = % Woody of total count 500 grains.

Table 5 Comparison of pollen grain counts - Total count 500 grains

[a] Same slide twice

Species	a	b	c	d	e	f	g	h	i	j	k	l	m	n
CML 81/5	35	3	18	2	2	7	3	10	39	2	14	342	4	3
Sample 5-10 cm Slide 1	26	4	21	2	3	9	1	16	34	2	22	336	5	1
[b] Duplicate slides														
81/4 General sample														
Slide 1	1	30	1	21	8	15	1	32	124	3	6	215	1	4
Slide 2	2	27	0	24	11	13	2	30	132	3	4	229	0	5
[c] Two sampling methods														
80/1 Sample 10-15 cm	2	117	22	3	20	13	6	46	51	3	4	8	32	8
81/6 Sample 15-16 cm	5	114	23	2	25	12	2	48	53	2	4	12	24	3

Discussion

It is considered that this investigation indicates that the methods used for the collection, processing and counting of pollen as used in this thesis produce results which are acceptable at the 95 percent confidence level and therefore provide data which is a valid base for the interpretation of changes in the percentages of pollen deposited. This statistical approach was used in testing the validity of all relevant changes in pollen curves at all the fossil sites investigated here. In the study described in Chapter 7 it was considered that the data base was inadequate for such an analysis. In considering the Delaware site, as CML 80/1 was the first experience of counting fossil pollen it was decided to use CML 81/6 for analysis and interpretation as this was counted later.

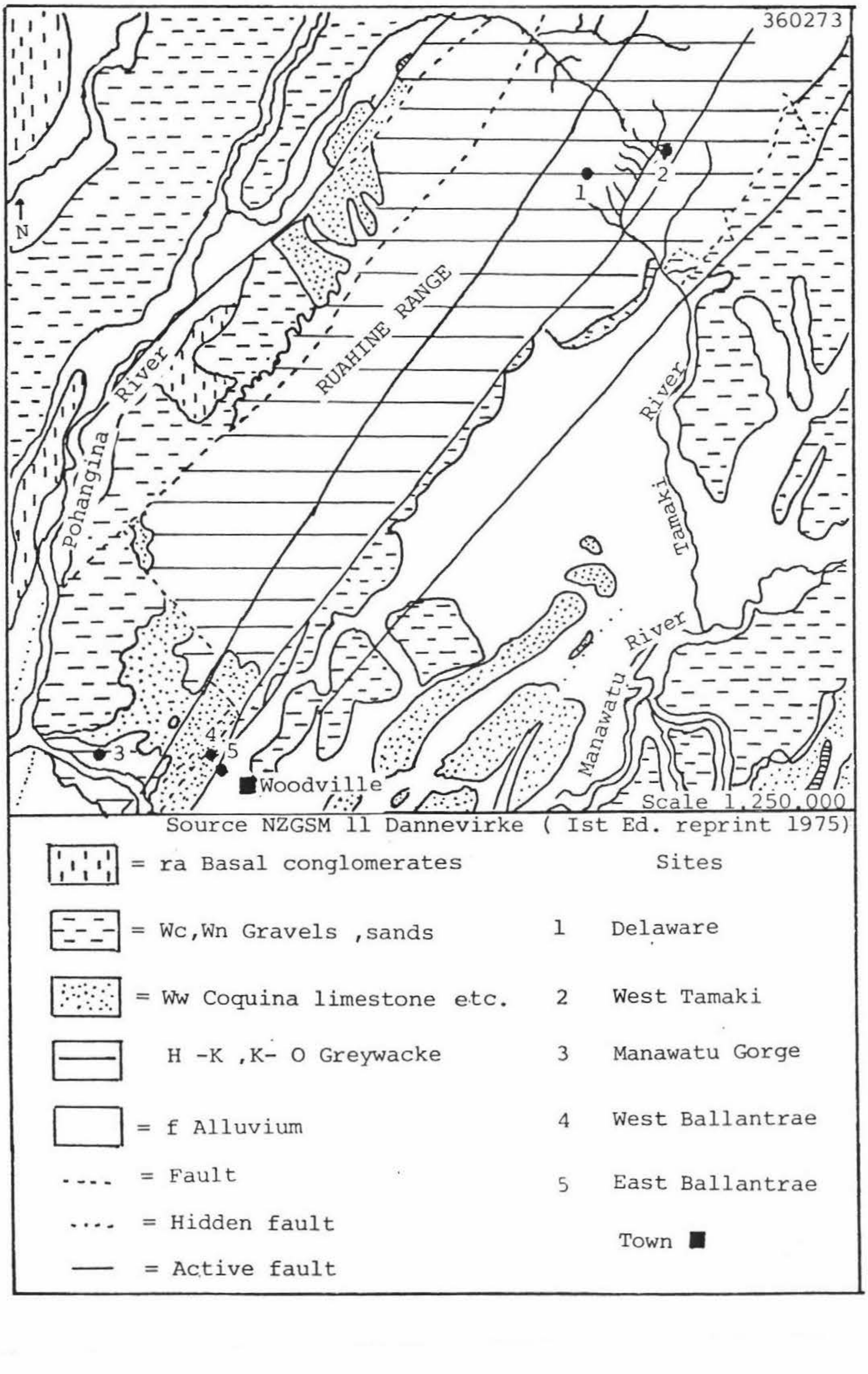
The location of the sites in relation to the geology of the S.E. Ruahine Range is shown in Figure 6.1, the vegetation of the Southern Ruahines in Figure 6.2 and the topography of the fossil pollen sites in Figure 6.3

FOSSIL POLLEN SITES

CML 80/1 Delaware Ridge Road

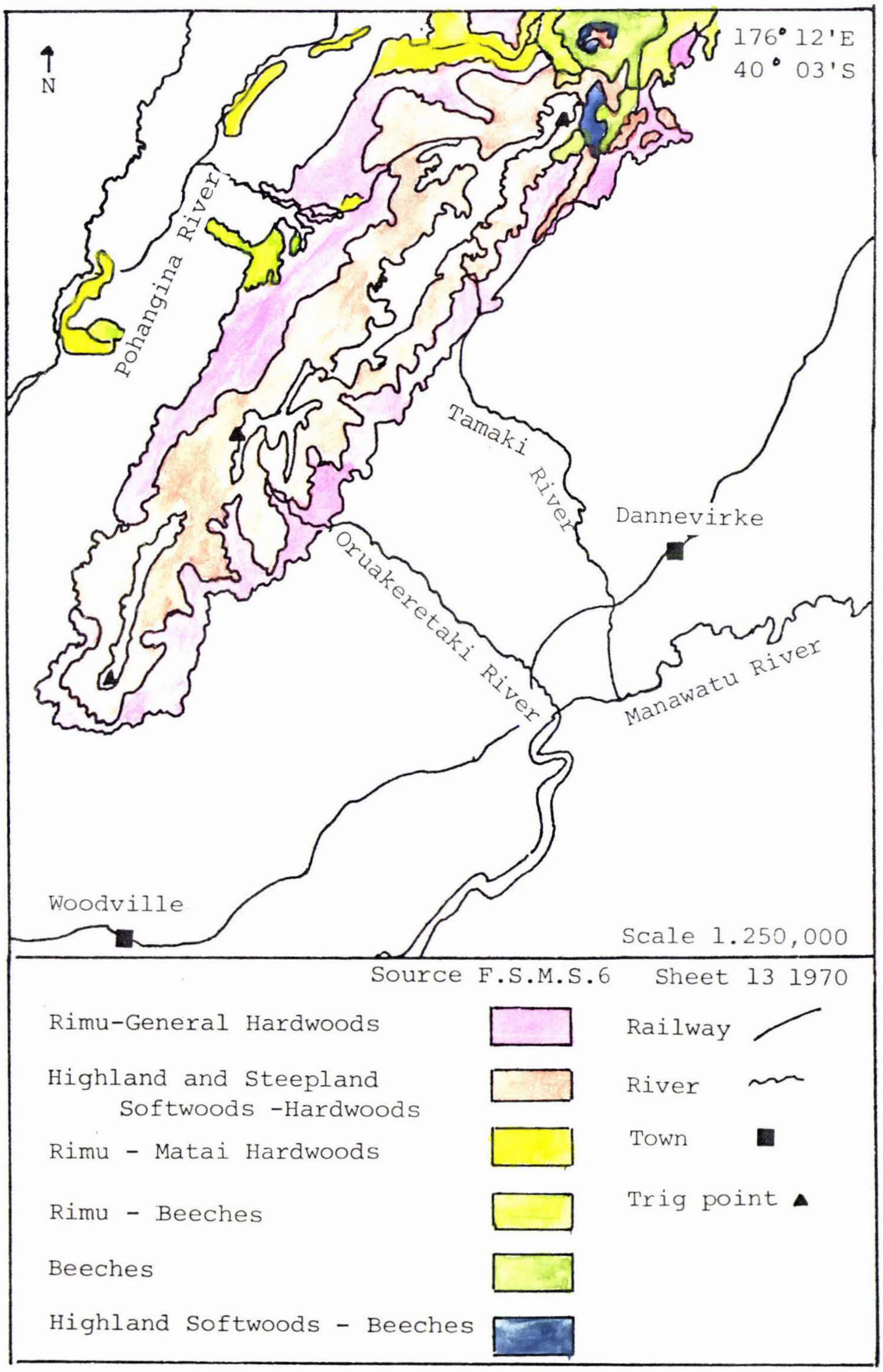
Altitude 1050 metres NZMS 18, Sheet 11 Dannevirke 348266. Nineteen channel samples of 5 cm were collected, the water table was considered to have caused some contamination and the lowest sample 90 - 100 cm must be treated as invalid. The lowest two samples contained abundant macrofossils. The profile consists of Takapari peaty loam and was described by Hubbard and Neall (1980 591 Figure 3).

Figure 6.1 Location of sites and geology of the S.E.Ruahine Range.



Source NZGSM 11 Dannevirke (Ist Ed. reprint 1975)

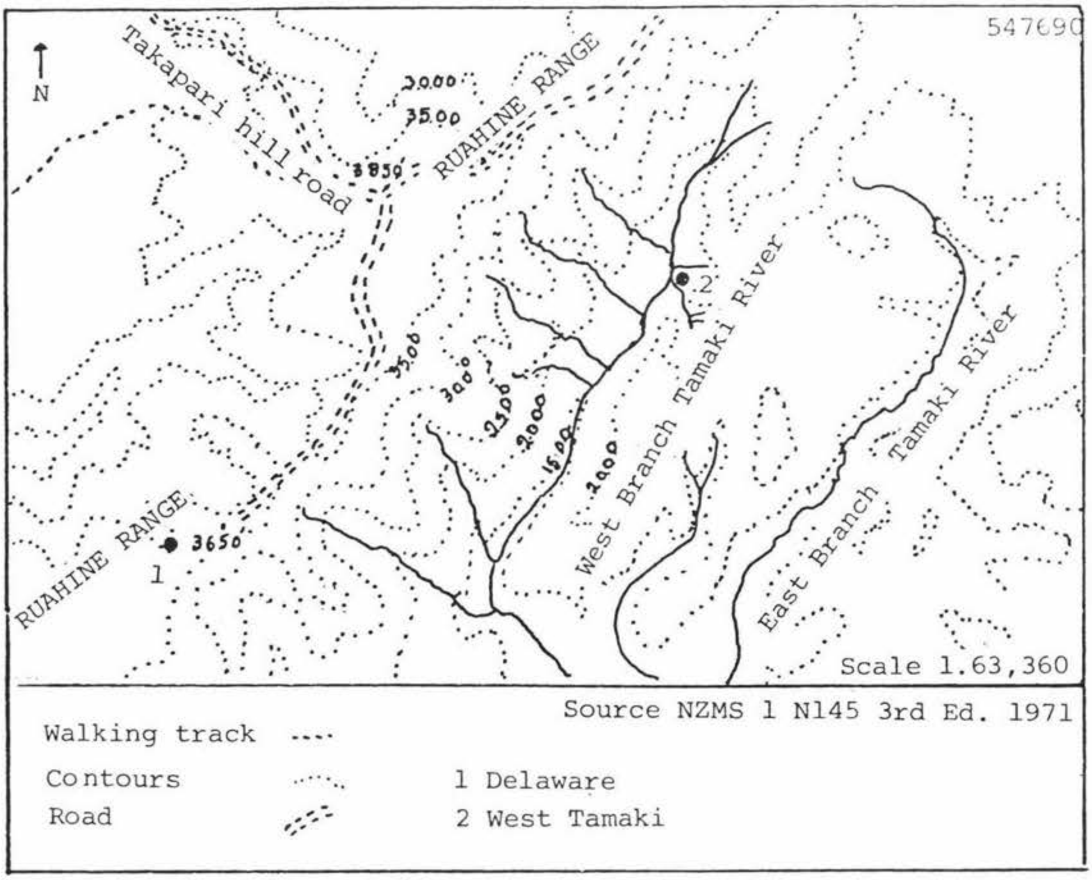
Figure 6.2 The Vegetation of the Southern Ruahines



Source F.S.M.S.6 Sheet 13 1970

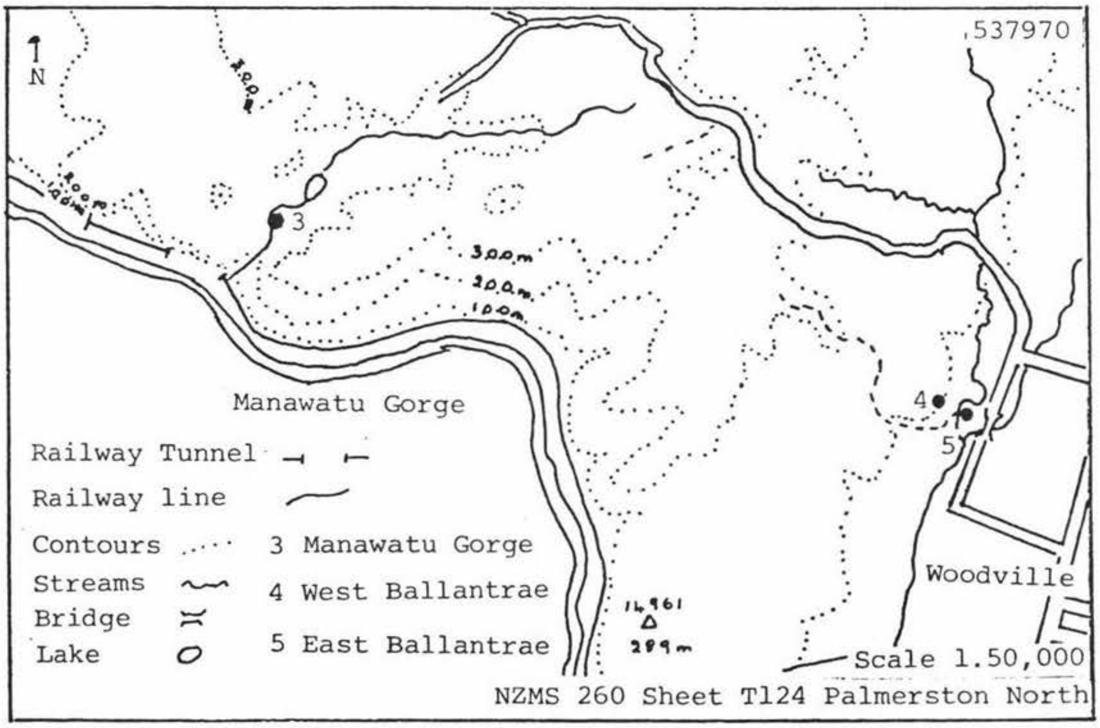
Figure 6.3 The topography of the Fossil pollen sites.

a Delaware ,West Tamaki



Source NZMS 1 N145 3rd Ed. 1971

b (Bolton's Farm)Manawatu Gorge West and East Ballantrae.



NZMS 260 Sheet T124 Palmerston North

Table 6 Profile description of Delaware Ridge site (after Hubbard and Neall [1980].)

Depth	Zone	Description
0 - 16 cm	Ha 1	Dark reddish brown peaty loam, slightly sticky slightly plastic, moderately developed fine crumbs, abundant fine - coarse roots.
16 - 55 cm	Ha 2	Dark brown slightly peaty loam, slightly plastic moderately developed medium blocky, many fine medium roots.
55 cm	Marker lapili	Taupo pumice 1891 ± 17 years B.P.
55 - 87 cm	Ha 3	Dark brown, slightly peaty loam, sticky plastic with greasy feel; moderately developed coarse blocky.
87 cm	Waimihia formation	Pocketing. 3440 ± 70 years B.P.
87 - 107 cm	Ha 4	Dark brown peaty loam, sticky plastic with greasy feel, weakly developed medium blocky.
110 cm	R	On weathering grewacke.

Note: At CML 80/1 and CML 81/6 Taupo pumice at 54.5 - 55.5 cm.
The Waimihia formation not located.

Wood lying on top of the greywacke base was identified by Dr R.N. Patel of the Botany Division, D.S.I.R. Lincoln as Compositae and has been dated by the Radio Carbon Laboratory of Lower Hutt at 8400 ± 130 yrs B.P. NZ5274B. The site is a very exposed broad plateau subject to high winds and fog shrouded on many days of the year. The present vegetation is almost totally dominated by *Olearia colensoi*, leatherwood scrub, which extends over many hectares with only small areas of tussock lying in depressions. The site has been exposed by the Forest Service cutting a road through what was originally a blanket bog. Dr E. Campbell of the Botany Department, Massey University has identified the plant material found at the base of the profile. They are a leaf of *Sphagnum*, a shoot of *Polystichum juniperus*, a root of *Baumea* species and abundant roots of probably, tussock. These identifications and the presence of *Myriophyllum* in lower samples indicate that a bog probably formed in a low depression in the greywacke base sometime before 8400 yrs B.P. The Compositae wood is in all probabilty *O. colensoi* and this would have invaded the bog after it was colonised by tussock. Deposition was slow, since only 23 cm of organic loam lie between the greywacke base and the position of the Waimihia Formation dated at 3440 ± 70 yrs B.P. a rate of only 0.05 mm/yr.

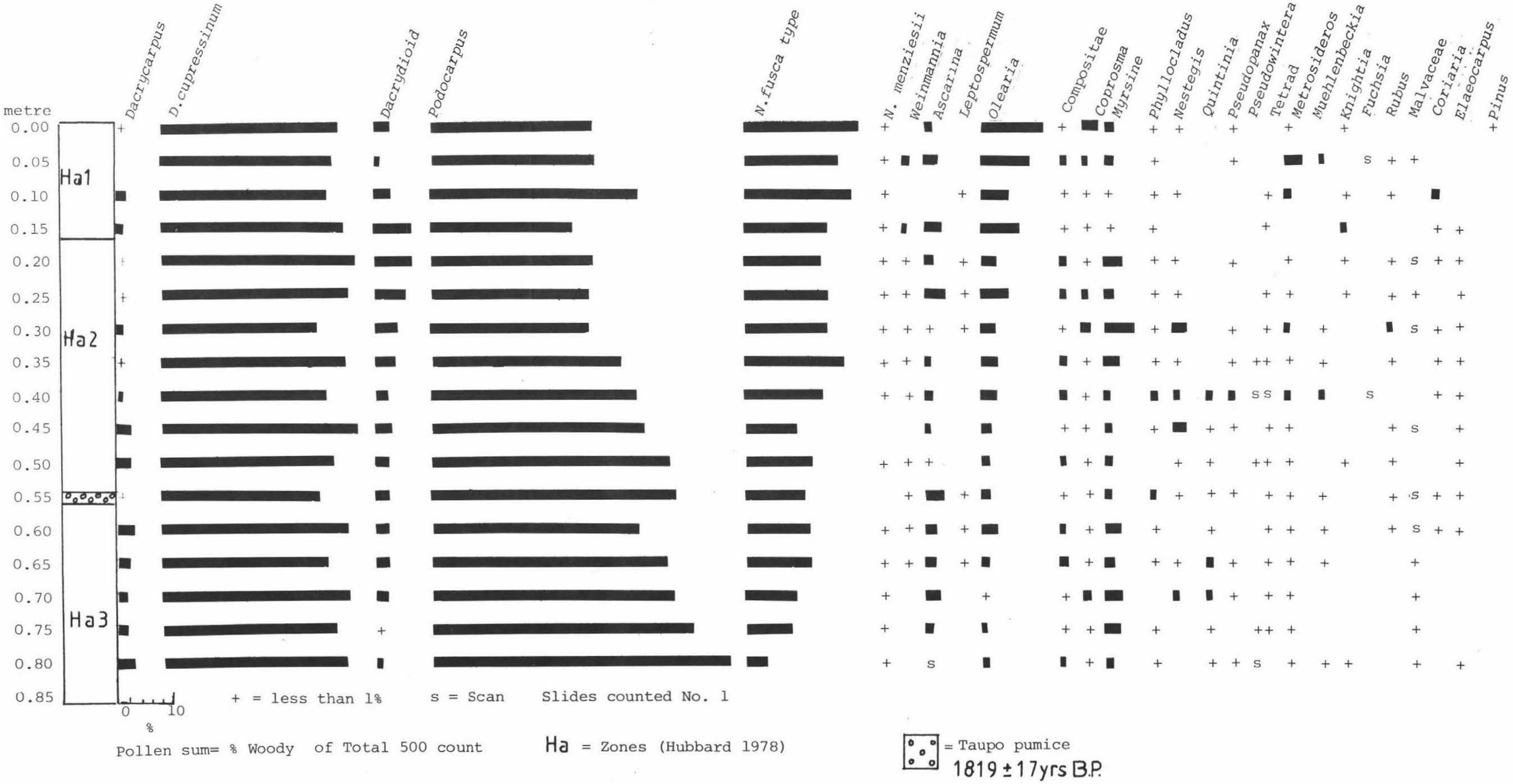
The change in drainage caused by the cutting of the road may mean that surface vegetation is very different from that formerly present on the site. The metre high *O. colensoi* covers a mat of moss, probably a species of *Rhacomitrium*. There are some clumps of *Chionochloa pallens*, an occasional *Astelia trinerva*, scattered small herbs include a species of *Epilobium*, *Pratia macrodon*, a species of *Hydrocotyle* and two small grass species. *Carex* is present at the base of the profile in the water logged area.

CML 81/6 Delaware Ridge Road

This site is only 10 cm away from CML 80/1 and was sampled in May 1981, eighteen 1 cm samples were collected. The water table was much higher and the lowest sample was at 85 cm. Following advice from Dr Moar the pollen sum was recalculated for both sites as a percentage woody out of a total of 500 grains rather than using the total count ex spores, Figures 6.4 and 6.5.

Figure 6.4 Pollen Diagram CML 80 /1 Delaware Ridge Road.

Figure 6.5 Pollen Diagram CML 81/6 Delaware Ridge Road.



+ = less than 1%   s = Scan   Slides counted No. 1

Pollen sum= % Woody of Total 500 count   Ha = Zones (Hubbard 1978)

= Taupo pumice
1819 ± 17yrs B.P.

Comparison of duplicate sampling of the same profile

which were 10cm apart

There are no gross differences in the two pollen diagrams for these sites but the point samples show a greater variation than do the channel samples, which in fact are average samples so this result is to be expected. Channel sampling does appear to pick up greater percentages of the minor species. All species are common to both profiles and for the major species *Dacrycarpus, D. cupressinum*. Dacrydioid (probably *D. biforme*), *Podocarpus (P. spicatus, P. ferrugineus, P. totara* and non-specific *Podocarpus) Ascarina* and *Olearia* the percentages and the trends shown are comparable. It was concluded that there was no significant difference between the sampling methods and that either method gave a fair representation of the pollen types preserved at the site.

Analysis of data CML 81/6 Delware Ridge Road

Table 7 Confidence intervals for selected species CML 81/6

Species	Sample	$\hat{p}$	Confidence interval
N. fusca type	1 cm	0.203	0.251 - 0.162
	46 cm	0.092	0.129 - 0.056
	81 cm	0.033	0.038 - 0.029
Podocarpus	1 cm	0.279	0.331 - 0.233
	46 cm	0.381	0.439 - 0.327
	81 cm	0.511	0.562 - 0.460
D. cupressinum	1 cm	0.294	0.346 - 0.247
	46 cm	0.345	0.398 - 0.305
	81 cm	0.323	0.373 - 0.281
Dacrydioid	16 cm	0.066	0.098 - 0.034
O. colensoi	1 cm	0.111	0.149 - 0.082
Ascarina [a]	66 cm	0.021	0.088 - 0.037
CML 80/1	65-70cm	0.063	

[a] Average sample from both profiles

Fig 6.4 & 6.5

The most significant changes that occur are the slow rise of *Nothofagus* and the slow decline of *Podocarpus* over the entire profile. Within the rise of beech there are at least three distinct populations as can be seen by the absence of overlap in the C.I. There is also a change of population at the 46 cm level in *Podocarpus* but it is not so marked. Throughout the profile at both sites *P. ferrugineus* is present in a greater proportion than either *P. spicatus* or *P. totara* but as the proportion of grains identified only as *Podocarpus* is more than fifty percent of the total podocarp pollen present it was decided that any comment would not be valid. *D. cupressinum*, however, remains very constant and all the calculated intervals overlap.

From the pollen diagram Figure 6.5 it appears that there is a decline in *N. fusca* type over the 31 - 16 cm levels accompanied by a rise in Dacrydioid, this is not significant for beech but is a significant change in Dacrydioid. *Olearia colensoi* increases tenfold over the profile but there is a significant change in the two top samples to a larger population. At the 10 cm level Dacrydioid decreases and returns to its pre 31 cm population.

The only other change of note is in the behaviour of the *Ascarina* curve. Here the two profiles do differ and this may be due to a very localised concentration. Although not shown in CML 81/6 at the 65 - 75 cm level, in CML 80/1 there is a significant increase and even when the two samples are averaged the difference is still significant.

Interpretation

In interpreting these pollen profiles at this alpine site it is essential to note Moar's comment (1967) that pollen carried by updraft can confuse the pollen spectra and it is not necessary to conclude that all species recorded here actually grew at the site. It is perhaps more reasonable to regard these findings as giving an overview of the regional pollen over the last 8400 years. The evidence to support this statement can be seen in Table 8, a summary of four moss polsters which have acted as pollen traps for an unspecified period of time. The variation in these is a clear indication of the need for multiple sampling when using moss polsters. They do indicate, however, that despite the extensive areas of *O. colensoi* only 7.5 percent of this pollen is collected which must indicate under representation. As can be seen from Figure 6.2 beech does not now occur near to the site and the 44.4 percent of *Podocarpus* must come from the lower slopes of the range and is therefore regional pollen.

The changes in the pollen curves do not indicate any major changes in climate. The rise of beech is, according to Moar (1967) an indication of a widespread increase of *Nothofagus* at the expense of *Podocarpus*. There is some indication of a less frost and drought free climate between 3000 and 2000 years ago in the increase in *Ascarina* and this agrees with the findings of McGlone and Moar (1977).

If it can be assumed that deposition has been constant since the Taupo eruption of ca 1819, then the rate has been 0.3 mm per year or 166 years for each 5 cm sample. On this basis about 1494 years ago there was an increase in the Dacrydioid pollen, this is probably *D. biforme* which occurs as a treeline species, but only in patches in the Southern Ruahines (Elder 1965). Moar (1961) also found an increase of Dacrydioid but on a much larger scale and occurring between 2000 and 3000 years ago. The decline

Table 8 Summary of surface samples Delaware Ridge Road sites

Data from number of pollen grains from count of 500

Collected	December 1980		May 1981		Average	
Species	CML 80/1	Downwind	CML/81/6	Downwind	Number	% Woody
Dacrycarpus	3	10	3	2	5	3
D. cupressinum	13	9	51	15	22	14
Dacrydioid	12	7	4		6	4
Podocarpus	63	119	68	32	71	44
N. fusca type	20	11	25	20	19	12
N. menziesii	1	2	2	1	2	1
Weinmannia	3	2	1	3	2	1
Ascarina			2		+	+
Leptospermum					0	0
Olearia	15	10	15	6	12	8
Compositae	6	5		4	4	3
Coprosma	4	1	3	6	4	3
Myrsine	10		5	4	5	3
Phyllocladus	2	2	2		2	1
Nestegis	4				1	+
Quintinia					0	0
Pseudopanax				1	+	+
Pseudowintera		1			+	+
Tetrad					0	0
Metrosideros	7		1		2	1
Muehlenbeckia	3	2	1		2	1
Knightia					0	0
Fuchsia					0	0
Rubus			1	1	+	+
Malvaceae					0	0
Coriaria	2		2		1	+
Elaeocarpus					0	0
% 500 grains						
Woody	34.8	36.4	37.6	19.0	32	
Spores	12.2	17.6	16.0	8.0	14	
Gramineae	35.8	36.4	28.8	62.4	41	
Herbs	13.8	5.4	2.6	4.0	7	
Aquatic						
Pinus	1.4	2.4	12.4	3.8	5	
Unidentified	2.1	1.8	2.6	2.8	3	

of Dacrydioid at the 10 cm level coinciding with the rise in *Olearia* suggests an adjustment of the treeline. There are indications on the pollen curves of an accompanying increase in rimu and decrease in *Podocarpus* and beech, but none of these are large enough to be significant at the 95 percent confidence level. They may however indicate that the nature of the change was to an improvement in conditions which permitted an upward movement of the *D. biforme* treeline. This was later followed by a downward movement and re-invasion of the area by *O. colensoi*. As one descends from the crest of the ridge dead branches lie bleached by the sun, Elder has described this as a 'boneyard' an apt description, of dead *D. biforme* trees (Elder 1965). Wardle and Campbell (1976) found that the related species *D. bidwillii* was notably frost tolerant more so than either *Nothofagus solandri var cliffortioides* or *N. solandri,* if this applies to *D. biforme* as well it would account for its increase over *Nothofagus* at the treeline.

Discussion

It was not considered that any of these changes were of a sufficient scale to warrant the demarcation of any zones on the pollen diagrams. Generally investigation of this site has added further support to the studies by Dr Moar of the Northern and Western Ruahine bogs. The findings are also similar to those of Dodson (1978) in N.E. Nelson. The tentative support of an *Ascarina* increase between the two eruptions also agrees with McGlone and Moar (1977).

CML 80/2 West Tamaki River

Altitude 500 metres. NSMS 18. Sheet 11 268353. This site lies near the mouth of the only catchment basin on the eastern side of the asymetrical faultline valley of the West Branch of the Tamaki River. Deposition of almost three metres of organic silts occurred as a swamp developed following the damming of the valley stream by a large deposit of gravel. Hubbard (1978) and Hubbard and Neall (1980) attribute this to the formation of a very large alluvial fan, following an erosional event, in the Whiteywood Creek on the western side of the valley. This creek lies some 100 metres or so to the north and round a bend in the valley. To have dammed the eastern stream it would also have had to fill the main channel downstream of Whiteywood Creek. Examination of the deposit shows that some of it is more angular than would be expected from entirely fluvial deposition but time did not permit further study. The hillsides of the West Tamaki are marked by erosional scars, the wide river bed is full of gravel of all grades and the channel is braided, all signs of recent erosion (Cunningham 1962).

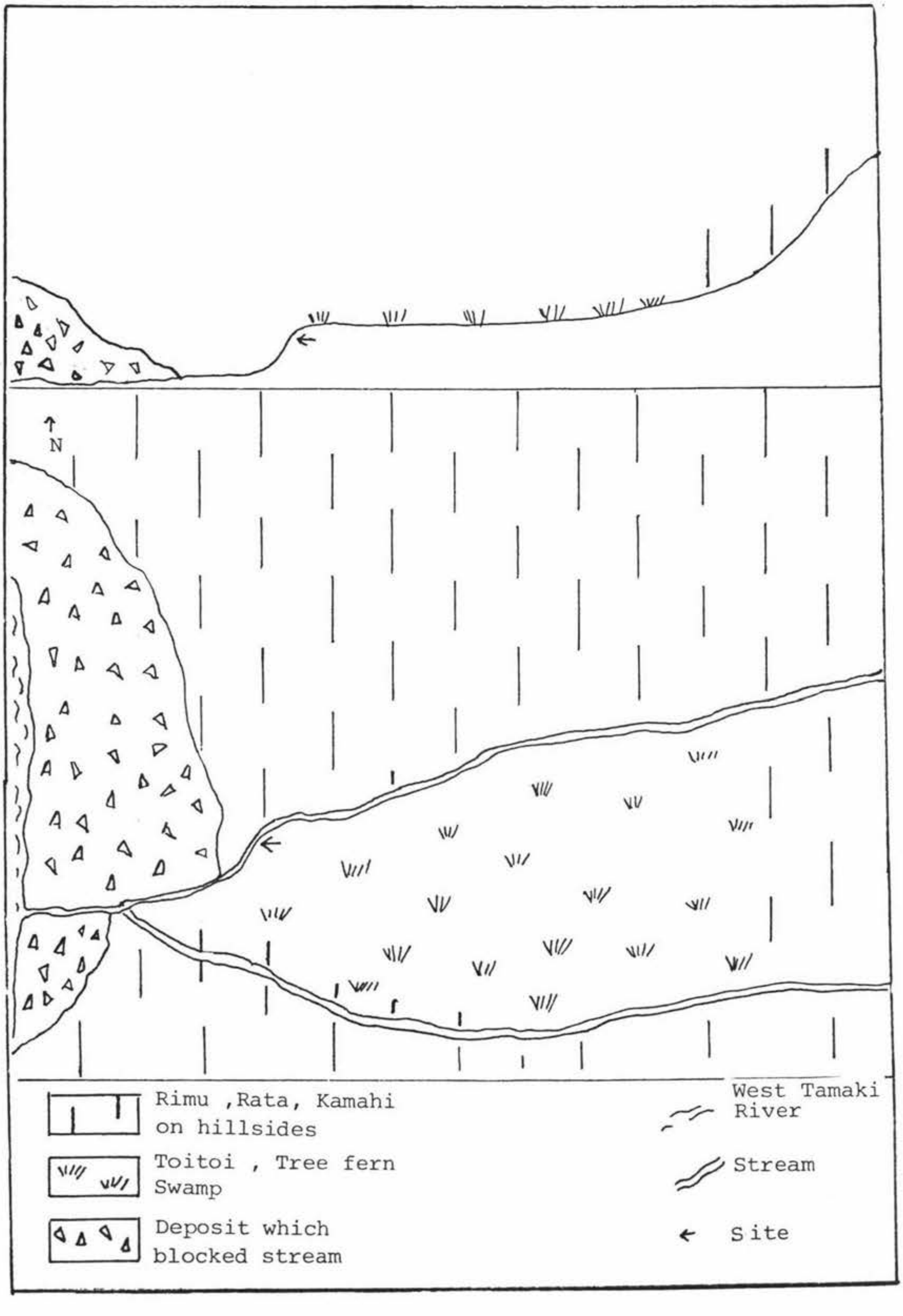
The infilling of the eastern valley by the swamp has caused a division of the stream into two minor tributaries which rejoin just prior to entering the main river. The profile has been exposed by the more northerly of these tributaries cutting a new course through the swamp. The base of the Whiteywood fan is older than 12,150 ± 150 yrs B.P. (Hubbard and Neall 1980, 588). The base of the profile has been dated at 770 ± 60 years B.P. (NZ 4547) from wood of *Pittosporum* species, identified by Dr R.N. Patel. Although the deposit reaches to the present surface it cannot be assumed that it represents the immediate past because a time period, possibly of the order of tens of years, must be allowed for the downcutting by the stream.

It is possible that the black organic silt at the base of the profile represents the original bog area formed by the damming of the stream when the deposit blocked the valley. It is considered that above 2.45 cm accumulation was more rapid due to the deposition of fine material and impeded drainage. Periods of faster deposition as shown by the sandy layers may have occurred during exceptional storms. The occurrence of these is well documented in the literature. Hubbard and Neall (1980), Grant (1981), Marden (1981). An increase in erosion rates for this valley has also been recorded by Stephens (1981). The large quantity of organic debris and corraded grains found in some samples are thought to be due to increased surface run-off at these times, which mobilised pollen lying on the soil surface.

The geology of the area is shown in Figure 6.1 (following page 41 Marden (1981) considered that the geology of the area and the climate are the basic causes of the erosion which is so evident in this valley and that all forms of slope failure have been found to be associated with faults. The vegetation of the valley is classified as rimu - general hardwoods by the Forest Service, Figure 6.2 (following page 42). The topographical map from which Figure 6.3 was drawn, NZMS 1.N145 does not show any streams on the eastern side of the valley. Those shown in Figure 6.3 (following page 43 were copied from Hubbard and Neall (1980 589, Figure 1). The profile and plan of the site are shown in Figure 6.6.

The present swamp is covered with *Cortaderia toetoe* and *Cyathea*. Some *Griselinia* trees are in poor condition and may be old or browsed and producing second growth. *Pseudowintera colorata*

Figure 6.6 Profile and plan of site CML 80/2 West Tamaki River.



trees about 3 metres high edge the swamp and may have established there since the drainage was improved by the downcutting of the stream. Kamahi - rimu forest covers the hillside. *Weinmannia racemosa*, Kamahi close to the site are only of pole size but the distant hills carry the gaunt dead limbs of older dead or dying Kamahi. Although there are dead *D. cupressinum* close to the site these have been undermined by the stream, others are in eminent danger of this also. On the hillside itself the rimu are in good health with large rounded crowns. A large *Podocarpus totara* was seen and both seedling and sapling *P. totara* occur. Young trees of *Knightia excelsa, Pseudowintera colorata, Carpodetus serratus, Hedycarya arborea, Hoheria* and *Pennantia corymbosa* (still with Juvenile foliage) are present. Saplings of most of these species were also seen. *Metrosideros diffusa* festoons the trees and there is an occasional *Lycopodium*. The forest floor is fairly bare but the following ferns were collected. *Pteris macilenta, Hypolepis tenuifolia, Rumohra adiantiformis*. *Urtica* species was abundant around the site itself but of small size. One large dead rata was seen but Strand (1977) observes that many large old rata are dead or dying. No signs of alluviation as described by Grant (1981) and as observed further down the valley were seen at this site.

Analysis of surface samples

Two moss polsters were collected, one from very close to the sampling site and the other from the forest on the hillside. Table 9 contains a summary of the data from these two samples, an average of the two samples and the uppermost sample from the fossil site. The data are derived from two different pollen sums and in the case of the fossil sample duplicate slides were counted. Table 10 contains the confidence intervals for some selected species taken from Table 9.

Table 9 Summary of pollen rain and uppermost sample
CML 8·0/2 West Tamaki River

	% Total Count 500			Slide 1	% Woody of 500			Slide 2
Species	Hill	Site	Ave	Sample 1	Hill	Site	Ave	Sample 1
D.cupressinum	13	7,2	10.1	4.0	29.3	27.9	28.6	14.8
Dacrydioid	1.6			0.2	3.6			
Podocarpus	6.0	1.6	3.8	1.2	10.4	3.6	7.0	2.7
N. fusca type	2.4	0.8	1.6	1.4	5.4	3.1	4.3	4.6
N. menziesii				0.2				1.9
Metrosideros	1.0	3.2	2.1	3.0	2.3	12.4	7.4	8.3
Weinmannia	13.0	8.2	10.6	12.4	29.3	31.7	30.5	39.8
Ascarina				0.2				
Leptospermum	0.2	1.4	0.8		0.5	5.4	3.0	2.9
Compositae	1.0	0.8	0.9	0.8	2.3	3.1	2.7	2.7
Coprosma	1.4	0.4	0.9		3.2	1.6	2.4	
Myrsine	0.4			0.2	0.9			3.7
Nestegis		0.6				2.3		0.9
Fuchsia		0.2				0.8		
Hedycarya	2.2	0.2	1.2	0.4	5.0	0.5	2.8	
Pseudowintera	0.2	0.2	0.2		0.5	0.5	0.5	
Quintinia	0.2				0.5			
Tetrad	0.2				0.5			
Rubus				0.2				
Meuhlenbeckia	0.2			0.2	0.5			
Knightia		0.4				1.6		0.9
Elaeocarpus	0.4	0.6	0.5		0.9	2.3	1.6	0.9
Pseudopanax		0.6				2.3		2.7
Monocat	0.4	1.0	0.7		0.9			
Astelia	0.4				0.9			2.7
Other herbs	1.8	0.8	1.3		4.0			
Cyperaceae	4.2	3.4	3.8	5.4				
Gramineae	15.6	20.2	17.9	12.8				
C.smithii type	16.8	27.8	22.3	12.2				
Dicksonia	0.4							
Monolete	11.6	19.2	15.4	31.4				
Lycopodiaceae	0.6	0.4	0.5	0.4				
Pinus	0.4	0.4	0.4	0.4				S
Total Woody	44.4	25.8	35.1	35.0				36.0
Total Spores	29.4	47.4	28.4	44.6				60.0
Total G & H	22.6	26.2	24.4	19.0				4.0
Unidentified	3.2	0.2		0.8				

Table 10 Confidence intervals for selected species from two surface samples and the uppermost fossil pollen sample from CML 80/2 at 95% confidence level

Species	Average sample count 500 $\hat{p}$	Confidence interval	Fossil sample count 500 $\hat{p}$
Gramineae	0.179	0.215 - 0.148	0.128
Cyathea smithii type	0.223	0.263 - 0.187	0.122
Monolete	0.154	0.186 - 0.122	0.314
	% woody		% woody
D. cupressinum	0.286	0.357 - 0.234	0.148
Podocarpus	0.07	0.118 - 0.041	0.027
Weinmannia	0.305	0.377 - 0.242	0.398

Inspection of these two tables reveals the following facts:

1) There is a significant difference in the percentage of *Cyathea smithii* type spores between the hill and the site samples.

2) The hill samples have a greater percentage of woody species than the site sample and the reverse is the case for the percentage of spores.

3) There is a significant difference for Gramineae pollen *Cyathea* and Monolete spores between the average surface sample and the uppermost sample from the fossil site, on a count of 500 grains.

4) There is a markedly significant difference for *D. cupressinum* and a significant difference for *Podocarpus* between the average surface sample and the fossil sample for the percentage woody count.

5) Reference to Figure 6.8 shows that the percentage of *Weinmannia* is greater in the 0 - 10 cm sample than in the 10 - 20 cm sample. The confidence interval for the latter where $\hat{p} = 0.356$ is 0.413 - 0.31 and the two samples therefore come from the same population. There is an overlap here with the average surface sample where $\hat{p} = 0.305$ and the C.I. is 0.377 - 0.242. It can therefore be stated that the population of *W. racemosa* contributing to the modern pollen rain is the same as that for the upper 20 cm of the profile.

It is obvious from the tables that the pollen spectra at this site will contain both a forest element and a swamp element. Averaging the two surface samples therefore gave a closer analogy with the fossil pollen. The significant differences between some pollen and spore types of the modern rain and the upper sample of the fossil site confirms the statement made earlier of a break in time required for the downcutting of the stream but only of the order of tens of years.

Analysis of data

Twentysix channel samples of 10 cm were collected. The data has been presented in three pollen diagrams to extract the maximum information. In Figure 6.7 the pollen sum is the total count of 500 grains. The swamp element represented by Cyperaceae, Gramineae and *Cyathea smithii* type dominates the lower 1.6 metres of the profile. The podocarp - broadleaf forest species show continuous fluctuation but there is also a significant decline in both *D. cupressinum* and *Metrosideros* over the period of the profile. The change in *Podocarpus* is not significant.

Table 11 Confidence intervals for selected species CML 80/2 West Tamaki

Species	Sample	$\hat{p}$	Confidence Interval
D. cupressinum	0 - 10 cm	0.072	0.108 - 0.048
"	250 - 260 cm	0.270	0.333 - 0.215
Metrosideros	0 - 10 cm	0.054	0.087 - 0.033
"	250 - 260 cm	0.131	0.183 - 0.092
Podocarpus	0 - 10 cm	0.022	0.047 - 0.01
"	250 - 260	0.094	0.141 - 0.017

Figure 6.7 Pollen diagram CML 80/2 West Tamaki River (Total count)
a Pollen sum = Total count 500 less spores.

continued overpage

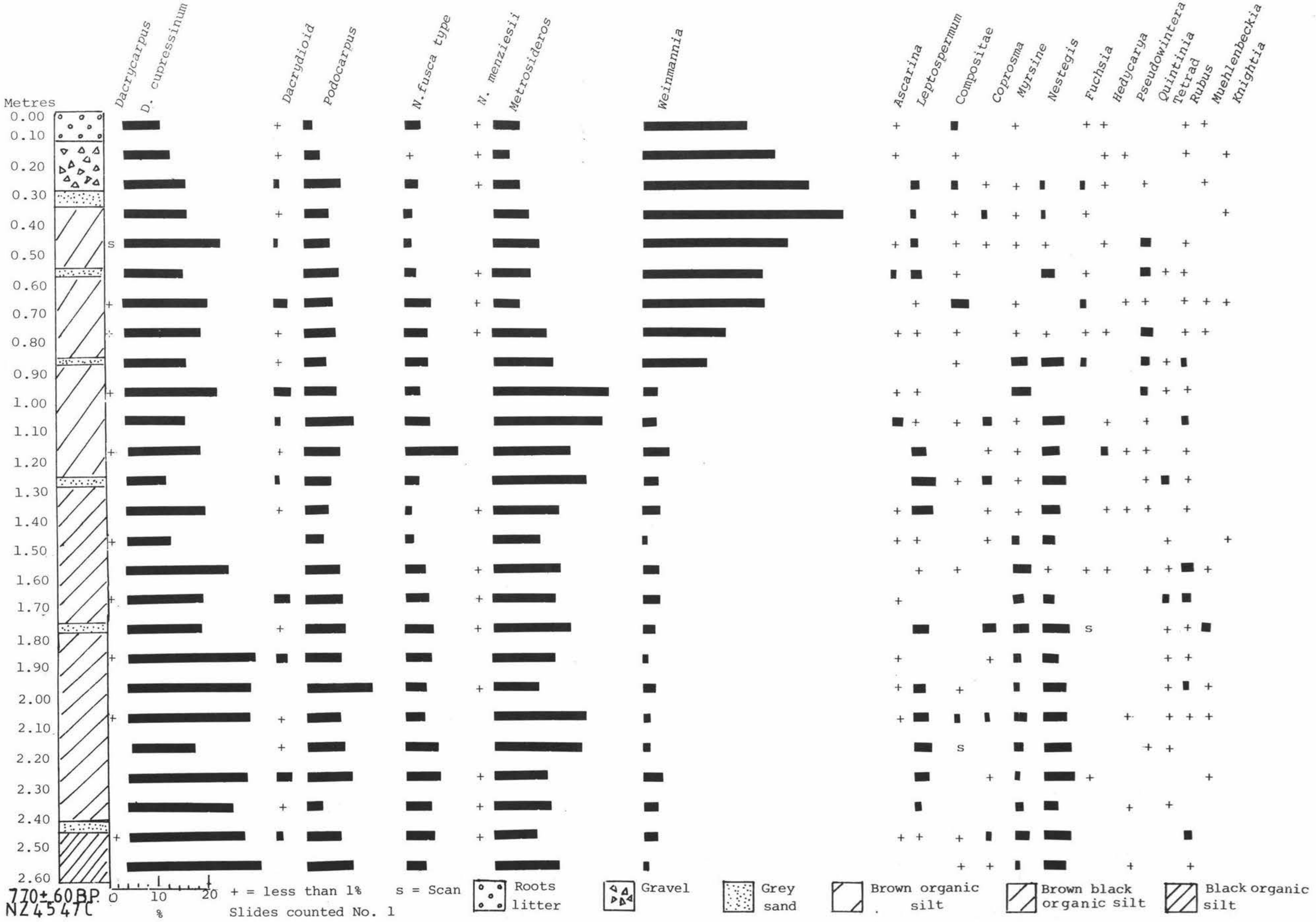
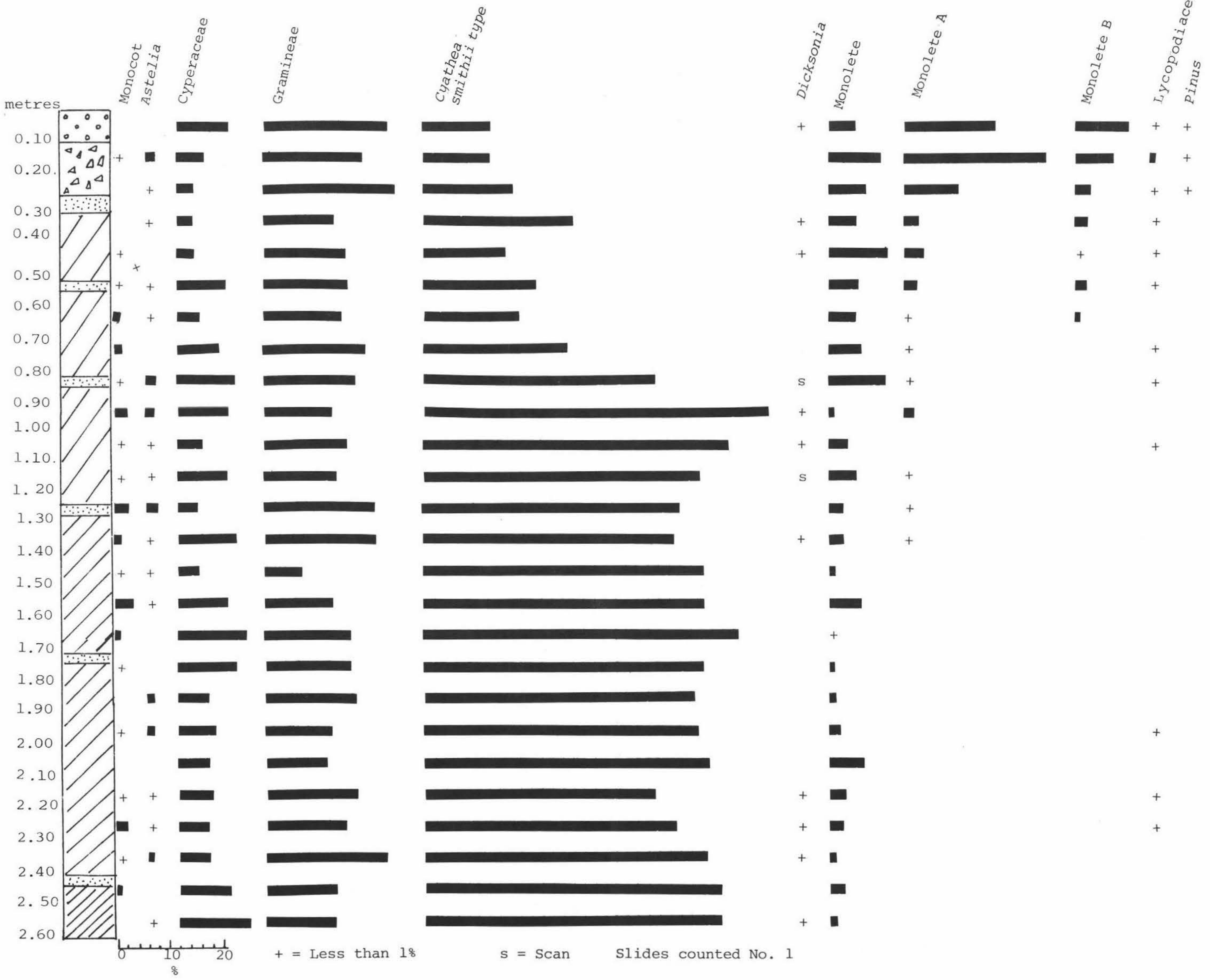


Figure 6.7 Continued

b Pollen sum = Total count 500



The greatest change occurs in the curve of *Weinmannia*. The rise and decline of this species has occurred in the forest. It was therefore relevant to further investigate the woody species. A count of 400 grains per slide was made on the duplicate slides and the percentage woody calculated for all samples above 120 cm. The data are shown in Figure 6.8. Using a set number of grains in the count inevitably means there will be a compensatory effect, as the percentage of one species rises others must fall. This is very clearly shown in Figure 6.8 for the rimu and kamahi curves. To overcome this problem a third count was made of 250 woody species but excluding *Weinmannia*. The data are graphed in Figure 6.9.

Figure 6.9 clearly shows that in fact rimu has been increasing at the same time as the kamahi. The sharp and significant decline at sample 0.30 cm cannot be explained by either fire or logging in the area, the check count on the duplicate slide had a slightly higher value but within the same confidence interval. All other woody species rise at this level but again this is regarded as a compensatory effect. From the peak at 40 - 50 cm there is a significant decline in rimu up to the surface.

The decline in tree ferns at the same time as the rise in kamahi and the increase in ground ferns with the decline of kamahi are regarded as normal seral stages in the long term succession in the forest, though they may be exaggerated due to the edge effect of the forest adjoining the swamp. Monolete spore A was tentatively identified as *Histiopteris* and Monolete B as *Polystichum* type. The latter is not thought to be *Rumohra adiantiformis*, previously *Polystichum adiantiformis*, which now occurs on the hillside, Harris (1955).

Figure 6.8 Pollen Diagram CML 80/2 West Tamaki River (Percentage woody).

Pollen sum = % Woody total count 400

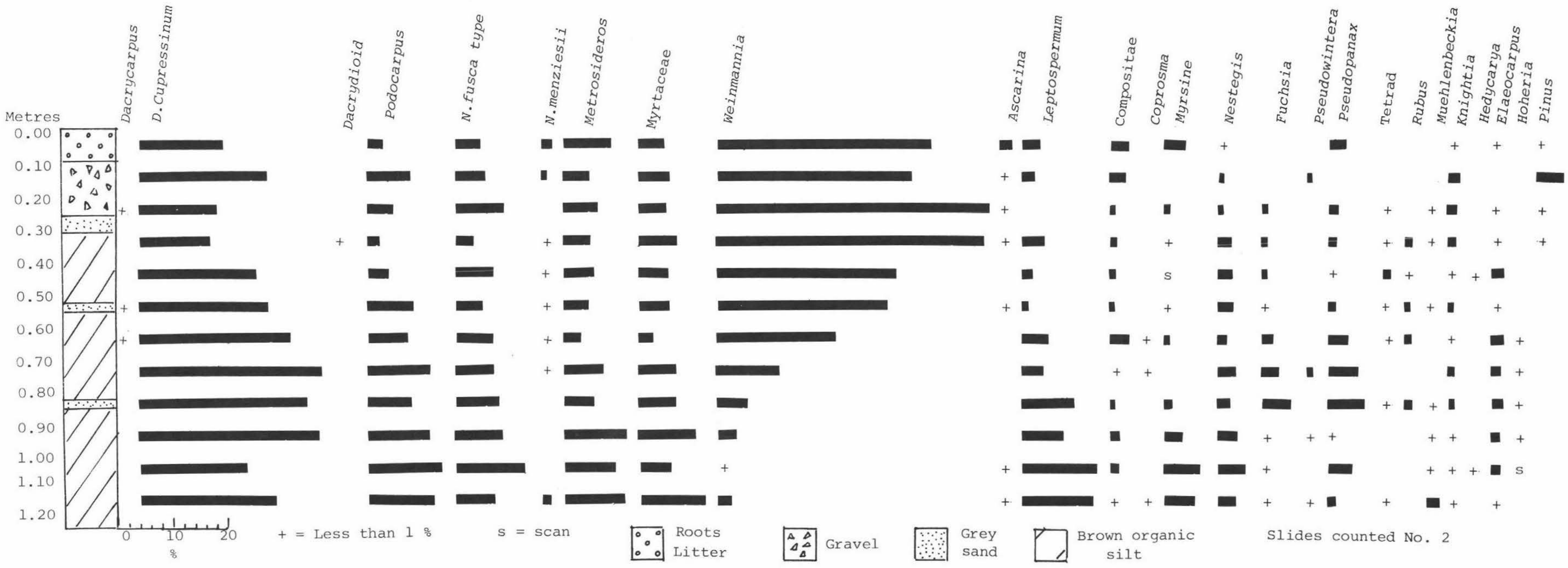
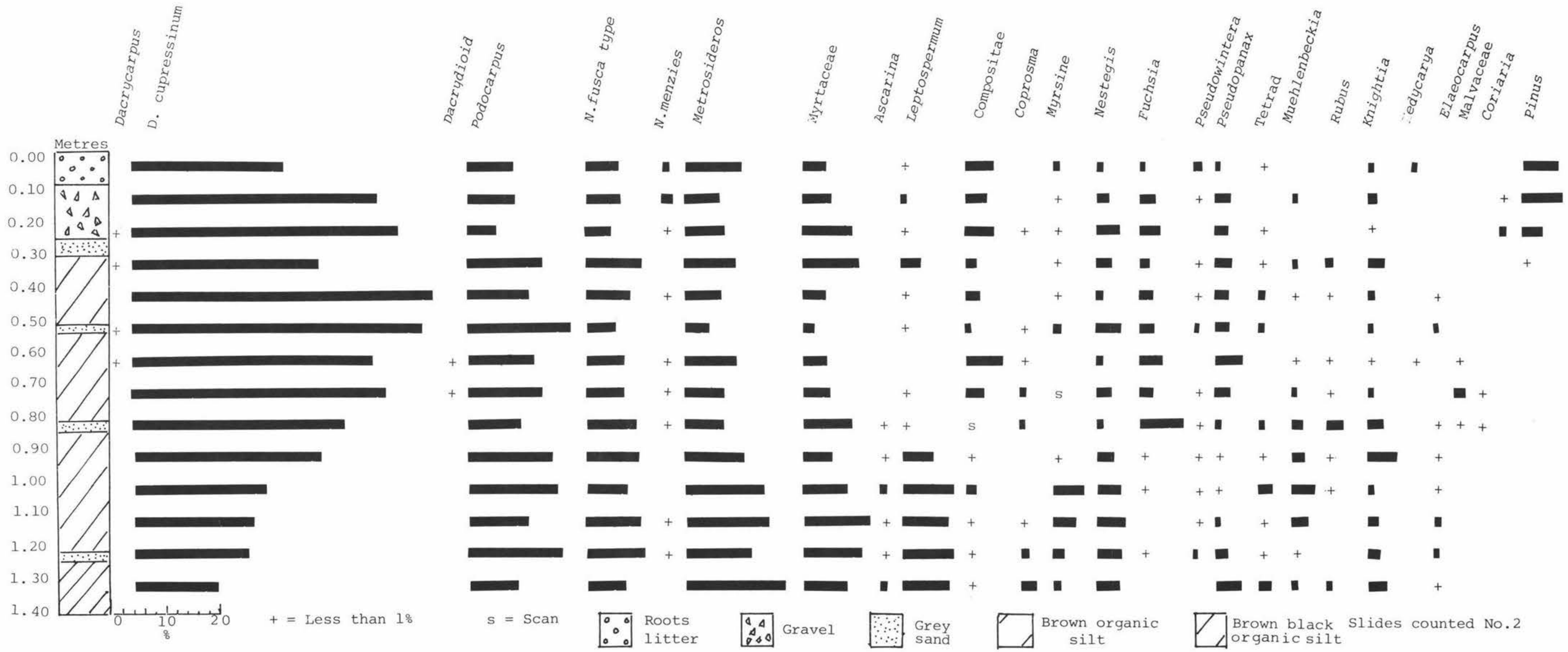


Figure 6. 9 Pollen Diagram CML 80/2 West Tamaki River. (ex *Weinmannia*)
Pollen sum = % 250 Woody ex Weinmannia



Interpretation of data

The steady increase in the percentage of kamahi occurring from a depth of 1 metre up to 0.3 metre is followed by a decline which coincides with the appearance of *Pinus* pollen Figure 6.7 indicating a period some time after European settlement, that is the top 40 cm of deposit. If a constant rate of deposition could be assumed this would give 2.90 cm in 770 years, 0.38 cm per year or 1 cm in 2.7 years. This gives a figure of 108 years from the 40 cm level to the top of the profile. The present bed of the downcutting stream lies about 0.5 of a metre below the profile. *Cyathea* ferns have become established at the base and higher up on the exposed face, these are about 1.5 metres high. It is thought that the fallen rimu close to the site may have lain there for about thirty years. On the basis of this evidence a tentative period of thirty years is proposed since the deposition ceased at the surface of the site.

The kamahi curve starts to decline at 30 cm Figure 6.7 and is very marked at 20 cm Figure 6.8. Assuming an average of 25 cm this would be about 98 years B.P. or about 1883. If a faster deposition rate is necessary to include the effects of storms, then for a rate of 1 cm in 2 years the date would be about 1900. The opossum was introduced into the Pohangina Valley in 1893 and colonisation of the range was only thought to be complete by 1953, Cuddihy (1977). It seems likely that the percentage of *Weinmannia* pollen was already declining before the full impact of opossum browsing occurred at this site. Since these rates can only be tentative and the critical period is relatively short in terms of fossil deposition no definite conclusion could be reached as to whether the opossum caused the decline or whether it was a stage in the natural life cycle of the kamahi. It was to seek more information on this point that the study of modern pollen rain as described in Chapter 7 was undertaken in the Kahuterawa Valley and on Mount Ruapehu.

The highest percentage of *Weinmannia* pollen was obtained from site 19 in the Mount Ruapehu study. This site has been marked by the staff of the Tongariro National Park as showing podocarps succeeding and overtopping kamahi. The kamahi are very large but obviously dying with exposed dead limbs. Table 12 compares the highest percentages and confidence intervals for the Ruapehu and West Tamaki sites. Figure 7.5 shows this graphically.

Table 12 Confidence intervals for *Weinmannia*, Mt Ruapehu and West Tamaki.

Sample	$\hat{p}$	No. woody grains	Confidence interval
Ruapehu site 19	0.443	409	0.49 - 0.396
W.T. 20-30 cm	0.513	191	0.584- 0.445
W.T. 30-40 cm	0.49	253	0.551- 0.429

Pollen sum percent woody of count 500 grains.

Comparison of the data in Table 12 would appear to indicate that the two populations were at a similar stage in the life cycle.

It is, however, necessary to consider the behaviour of other species on the sites. By taking the percentage of *Weinmannia* for the West Tamaki surface sample from the forest, locating it on the graph, Figure 7.6, showing succession in the podocarp - broadleaf forest on Ruapehu and reading off the values for the other species a valid comparison can be made, if it is assumed that the West Tamaki site has passed through the stage shown by site 19 on Mount Ruapehu.

Table 13 Comparison of percentages of selected species of West Tamaki pollen rain with data from Figure 7.6

Species	$\hat{p}$ West Tamaki	$\hat{p}$ Mount Ruapehu
Weinmannia	29.3	29.3
D. cupressinum	29.3	40.0
Podocarpus	10.4	13.0
Nothofagus	5.4[a]	6.0
Cyathea smithii type	16.8	8.0
Dicksonia	0.4	0.8
Nestegis	2.3[b]	4.0
Coprosma	3.2	1.2
Other woody	8.8	3.0

a Regional pollen

b Surface sample on site

c The positions are shown by red dots on Figure 7.6

d Pollen sum percent woody count 500, ferns count 500

The above data are similar except for *D. cupressinum* and *Cyathea*. The eratic behaviour of the *D. cupressinum* in the West Tamaki profile has already been noted. Pocknall (1978) has stated that much of the pollen of *D. cupressinum* falls close to the source tree leading to over representation. It may follow that the sudden removal of a large healthy tree by a catastrophy such as undermining by a stream would have a large effect. It must be remembered that one 10 cm channel sample may record the average pollen rain for between 20 -27 years, moreover, it is not known if the rimu were alive, dying or dead at the time they fell or if the fallen trees were males. The significant increases shown by the forest pollen rain over the uppermost fossil sample may reflect a response by other emerging podocarps to a gap in the canopy. The larger percentage of *Cyathea smithii* type in the West Tamaki spectrum can be reasonably accounted for by the close proximity of the swamp.

The rise of monolete fern spores over the upper portion of the profile is also of interest. Monolete A, tentatively identified as *Histiopteris incisa* is present though only as a trace from a depth of 1.40 cm. It increases steadily from 60 cm up to 20 cm and there is a ten percent decrease in the uppermost sample. There is only one species, Allan (1961). Commonly known as water fern it grows especially in swampy places or on the outskirts of forests, Hamlin (1963). The significant decrease at a level of about 10 cm may be an indication of the improved drainage due to the downcutting of the stream, the previous increase may be due to an opening up of the canopy by the deterioration of the kamahi crowns. Monolete B possibly *Polystichum* species also responded in this way. These ferns were not collected during a second visit to the site when three different species were collected but it is possible they may still occur there. Photographs of these spores appear in the Appendix.

Elder (1965) states that in the aerial photographs taken in 1946 the canopy was still substantially intact at least in the *Weinmannia* belt. By 1953 the defoliation was obvious even from the plains. A date in the 1950's would not be possible for the decline of the percentage of kamahi pollen shown in this profile, it would require an impossibly high rate of sedimentation. Moore and Bellamy (1974, 105) quote an average figure for peat accumulation of between 20 -80 cm per 1000 years or 0.08 cm/yr. Even allowing for a reduced compaction factor and drastically cutting the time period since downcutting would still give a too high rate.

On the evidence presented here it would seem that the decline of the percentage of *Weinmannia* pollen shown in the profile cannot be associated with the destruction of kamahi tree crowns by the browsing of the introduced opposum. The evidence tends to show that kamahi does follow a natural cycle of a rise and decline in the life span. Comparison with data from Mount Ruapehu indicates that the highest percentage of pollen is contributed when the tree crowns are exposed and the trees in poor health. Elder (1965) has commented that opossums show a strong preference for leaves fully exposed to light also that browsing may stimulate the production of fresh shoots, repetition of this cycle would exhuast the tree. It is therefore possible that once a kamahi reaches its maximum height and has an exposed crown it is then particularly vulnerable and may succumb quickly. The fact that the population contributing to the upper 20 cm and the modern pollen rain appears to be the same may be accounted for by the young kamahi which are replacing those which have died. No old kamahi were observed on the hillsides close to the site. Both Elder (1965) and Strand (1977) have observed healthy young kamahi which are almost completely unbrowsed.

Discussion

It is fully realised that these conclusions based as they are on so few samples of pollen rain must be regarded as very tentative, but other evidence does seem to lend support to the hypothesis suggested, namely that a rimu - kamahi forest at this altitude does involve a cyclical succession of dominants similar to that described in North Island podocarp forests by Cameron (1954). The decline of the *Weinmannia* element precedes the rise to dominance of the emergent *D. cupressinum*, in a natural succession. The increase in the *Weinmannia* curve was not therefore considered to indicate any change in the physical environment so no pollen zones are justified.

CML 81/5 Manawatu Gorge

Altitude 300 metres NZMS 18 Dannevirke Sheet 1 329 241. The location of this site is shown in Figure 6.3 between pages 43 - 45 Figure 6 Plate 1 is an aerial photograph of the area. The site lies in the eastern bank of a small unnamed stream which takes a sinuous course through G. Bolton's farm, situated on Cook Road, off Saddle Road. The stream flows into a lake and crosses a ridge of greywacke, then takes a large meander through a swampy area located in a depression between the two greywacke ridges before it falls over the lip of the Gorge, often forming a waterfall which can be seen from the Gorge Road. The geology of the area is shown in Figure 6.1 between pages 41 - 43 some Pleistocene deposits overlie the greywacke at the point where it leaves the lake and enters the forest which is part of the Crown land forming the Manawatu Gorge Reserve. The statigraphy of the site is shown in Table 14.

The present vegetation is dominated by *Beilschmiedia tawa* but there is a plentiful regeneration of podocarps and some of these are beginning to emerge through the canopy of *B. tawa* crowns. Seedlings of *Dacrycarpus dacrydioides* are abundant and saplings of this species and *Podocarpus spicatus, P. ferrugineus,* also *Dacrydium cupressinum* are fairly common. The subcanopy is composed of tree ferns mainly *Cyathea smithii* and *C. dealbata*. The *Dicksonia* ferns actually on the site appear to be dying. *Metrosideros diffusa* is common on the tree trunks. A very large podocarp trunk lies over the site and has possibly caused a diversion of the current thus exposing the site by the removal of liverworts which clothe the other banks. *Phymatodes diversifolia* and seedlings of *D. dacrydioides* are growing on the trunk, which is well rotted. A sapling *Pittosporum eugenioides* is growing above the site.

Figure 6 Plate 1 Manawatu Gorge
N.Z.M.S. 18 Dannevirke Sheet 1 329241
Reference . M.U. Geog. Dept. 236/36

Table 14 Stratigraphy and development of site CML 81/5
Manawatu Gorge

Depth m	Deposit	Possible explanation of events
0.00	Free draining silt, yellow brown in colour.	Overbank deposits. Probably at edge of new channel prior to period of downcutting that exposed the profile.
0.4	Strongly mottled imperfectly draining silt. Leaching and oxidation of iron.	Intermittent flooding as stream channel changes.
0.9	Blue reduced silty sand. Accumulation of silty sediments now gleyed owing to saturation with ground water	Water flow impeded.
1.08	Carbonaceous silty sands.	Organic debris accumulated in slow flowing water, possibly in a subsidary channel, backwater or lag at edge of bog.
1.38	Rimu and other logs tilted down into the silts and gravels.	An event caused uprooting of the trees and damming of the stream, gravel deposited.

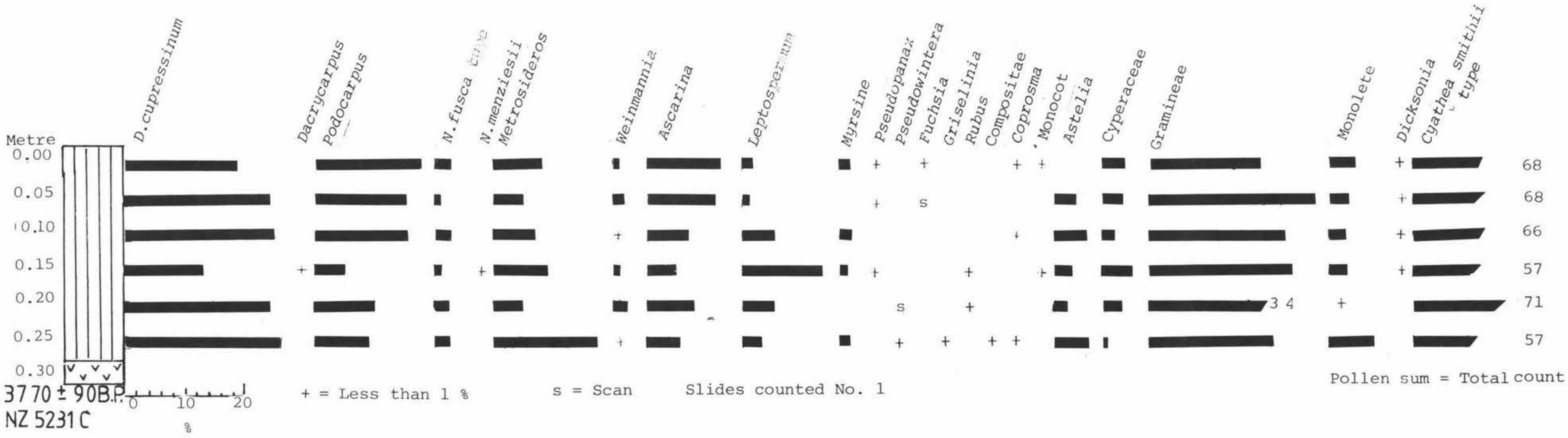
The 30 cm of carbonaceous, silty sands were sampled by collecting 6 channel samples of 5 cm. Wood from a log at the base was identified as *Dacrydium cupressinum* by Dr R.N. Patel and dated by the Radio Carbon Laboratory at 3770 ± 90 NZ 5231 C.

On the hillside away from the swamp area there is typical podocarp - broadleaf forest. Large *Knightia excelsa*, *B. tawa* and large ageing *P. totara* form the canopy over *Alectryon excelsus*, *Olearia arboresens*, abundant *Ripogonum scandens*, *Lophomyrtus bullata* and the occasional *Weinmannia racemosa*. Very large *Dicksonia* were seen and one *Rhapalostylis sapida*, about 50 cm high. *Freycinetia banksii*, *Asplenium falcatum* and *Blechnum discolor* are also present. Fallen trunks of *Knightia excelsa*, *B. tawa* and *Podocarpus* are lying in this forest. Groups of *B. tawa* stems of 20 cm dbh surrounding a rooted trunk indicate the coppicing of the tawa.

The pollen rain from a moss polster collected 20 yards from the site does not reflect the true composition of the forest because *B. tawa* pollen is not preserved. For sites at this altitude this fact must be borne in mind when interpreting a fossil pollen profile. Table 15 shows a comparison between the fossil pollen from the base of the profile and the modern pollen rain from the moss polster. The much larger percentages of *D. cupressinum*, *Metrosideros*, *Cyathea smithii* type and absence of *Dicksonia* indicate that the forest was probably in a different seral stage than at present. All the minor woody species present in the fossil spectrum occur in the modern spectrum with the exception of *Leptospermum*, *Griselinia*, and *Ascarina*. Time did not permit a more extensive counting of the modern pollen rain which would have been desirable. The rise and decline of *Leptospermum* throughout the profile, Figure 6.10 a & b would occur on newly exposed ground as indicated by the events described in Table 14.

Figure 6.10 Pollen Diagram CML 81/5 Manawatu Gorge

a Pollen sum = Total count 500 less spores



b Pollen sum = % 250 woody

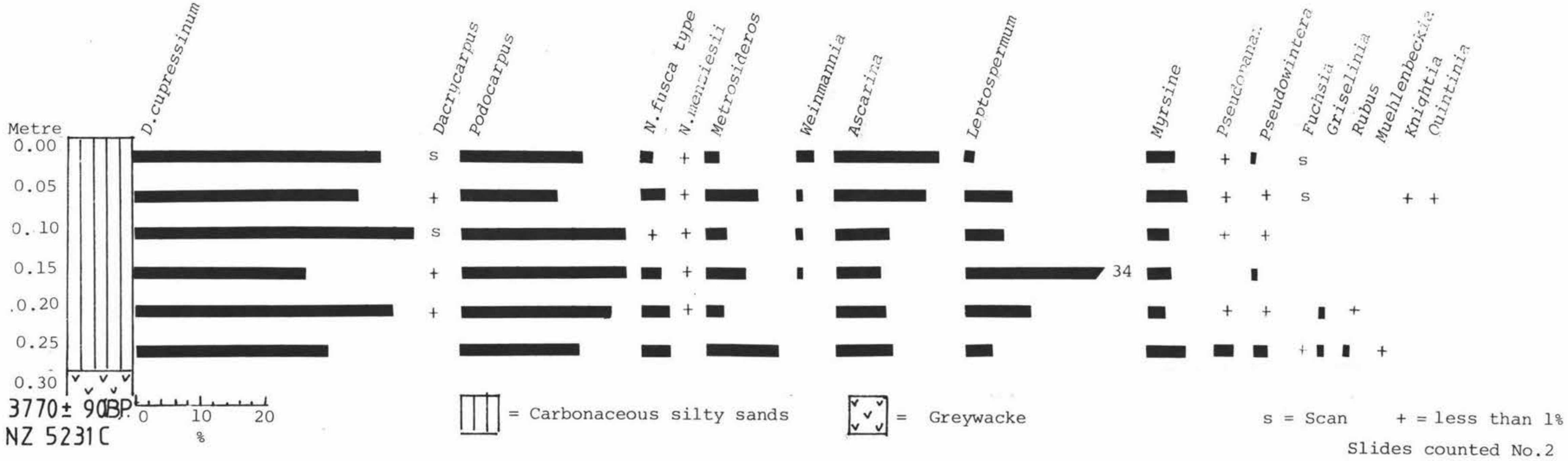


Table 15 Comparison of percentages of pollen for selected species from the base of CML 81/5 and for modern pollen rain

Species	$\hat{p}$ - 30 cm[a]	Confidence interval $\hat{p}$ (fossil)		$\hat{p}$ Modern[b]
Dacrycarpus	-			11.2
D. cupressinum	26.2	$\hat{p} = 0.262$ n = 168	0.333 - 0.214	
Total *Podocarpus*	7.1			6.3
Metrosideros	17.3	$\hat{p} = 0.173$ n = 168	0.227 - 0.115	4.9
Weinmannia	0.6			4.2
Ascarina	4.8			-
Cyathea smithii[c] type	57.2	$\hat{p} = 0.572$ n = 500	0.62 - 0.531	21.7
Dicksonia[c]	-			17.4
Monolete[c]	8.0			4.3
Phymatodes[c]	0.8			0.9

a = CML 81/5 Total count 500 grains less spores (168)
b = Moss polster Total count 350 grains less spores (142)
c = Total count

The most important feature of this profile is the high percentage of *Ascarina lucida* pollen that rises throughout the profile. This supports the findings of McGlone and Moar (1977) for a rise of this species between the two eruptions, namely the Waimihia 3440 years B.P. and the Taupo 1819 years B.P. The percentage from the uppermost sample is 18 percent of Woody species and this is high enough to suggest that a population of *Ascarina* existed close to the site during this period. The presence of this species is thought to indicate a less frosty and droughty climate.

Discussion

Although there are indications of a climate somewhat different from the present one shown by the percentages of *Ascarina* in this profile there is no change indicated within the profile itself. No pollen zones are justified.

CML 81/3 West Ballantrae

The locations of both the Ballantrae sites are shown in Figure 6.3b and the Geology in Figure 6.1 following page 41. Figure 6. Plate 2 is an aerial photograph of the area which lies to the west of Woodville. It can be seen in both Figure 6.1 and in the photograph that the fault line lies slightly to the east of this site. The altitude is about 80 metres and the map reference is NZMS 18 Dannevirke, 333239. The carbonaceous silts which were sampled lie within mainly fluvial deposits and are exposed in a road cutting some 20 metres above the present stream bed. The regional setting and the stratigraphy suggest that the silts were deposited on the flood plain of a much larger stream possibly that of the Mangapapa Stream which now flows some 1.5 km to the east. Terrace remnants can be seen above the present site and the house and car park of the D.S.I.R. station are located on a terrace.

Wood from the base of the deposit has been identified as Conifer, (poorly preserved) but probably *Podocarpaceae* by Dr. R.N. Patel. Other wood from the same level has been dated at 13,000 ± 200 years B.P. NZ 4651 B. A similar site is located on the eastern bank of the small stream on the opposite side of the fault. Wood from this site, sampled as CML 81/9 East Ballantrae, has been identified as *Leptospermum* and provisionally (No NZ number yet received) dated as 10,650 years B.P. There is an altitudinal difference of 19.1 metres between the two sites. It is possible therefore that the uplift on the fault during the last 13,300 years has been as least that distance, but other explanations could also be offered. Table 16 contains details of the stratigraphy of site cm 81/3.

Table 16 Stratigraphy of CML 81/3 West Ballantrae

Depth-metres	Deposit	Comment
0.00 - 1.5	Colluvium derived from loess	
1.5 - 2.5	Gravelly sandy silts iron stained with fine sandy lenses	Some angular fragments as well as rounded gravel
2.5 - 2.9	Carbonaceous silts as follows:	
2.55	Predominantly sand	Two thin carbonaceous layers
2.60	Sandy silt	More carbonaceous
2.60 - 2.70	Alternating layers silt/sand/carbonaceous	Wood 5 cm diameter
2.70 - 2.75	Carbonaceous silty sands	More wood pieces
2.75 - 2.85	" " "	Wood 2 cm diameter
2.85 - 2.90	Base of silty sands	Conifer wood, Wood dated at 13,300 ± 200 years B.P.

The vegetation at the site is pasture. Present forest at similar altitudes would be represented by Keeble's Bush on the western side of the range which has mixed podocarp forest or by the lower parts of the Kahuterawa valley or Tiritea valley which are mainly dominated by *Beilschmedia tawa*. In these latter forests a few old emergent rimu and northern rata remain. The very long life span of members of the Podocarpaceae may be responsible for the somewhat confusing mosaic of 'forest types' observed within a narrow altitudinal range, so that over a period of time quite a different forest type could exist on any one site. It is, however, useful to have some idea of the possible modern native forest at a similar altitude to the fossil pollen sites. These forest remnants are described by Esler (1978).

Analysis of data

The 40 cm of carbonaceous sandy silts were sampled by 8 channel samples of 5 cm each. This site developed after an erosional event, possibly a change in channel location that left new ground exposed. This is obvious from the rise and decline of *Leptospermum* which dominates the pollen profile Figure 6.11a, reaching a peak of 95 percent which completely masks the presence of all other pollen types. These are present in very small amounts and were picked up on the low power scanning after the formal counting had finished. The large percentage of *Cyathea smithii* type and Gramineae are probably also associated with this colonisation process.

To overcome this problem of masking and to find out what the undisturbed vegetation surrounding the site could have been, a second count was made of 250 woody species excluding *Leptospermum* and using the duplicate slides. There is only a trace of *Dacrydium cupressinum* and the profile is dominated by Podocarpaceae. A large proportion of these grains were identified at the specific level as *P. spicatus*, and these have been graphed separately on both diagrams Figures 6.11a and b. The apparent complementary swings in these two types is an indication of the state of preservation of the pollen.

There is a significant rise in both *P. spicatus* and total *Podocarpus* over the profile and also in the proportion of *P. spicatus* to total *Podocarpus*.

Table 17 Confidence intervals of *P. spicatus* and *Podocarpus* CML 181/3 West Ballantrae

Species	Sample	$\hat{p}$	n	Confidence Interval	Sample	$\hat{p}$
P. spicatus	35 - 40 cm	0.18	150	0.249 - 0.127	5 - 10 cm	34
Podocarpus	35 - 40 cm	0.40	150	0.492 - 0.338	5 - 10 cm	58
P. spicatus/ Podocarpus	35 - 40 cm	59%			5 - 10 cm	45%

Pollen sum = Percent 150 + Woody species ex *Leptospermum*

Among the hardwoods present *Myrsine* shows an increase over the profile. The confidence interval for *Myrsine* for the uppermost sample where $\hat{p} = 0.082$, $n = 207$, is 0.129 - 0.052. The value of the lowest sample would lie just outside this interval.

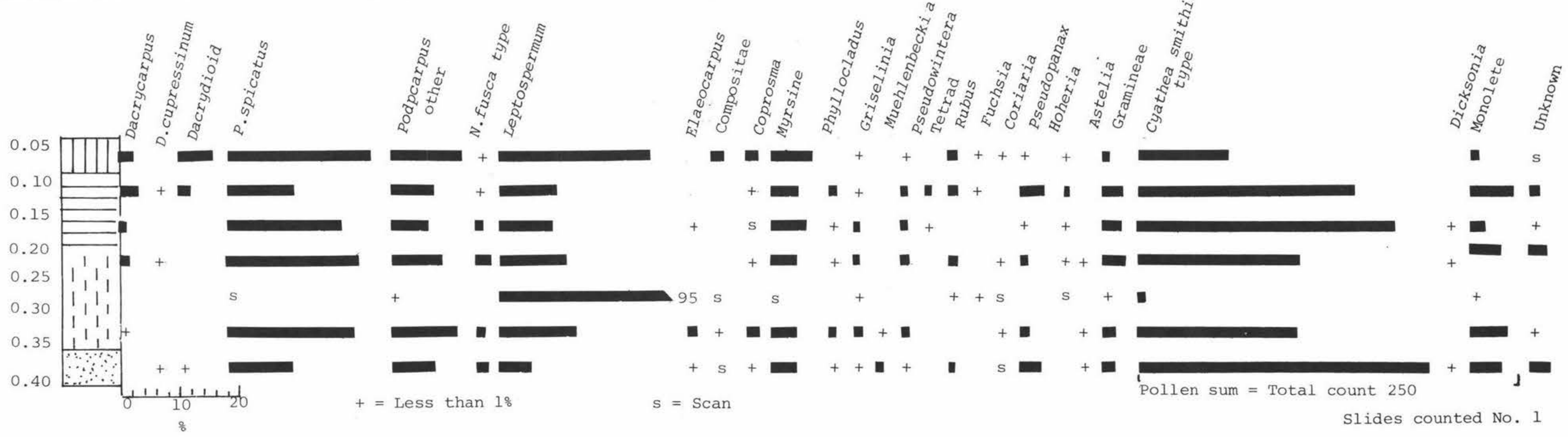
A large grain listed as 'Unknown' occurs throughout the profile. Assistance was requested from both the palynologists at Botany Division D.S.I.R., Lincoln and at the Geological Survey, Lower Hutt but it was not known to any of them. It may have washed out of older sediments. All the grains of this type are very well preserved. Two views of the grain from sample 10 - 15 cm have been photographed, Plate D in the Appendix.

Interpretation of data

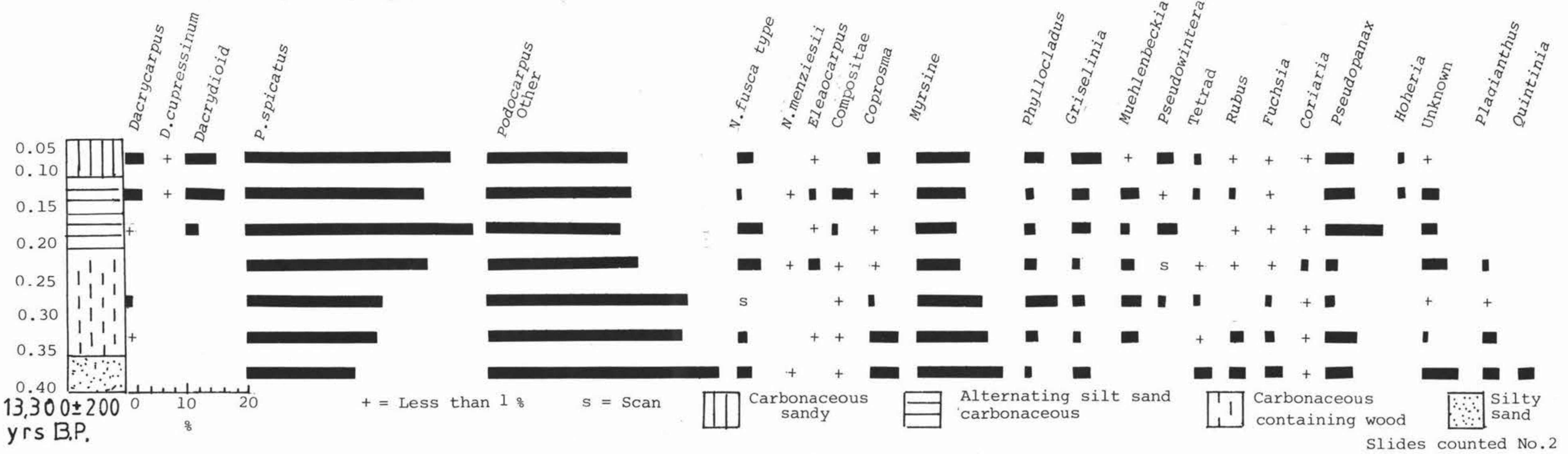
The pollen spectra indicate the presence close to the site of a podocarp forest dominated by *P. spicatus*. McGlone and Topping (1977) have recognised three pollen zones in their studies of fossil pollen sites on Tongariro. The first of these is for the period 14,000 - 10,000 years B.P. when *P. spicatus* was dominant. This profile and the radio carbon date for wood from the base of the profile would seem to indicate that this site should be classified as in the first postglacial zone. They supposed that

Figure 6.11 Pollen diagram CML 81/3 West Ballantrae.

a Pollen sum = Total count 250 less spores.



b Pollen sum = % 150 + Woody ex Leptospermum



this type of forest would indicate annual temperatures of only 2 - 3°C lower than present but a climate that was substantially drier. A trend to a drier climate may be indicated by the increasing proportion of *P. spicatus* to the total *Podocarpus*.

The presence of *Phyllocladus* at this low altitude while, probably regional, may indicate that it occurred at a lower altitude than at present. The pollen percentage for *Phyllocladus* at West Ballantrae and Delaware are comparable (for a total count of 250 grains West Ballantrae and 500 grains Delaware Ridge), though the latter is at 1050 m. Both *Myrsine* and *Pseudopanax* which have the largest percentages of the other hardwoods have species which are favoured by forest margins and may have increased following the creation of disturbed ground, later colonised by *Leptospermum*.

Discussion

No change in physical conditions is demonstrated in the profile but the indications are that it should be placed in the first post-glacial pollen zone of McGlone and Topping (1977).

CML 81/9 East Ballantrae

This site lies on the opposite side of the faultline and is offset to the south east by about 100 metres and downthrown by 19.1 metres, that is assuming that movement on the fault line has in fact occurred. The altitude is therefore slightly less than that of the West Ballantrae site, the map reference is the same for the two sites. The stratigraphy of this site is shown in Table 18 and is very similar to that of site CML 81/3 it is supposed that deposition occurred under the same conditions. This site has been exposed by the downcutting of the small stream.

Table 18 The stratigraphy of CML 81/9 East Ballantrae

Depth-metres	Deposit	Comment
0.00-2.00	Colluvium derived from loess.	
2.00-3.70	Medium gravels	Some angular fragments among rounded gravels.
3.70-4.10	Grey carbonaceous silts as follows:	
3.70-3.75	Grey brown sandy silt	
3.75-3.80	Grey brown silt/ olive sand.	Organic material at base.
3.80-3.85	Olive sand with iron staining	Many roots.
3.85-3.90	Olive sand with organically enriched streaks, slightly greasy.	
3.90-3.95	As above but some iron staining.	Marked organic layer top 2-3mm thick.
3.95-4.05	Olive sand, minor iorn staining, grey mottles	
4.05-4.10	Greyish brown sand with iron staining.	

Table 18.

Depth-metres	Deposit	Comment
4.10	Compaction at base.	Greasy layer with wood fragments. *Leptospermum* wood (provisional date 10,650 yrs B.P.)
4.15	Strong iron staining on indurated iron pan on gravels.	

The 40 cm of carbonaceous silts were sampled by collecting 8 channel samples of 5 cm each. The present vegetation is pasture though exotic conifers are growing directly above the site. The possible native forest type prior to European settlement has been discussed under CML 81/3, West Ballantrae.

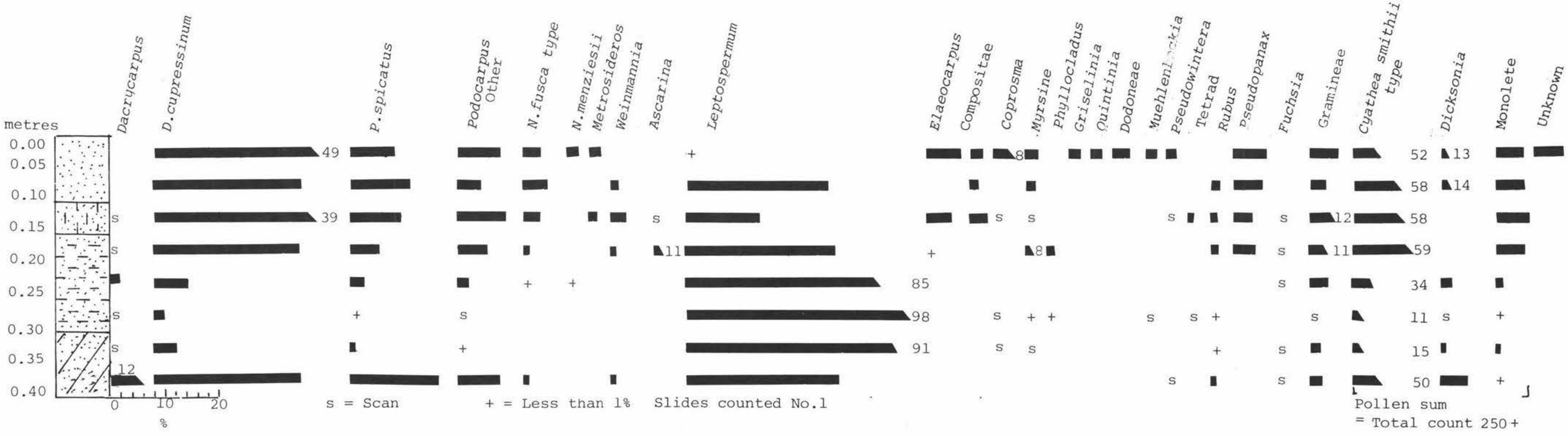
Analysis of data

This is another site where the colonisation of newly exposed ground is revealed by the rise to an extremely high value by *Leptospermum* followed by a fall. This trend is further indicated by the high percentages of *Cyathea smithii* type and Gramineae. The rapid decline from 70 percent for *Leptospermum* to 27 percent is reflected in the stratigraphic column by a marked organic layer at 3.95 m. The almost complete absence of *Leptospermum* in the uppermost sample would seem to indicate a sudden event of a catastrophic nature. The apparent increase of *D. cupressinum* at this level shown in Figure 6.12a is not indicated when *Leptospermum* was ignored and only other woody species counted to produce Figure 6.12b. The increases shown by almost all other hardwoods at this level in Figure 6.12a are similarly invalidated in Figure 6.12b.

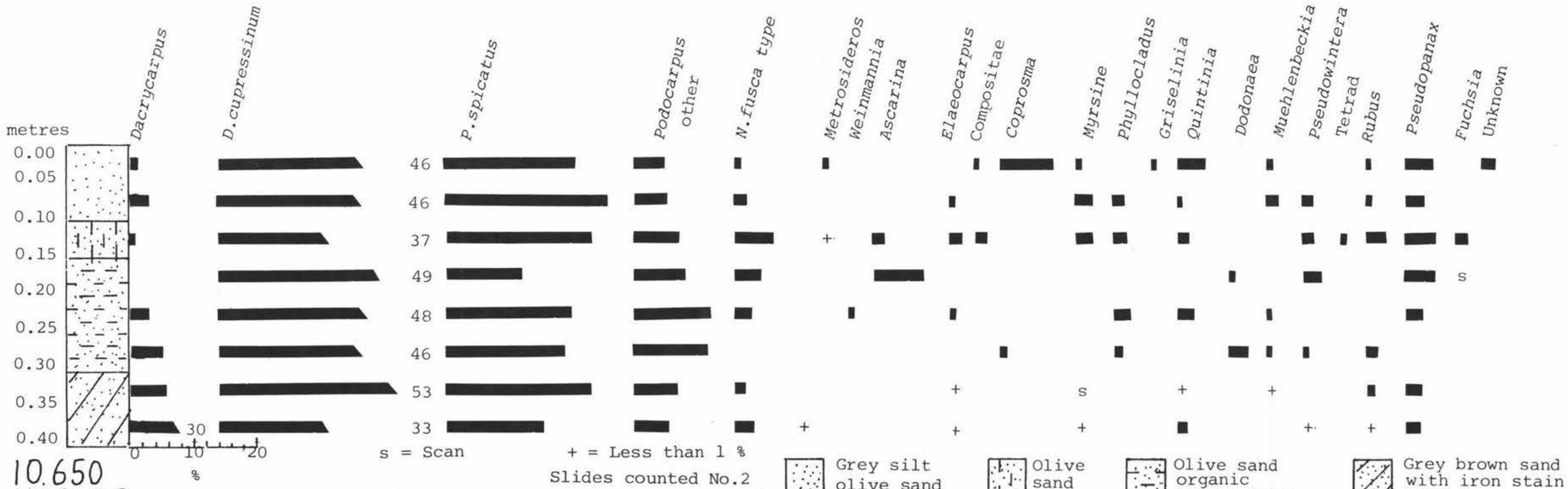
There are several important features shown in Figure 6.12b. They are the dominance of *D. cupressinum*, the large proportion of *Podocarpus spicatus*, the marked and rapid decline of *Dacrycarpus*

Figure 6.12 Pollen Diagram 81/9 East Ballantrae;

a Pollen sum = Total count 250+ ex spores



b Pollen sum = Woody ex Leptospermum



10.650
±150 B.P.

after the lowest sample and the rise and decline of *Ascarina* at the 10 - 20 cm level. The small rise and decline of *Nothofagus fusca* type is not thought to be significant, it could not be tested by Mosimann's method because the number of grains counted was below 150, the effect of a smaller number of grains (n) is to widen the confidence interval so that it is unlikely the differences shown are significant.

D. cupressinum shows a significant increase between the lowest and uppermost samples but the real change occurs in sample 30-35 cm. This high percentage of 53 cannot have been produced by the same population that is represented by sample 35 - 40 cm but all samples above this fall within the confidence interval for a value of 53 percent. *P. spicatus* does not show any real change and the two confidence intervals that have been calculated overlap to include all samples. Lastly the unknown grain which occurred throughout the West Ballantrae profile only occurs in the uppermost sample of this profile.

Table 19 Confidence intervals for two species from CML 81/9 East Ballantrae

Species	Sample	$\hat{p}$	n	Confidence interval	Sample	$\hat{p}$
D. cupressinum	35 - 40 cm	0.33	250	0.392-0.275	0 - 5 cm	0.46
D. cupressinum	30 - 35 cm	0.53	160	0.606-0.453		
P. spicatus	35 - 40 cm	0.16	250	0.211-0.12	0 - 5 cm	0.19
P. spicatus	30 - 35 cm	0.23	160	0.302-0.172		

Because of the complexity of the changes found in this profile it was decided to attempt to obtain information about the conditions for the preservation of the grains. In a paper by Cushing (1967) reported by Birks and Birks (1980) he distinguished five main categories of pollen preservation, well preserved, corroded, degraded, broken and crumpled and was able to demonstrate that different types of deterioration occurred in different types of sediment. Pocknall (1980) used the percentage of corrosion of *Cyathea* spores and *D. cupressinum* pollen to investigate redisposition of grains. Pocknall quotes Havinga (1964) as stating that fern spores are generally more resistant to corrosion than pollen, although Pocknall did not find this to be the case he attributed this to the possible mobilisation of spores by surface wash.

It was decided to establish classes of deterioration which could be easily distinguished and to count 100 spores of *Cyathea smithii* type in each sample. The classes used in this study were as follows:

Class 1 Well preserved entire grains.
2 Well preserved but broken or split.
3 Etched, these have characteristic 'stars' of lighter colour in grains stained with Basic Fuchsin.
4 Corroded, entire surface etched.
5 Faint grains, 'ghost' grains, almost transparent but recognisable by shape and sice.

Grains were put in lowest class - split and etched put in Class 3

Index. No. in class x class number/100.

Table 20 Summary of the state of preservation of *Cyathea smithii* type spores in samples from CML 81/9 East Ballantrae.

Sample^a			Class			Index	No. *Cyathea smithii* type^b
	1	2	3	4	5		
0 - 5 cm	28	28	13	13	18	2.7	132
5 - 10	23	12	24	33	8	2.9	146
10 - 15	13	19	21	43	4	3.1	146
15 - 20	29	17	26	23	5	2.6	148
20 - 25	45	19	11	25	-	2.2	91
25 - 30	55	13	18	13	1	1.9	28
30 - 35	42	20	7	29	2	2.3	38
35 - 40	40	10	26	16	8	2.4	124

a = From percent woody ex *Leptospermum* count (Figure 6.12b)

b = From Total count 250 + (Figure 6.12a)

Unfortunately the complementary effect again masks the true proportions of the spores as the percentage is affected by the high *Leptospermum* value. It is considered unlikely that the *Cyathea* ferns were really reduced by the *Leptospermum* peak as the upper samples are so consistent, and that therefore the discrepancies between the spore numbers are not relevant. It would appear that the spores had at least a 10 percent better chance of being well preserved in the lower half of the deposit than in the upper half. This conclusion is reinforced by the small number of woody grains apart from *Leptospermum* that could be counted in the upper half of the profile. It is tentatively suggested that this may be a useful standard by which to gauge preservation conditions. It is fully realised that far more work would be necessary before it could be validated.

Interpretation of data

The decline of *Dacrycarpus* appears to correlate with the decline in preservation conditions, possibly the site became better drained with the change in channel in the vicinity of the *Dacrycarpus* population. Other explanations are possible, undermining by the stream, or burial by gravel might cause a rapid decrease in mature trees producing pollen. The decline is not considered to be climatically significant.

The high percentages of *D. cupressinum* indicate a warm and moist climate, and the increase over the profile probably shows that these conditions were increasing also. There is an indication in the rise of *Ascarina* that the climate fluctuated and was at one stage frost and drought free. The proportion of *P. spicatus* is much less than that for the West Ballantrae and may represent an ageing population but without an indication of accumulation rates it is difficult to reach a definite conclusion.

McGlone and Topping (1977) defined the second post-glacial zone beginning at 10,000 years B.P. as being dominated by *D. cupressinum*. The profile shows some elements of both zones and the provisional radio carbon date of 10,650 seems to bear out this conclusion.

Discussion

It was considered that the whole profile would be included in postglacial pollen zone two. The minor fluctuation indicated by the presence of *Ascarina* was not considered justification for assuming a sub-zone on this profile.

CHAPTER 7

AN INVESTIGATION INTO THE PODOCARP-HARDWOOD FORESTS USING POLLEN ANALYSIS

INTRODUCTION

This research project was designed primarily to discover details of the life cycle of kamahi, *Weinmannia racemosa*. This species is of particular interest at the West Tamaki River fossil pollen site. In carrying out this project a greater knowledge of the forest species and an understanding of forest communities was obtained. This was considered for interpretation of the palaeoecology of fossil pollen sites which are the subject of this thesis.

ASSUMPTIONS

In order to proceed the following assumptions were made:

1) That the proportion of regional to local pollen has not changed over the lifetime of the longest lived species, this is estimated to be between 600-800 and up to 1000 years (Chavasse 1954).

2) That there have been no marked changes in the environment in this period.

3) That the proportional representation within a species has not changed over this period.

4) If the above assumptions are accepted then it can be assumed that modern pollen rain is a valid measure of the pollen by a community on a particular site.

STUDY PLAN

Information Required

1) Contribution to the pollen rain of individual trees of kamahi, *Weinmannia racemosa*.

2) Pollen rain fall out at known distances from kamahi trees.

3) Pollen rain derived from present podocarp broadleaf forest communities of differing species composition and different life cycle stages.

4) Pollen rain from the immediate past.

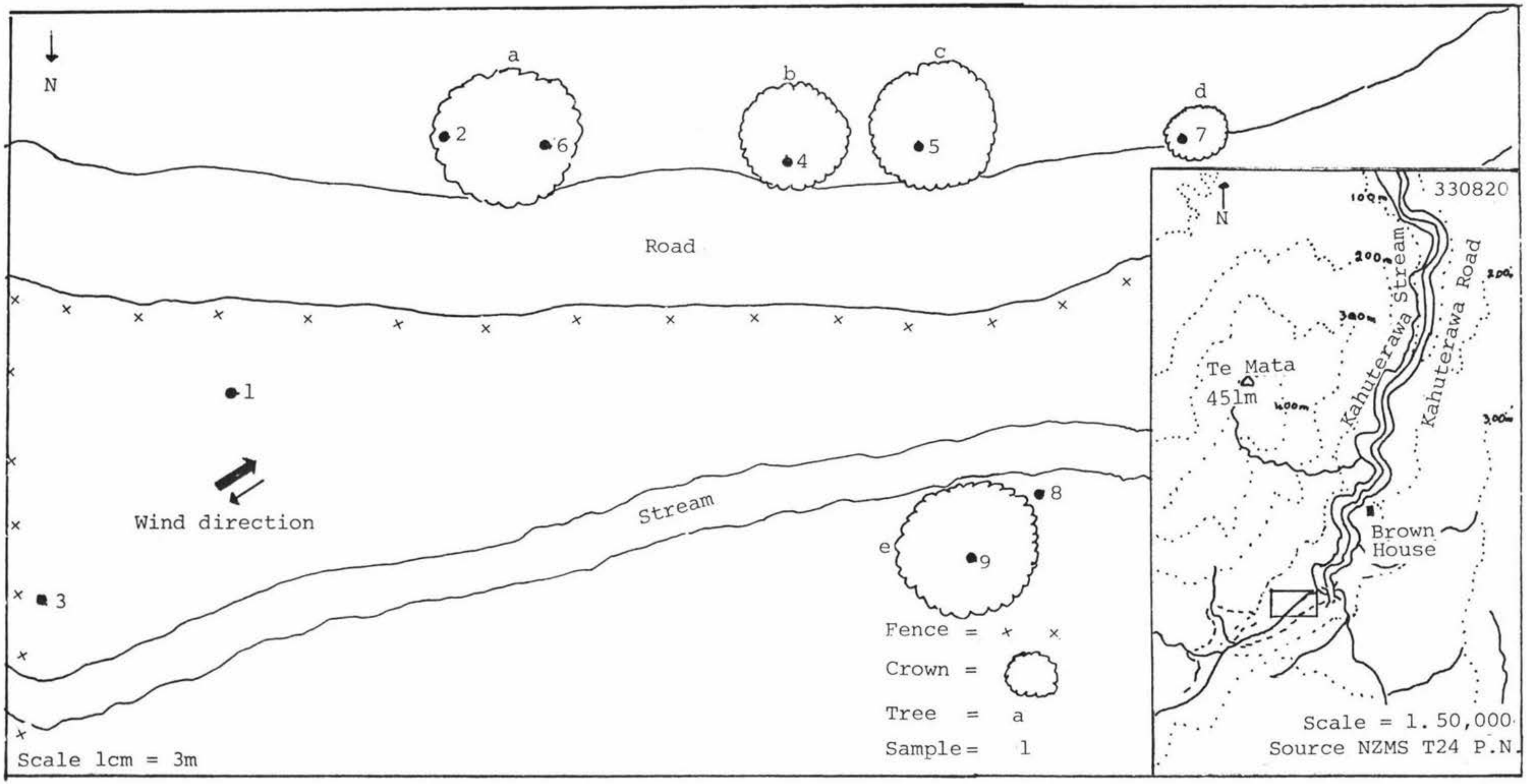
Methods

To obtain information from individual kamahi trees a convenient study area in the Kahuterawa Valley NZMS T 24 314784 was chosen. Moss polsters were collected below kamahi trees of varying crown size and at measured distances from these trees. The openess of the canopy was also noted. Figure 7.1 shows the location of the study area and the plan of the sampling sites.

To obtain information on the forest communities, moss polsters were collected from 1505 m to 609 m on the Ohakune side of Mount Ruapehu. Of the 20 samples collected, samples 13 to 20 fall in the podocarp broadleaf forest and were used in this study. Figure 7.2 shows the location of the area and the distribution of the sites. Access was by the Ohakune Mountain road and the Mangawhero forest walk. The previous history of the sites is not known.

To obtain information about the immediate past vegetation a trial sampling of soil for pollen was made. At site 18 duplicate soil profiles were sampled, these were 10 cm apart. The loose material and debris was removed and eight samples at 1 cm intervals were collected.

Figure 7.1 Plan of sites Kahuterawa Valley.



Part 1 The Kahuterawa study area

Some difficulties in sampling were encountered these were due to:

1) The occurrence of other kamahi trees within measured distances.

2) The moss polsters tended to crumble due to the very dry summer.

3) It was not possible to obtain moss of the same species, the polsters therefore varied in their capacity to trap pollen. Extraction from all moss polsters was by the standard methods outlined in Appendix I. The results of this study are shown in Table 21.

Table 21 Percentage of kamahi pollen in a count of 500 pollen grains

Sample No.	% Kamahi Pollen	Crown Diam. of sample tree		Nearest other tree sampled	No. of other tree	Diam. of other	Site Description
1	8.8			14.5 m	a	5 m	
2	7.2	5 m	(a)	14.5 m	b	3 m	forest edge
3	6.0			30.0 m	a	5 m	open
4	12.4	3 m	(b)	3.0 m	c	5 m	forest edge
5	3.2	5 m	(c)	3.0	b	3 m	forest edge
6	Sample discarded too poor to count						
7	4.6	1.5 m	(d)	7.0 m	c	5 m	open
8	3.8	3.5 m	(e)	x17.0 m	b	3 m	open
9	15.8	3.5 m	(e)	17.0 m	b	3 m	open

x Sample at edge of crown and also subject to possible flooding

Average under trees (6 samples)	7.8 %	range 3.8 - 15.8 %
Average in open (2 samples)	7.4 %	range 6.0 - 8.8%
Average crown diam. (5 trees)	3.6 m	range 1.5 - 5 m

Discussion

It is fully appreciated that the nature of the sampling provides an inadequate data base for such a study. Results must therefore be treated as indications only. The data do appear to show that the largest crown does not necessarily give the largest percentage of pollen. Factors which may be relevant:

1) Openess to sky. Tree 4 with a small crown gave a greater percentage than tree 3 with a large crown which was under shade at the forest edge.

2) Rain out component may have been greater than trunk space component (Tauber 1965) as sites in open had a greater percentage than some samples under trees.

3) Presence of other kamahi trees nearby. It is difficult to find isolated trees of forest species.

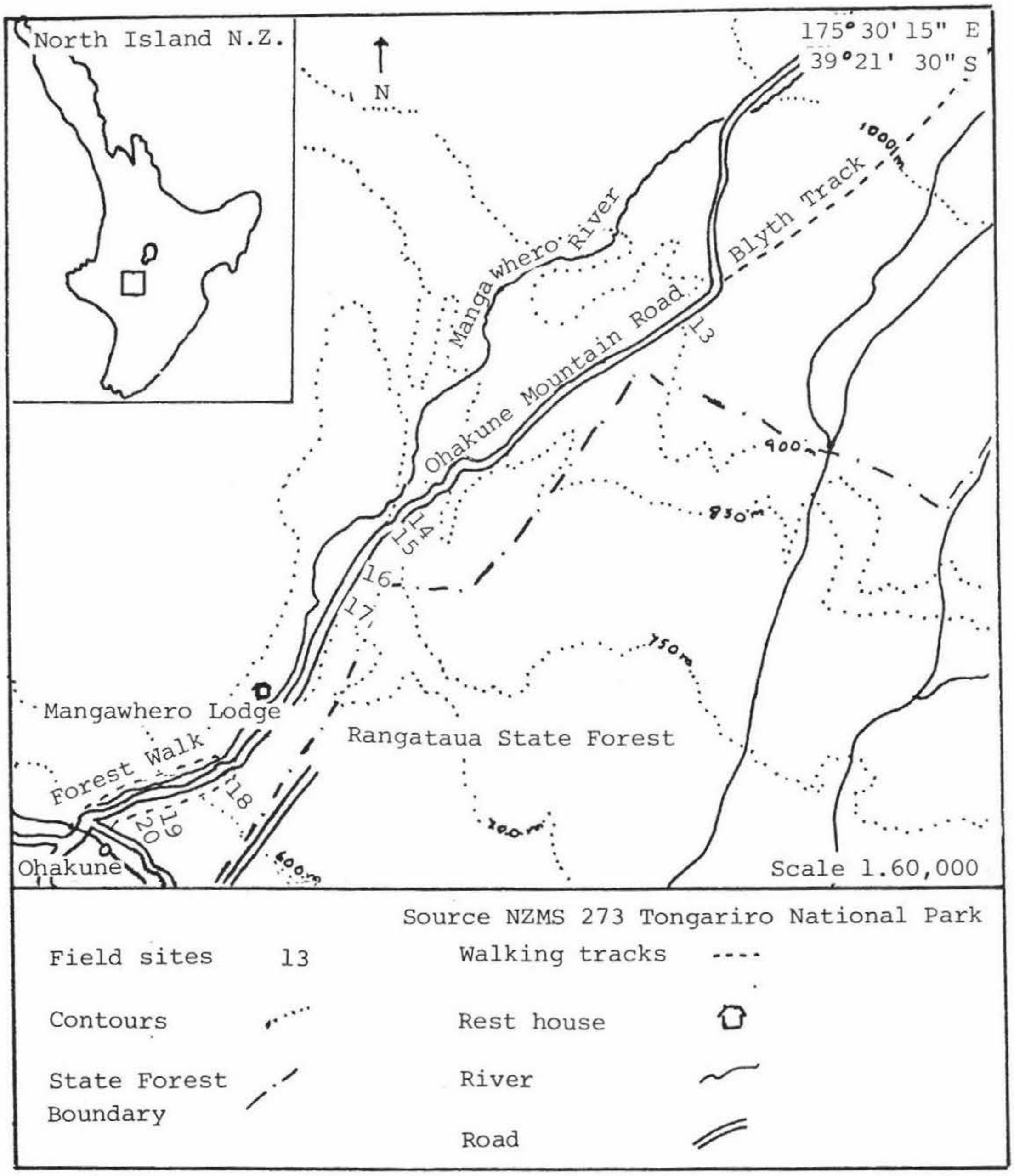
Part 2 Mount Ruapehu study area

Three field trips were made to this area during April and May 1981. Detailed notes of the communities sampled were made and in most cases it was possible to collect good polsters of the moss of *Rhacomitrium* species. Site 18 was regarded with particular interest as it showed past vegetation in the form of decaying logs and stumps of podocarps, an understory of old *Cyathea* fern and dead *Dicksonia* and kamahi emergent over the ferns. It was felt this site could provide valuable information about forest changes if only the immediate past vegetation could be discovered. It was decided to take the two soil samples here.

Manipulation of data from the Ruapehu study

Data used was the percentage of each pollen type as a percentage of the woody species present in a total count of 500 pollen grains. Only selected pollen types were used to avoid confusion, these were, Rimu, *D. cupressinum*.

Figure 7.2 Location of sites, Mount Ruapehu.



Source NZMS 273 Tongariro National Park

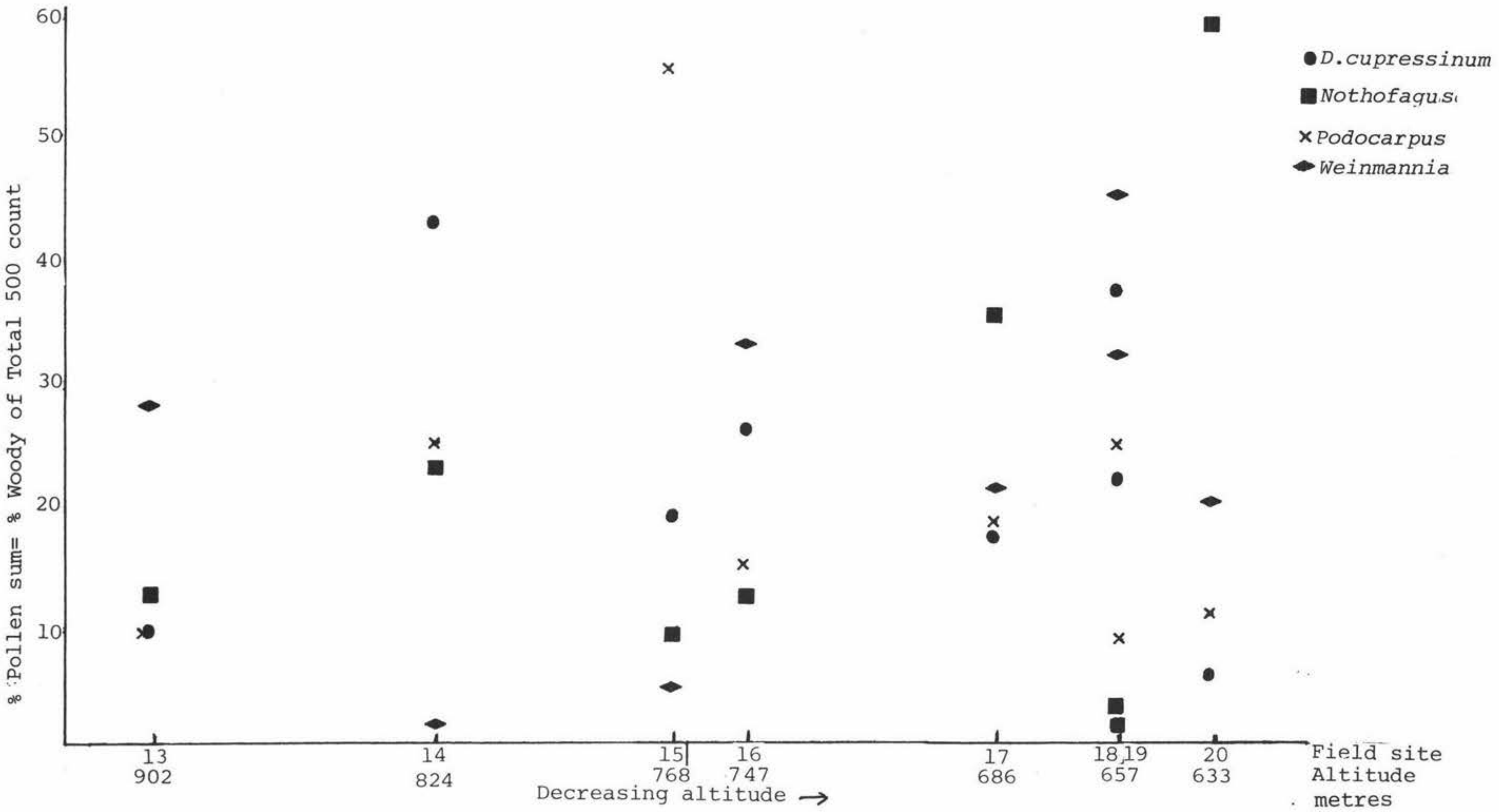
Podocarps, includes *P. spicatus, P. ferrugineus, P. totara* plus those grains which could only be identified at a generic level.

Kamahi, *Weinmannia racemosa*.

Beech, *Nothofagus fusca* type, which includes all species except *N. menziesii*, in the field this was observed to be mainly *N. solandri*, *Nestegis, Coprosma* and 'other woody' which includes all other hardwoods.

The percentage of the four most important species, rimu, podocarps, kamahi and beech are plotted for each site against altitude in Figure 7.3. It is concluded that within the limited range of the study area, 902m to 633m, altitude does not determine the distribution of these species to any great extent. Altitude was therefore not considered as a relevant factor in this study.

Figure 7.3 Relationship of sites to altitude ,Mount Ruapehu.



Descriptions of pollen rain sites, Mount Ruapehu

Location of these sites is shown in Figure 7.2. The descriptions are listed in the order in which they have been graphed in Figure 7.6

Site 14

Altitude 824 m. Mature *Podocarpus - Nothofagus* forest. Right hand side of Mountain Road (descending).
Large trees of *Dacrydium cupressinum, Podocarpus spicatus, P. ferrugineus* and *Nothofagus solandri*. An occasional *Pseudopanax ferox*. *Pseudowintera* in fruit. Abundant *Cyathea ferns*. *Blechnum* fern abundant but dry at the end of summer. *Cortaderia* edges the road.
Moss polster collected from earth bank at roadside, access to site difficult.

Site 15

Altitude 768 m. R.H. side descending Mountain Road.
Mature *Podocarpus* forest. *Dacrydium cupressinum, Podocarpus spicatus, P. ferrugineus* all large trees. *Nestegis cunninghamii* present. Understory *Carpodetus serratus, Brachyglottis repanda, Cyathea smithii* and *C. cunninghamii, Coprosma tenuifolia, C. australia, Pseudowintera colorata, Melicytus ramiflorus*. Juvenile *Pennantia corymbosa*. *Cortaderia toetoe* at forest edge. Moss polster from under *D. cupressinum*. Access difficult because of dense understory.

Site 18

Altitude 657 m. Mangawhero Forest Walk. L.H. side of Mountain Road. *Weinmannia racemosa* forest emergent over tree ferns of *Cyathea* species. Large *C. cunninghamii* has a trunk of 45 cm diameter at

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breast height. Old stumps and fallen logs conspicuous, mainly *Dacrydium cupressinum* but angles of logs do not suggest windthrow. Dead *Dicksonia*, trunks only standing. Shrub layer sparse, spindly *Melicytus ramiflorus. Blechnum discolor* frequent especially on fallen logs. Young *Podocarpus totara* and seedling *P. spicatus.* Moss polster from base of *Dicksonia* fern, moss rare. At a later visit two sets of soil samples taken from centre of grove. Top 4 - 5 cm removed as it was very loose and full of debris, samples taken at 1 cm intervals from the two sites 10 cm apart.

Site 16

Altitude 747 m. Mangawhera Forest Walk L.H. side descending Mountain Road. *Dacrydium cupressinum* forest emergent over *Weinmannia racemosa* which forms a complete subcanopy but is still vigorous.

Below the *W. racemosa, Pseudowintera colorata, Coprosma tenuifolia, Elaeocarpus hookerianus* juvenile *Pseudopanax ferox* juvenile, seedling *Podocarpus spicatus* and *Nestegis cunninghamii.* Young trees and sapling *P. totara,* sapling *Nothofagus* and coppicing *W. racemosa. Asplenium flaccidum, Blechnum discolor* Moss polster from base of *D. cupressinum.*

Site 17

Altitude 686 m. Mangawhero Forest Walk. L.H. side descending Mountain Road. *Podocarpus* species emergent over *Nothofagus solandri* as a subdominant. Subcanopy *Weimannia racemosa. Podocarpus halli, P. spicatus, Dacrydium cupressinum* all large trees. Large stump of *D. cupressinum.* Shrub layer *Melictyus ramiflorus, Coprosma tenuifolia, Pseudowintera colorata,* young *W. racemosa* and sparse *Ripogonum scandens. D. cupressinum* 1.3 m high, young *P. spicatus* *P. totara*. Abundant *Blechnum discolor*, some *Astelia, Asplenium flaccidum*.

Moss polster from base of *P. spicatus*.

Site 20

Altitude 633 m Mangawhero Forest Walk. L.H. side descending Mountain Road.

Pole stand of *Weinmannia racemosa* under some very large *Nothofagus solandri*. *W. racemosa* are about 10 - 13 m tall but with many small branches and many trunks appear to be of the same diameter all the way up, possibly ageing coppice. Shrub layer *Brachyglottis repanda, Coprosma tenuifolia, Melicytus ramiflorus, Neopanax arboreum* and a few very young *Cyathea dealbata*, many *P. totara* saplings. *Blechnum discolor* abundant. Small *Cyathodes* species 50 cm high. *P. totara* and *P. spicatus* seedlings. Moss polster from old *Podocarpus* stump.

Site 13

Altitude 902 m L.H. side descending Mountain Road. *Weinmannia racemosa* thicket within a *Nothofagus - Podocarpus* forest. Many stems of *W. racemosa*, some appear to be growing from old fallen trunks, that is as coppice. *Podocarpus* and *D. cupressinum* are dead but upright. Shrub layer sparse but diverse, *Coprosma tenuifolia, Nestegis cunninghamii, Pseudowintera axillaris, Aristotelia serrata, Pseudopanax ferox, Phymatodes diversifolia, Blechnum discolor, Polystichum richardii, Asplenium falcatum, seedling Podocarpus ferrugineus.*

Site 19

Altitude 657 m Mangawhero Forest Walk L.H. side descending Mountain Road. Site bears park notice on succession;

'Here, various podocarp trees, maitai, miro, kahikatea and totara are over topping kamahi under which they regenerated.' Canopy fairly open. Dead and moribund *Weinmannia racemosa* are very tall with reduced crowns. Some *W. racemosa* have dead twiggy branches which suggests recent death possibly due to dry summer. Prolific undergrowth up to 2 m high. *Melicytus ramiflorus, Coprosma tenuifolia, Carpodetus serratus,* occasional *Cyathea dealbata*. *Podocarpus ferrugineus* up to 1 m.
Moss polster from base of large *D. cupressinum*.

Table 22 Data modern pollen rain from Mount Ruapehu

Sites →	13	14	15	16	17	18	19	20	Soil 5 cm	Soil 6-13 cm
Species										
D. cupressinum	9.7	42.6	18.8	25.8	17.0	22.7	37.0	5.4	40.0	46.0
Podocarpus	9.5	24.8	55.0	14.5	18.0	24.3	8.5	10.5	31.0	25.0
N. fusca (type)	12.7	22.5	8.7	12.0	35.0	2.1	1.7	58.5	15.0	16.0
Weinmannia	27.2	1.9	4.3	32.7	20.6	31.4	44.3	19.4	3.0	2.0
Coprosma	2.2	0.0	0.0	0.6	0.7	4.8	0.7	0.5	0.0	0.3
Nestegis	3.3	0.5	2.4	1.1	1.2	2.0	3.4	0.2	6.3	4.0
Other woody	4.4	11.5	4.0	3.8	1.8	7.8	2.4	4.5	3.8	3.4
Cyatheasmithii (type)	2.8	29.7	36.8	3.0	4.0	19.6	1.0	0.7	16.0	16.3
Dicksonia	0.0	0.9	0.0	0.9	0.5	4.2	0.0	0.5	11.6	2.8
No. of grains wood species	435	204	208	332	298	290	409	445	340[a]	363[b]

Pollen sum % woody species out of count 500 grains

a = average of 2 samples

b = average of 14 samples

The use of soil samples is only possible in mor soils (Moore and Webb 1978) and does not appear to have been widely investigated. The data obtained were therefore very carefully scrutinised by:

1) Comparing the values of the duplicate sets of samples from the two soil profiles.

2) Applying tests of significance were applicable.

3) Graphing the pollen spectra for the two profiles, Figure 7.4. It was considered that the pollen was sequential and had not been unduly disturbed by soil fauna.

Examination of the data of profile A showed that there was a significant difference between the uppermost sample and all those below it for the pollen of rimu and podocarps. Using the Mosimann method the following confidence intervals were obtained for a 95 percent confidence level.

Table 2 3 Confidence levels of soil sample 5 cm. Profile A.

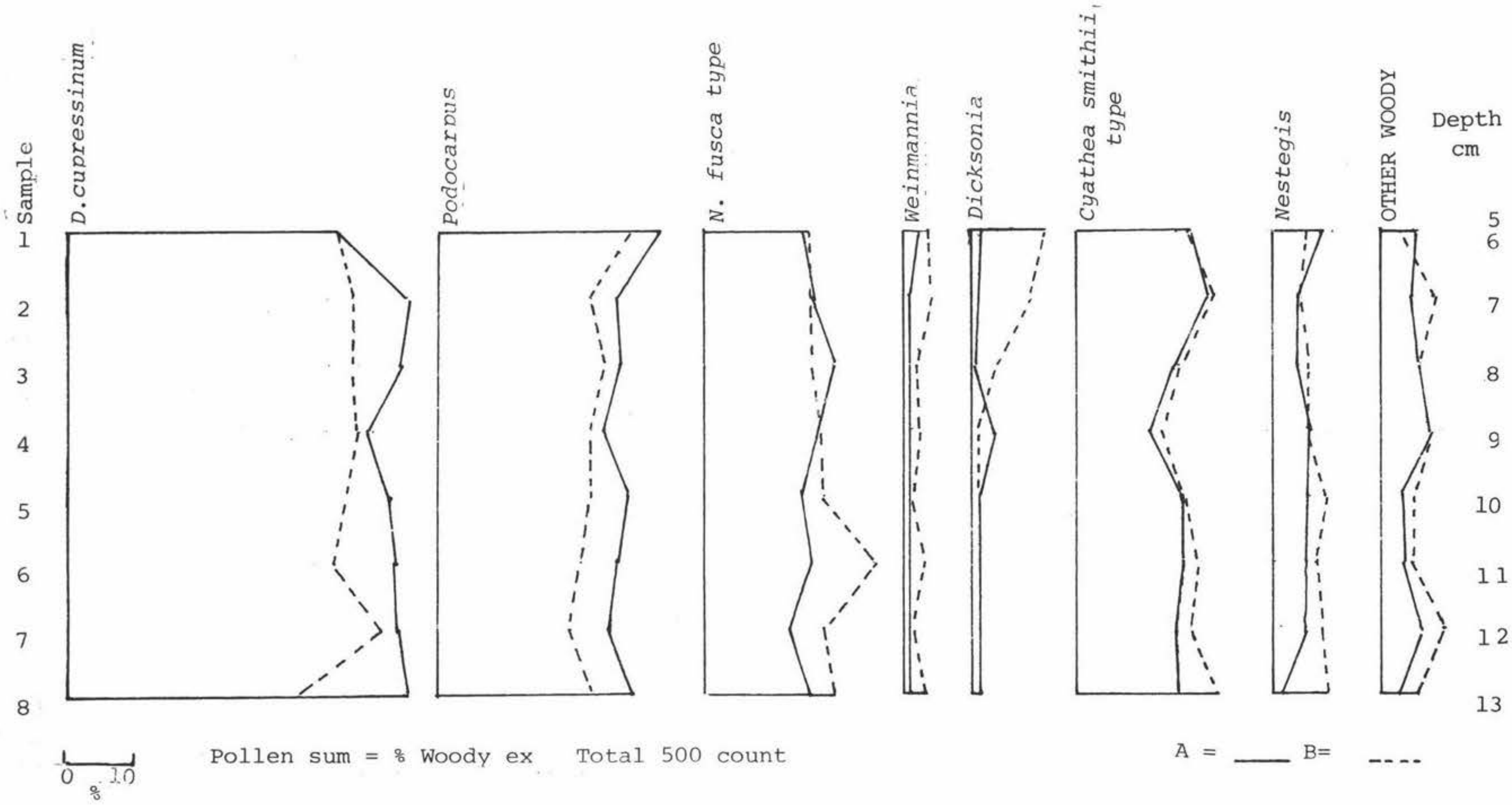
Species	Sample 5 cm	Confidence interval	Sample 6 cm
D. cupressinum	38.6 %	0.4409 - 0.3413	48.8 %
Podocarpus	32.6 %	0.4852 - 2837	26.3 %

Although the differences, for similar samples from profile B were not significant, when the two sets of samples were combined there was still a difference of 6 %.

Table 24 Confidence level of combined samples profiles A & B

Species	Sample 5 cm	Sample 6 cm	Samples 6 - 13 cm
D. cupressinum	40 %	45.6 %	46 %
Podocarpus	30.6 %	28.6 %	24.6 %

Figure 7.4 Pollen Diagram of Soil profiles A and B.



Pollen sum = % Woody ex Total 500 count

It was decided therefore to use the values of the combined 5 cm samples and the average of all the 6 - 13 cm samples to obtain maximum information from the limited data available.

Table 2.5 Summary of selected species. Soil profiles A & B

D. cupressinum	38.6	48.8	48.1	43.2	46.8	47.8	47.8	49.2
	41.4	42.6	42.6	44.1	42.3	40.2	47.9	35.6
Podocarpus	32.6	26.3	26.7	25.3	28.5	26.4	25.7	28.7
	28.6	22.6	25.1	23.4	23.6	21.6	19.7	23.9
N. fusca (type)	14.8	15.6	16.0	17.2	14.4	16.2	13.5	16.3
	15.3	16.3	19.0	17.6	18.0	24.5	17.8	19.3
Weinmannia	1.9	0.6	0.8	1.2	0.8	0.6	0.8	0.8
	3.8	4.1	1.2	2.1	1.4	2.7	0.6	2.4
Dicksonia	1.6	1.1	0.4	2.7	1.0	0.8	0.8	0.4
	11.6	9.4	3.8	1.2	1.6	0.8	1.4	1.6
Cyatheasmithii (type)	14.2	20.0	15.6	12.7	15.6	16.2	15.2	15.6
	17.8	18.6	15.4	13.2	15.2	18.5	17.4	19.6
Nestegis	6.3	3.6	3.5	5.1	5.1	4.4	4.7	1.6
	4.7	4.1	4.9	4.3	7.5	6.0	6.8	8.2
Coprosma	-	-	0.5	0.5	0.5	-	0.3	
	0.3	0.3	0.6	1.1	-	-	0.6	1.2
Other woody	4.4	4.7	5.5	7.1	2.7	3.8	6.0	2.5
	3.2	8.0	6.0	6.9	5.1	4.8	9.6	5.7

Data = Percentage of pollen sum of woody species from total count of 500

In the construction of Figure 7.5 two criteria were used;

1) Time control. The series 6 - 13 cm soil, 5 cm soil and site 18 pollen rain were linked in order over time and this had to be maintained.

2) Sequences had to be consistent with the appearance of the species in the field as recorded in the description of sites. A graph of the percentages of rimu and kamahi on Mount Ruapehu sites was constructed, Figure 7.5a. This was then compared with a graph Figure 7.5b of the data from the West Tamaki fossil pollen as set out in Figures 6.8 and 6.9. It was considered that the graphed line from the Ruapehu data sequence;

Soil 6 - 13 cm, soil 5 cm Sites 18, 16, 17, 20

was similar to the West Tamaki data.

It was realised that a critical test could be applied to the data as graphed by following a similar procedure for other forest species and more sites. Two additional criteria were used:

1) The rise and decline of any pollen type had to be internally consistent and not subject to frequent wide fluctuations.

2) Life cycles should be consistent with the literature as far as this was known. Indications for these are

Rimu and podocarpus 600 - 800 and maybe 1000 years Chavasse (1954).

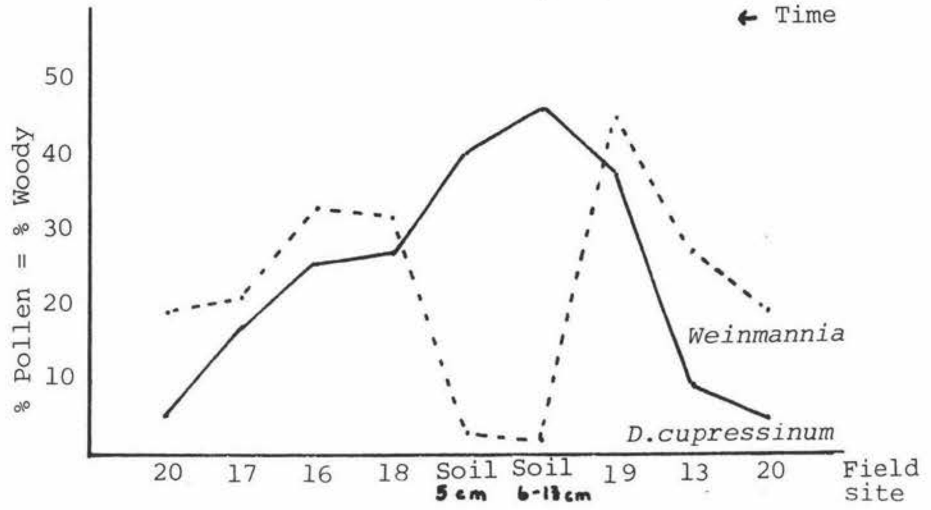
Beech 450 years Elder (1965).

Kamahi, Wardle *et al* (1966) state that life span is unknown but available growth data gives a maximum of 250 years from ring counts, (121 Table 1).

Background knowledge was also used to confirm the placing of one site in relation to any other sites. Figure 7.6 shows the resulting graph for nine pollen types and eight sites plus two soil samples. From this graph it is possible to propose the following stages in the life cycle of kamahi.

Figure7. 5 Percentage D.cupressinum and Weinmannia pollen at two localities.

a Pollen rain from Mount Ruapehu.



b Fossil pollen from CML 80/2 West Tamaki River.

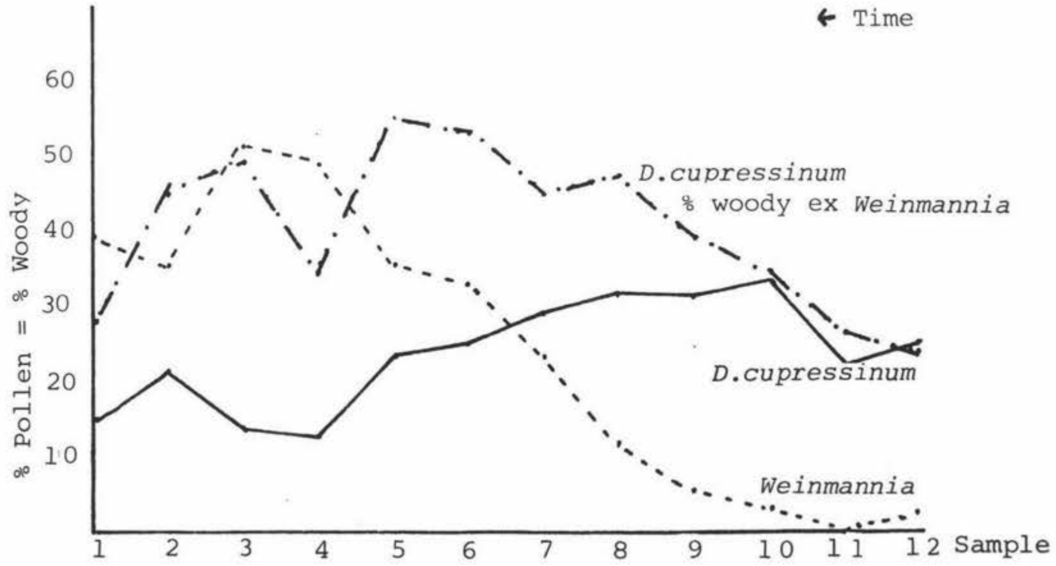
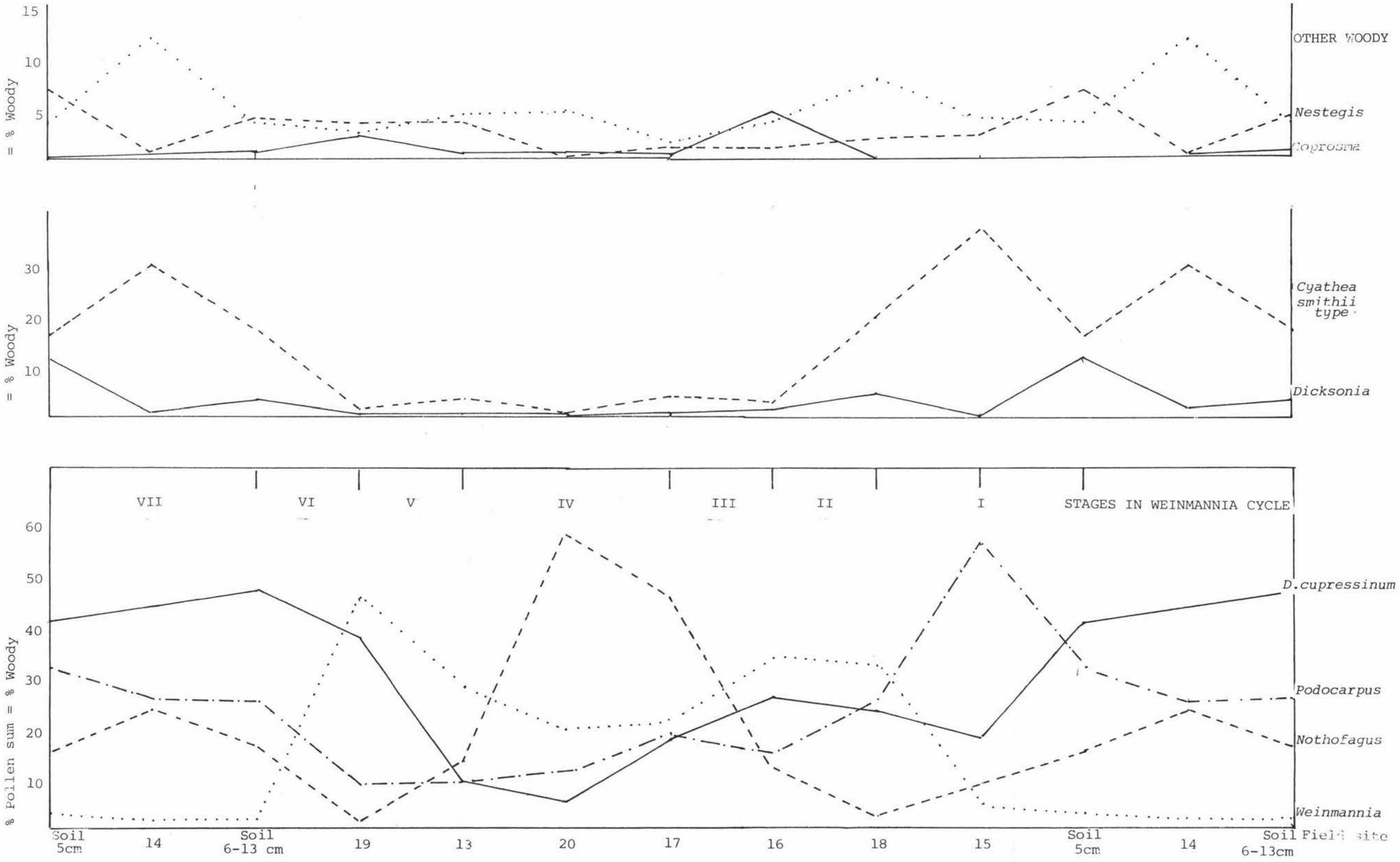


Figure 7.6 Succession in Podocarp -Broadleaf Forest derived from pollen rain studies.



Stage I

5 cm soil, Site 14, Site 18.

Kamahi establishes on dying and dead *Dicksonia*.

Rimu postmature, podocarps maximum pollen production.

Beech suppressed under podocarp canopy.

Cyathea abundant.

Stage II

Site 16

Kamahi reaches maturity.

Both podocarps and rimu postmature.

Cyathea suppressed by kamahi.

Growth of beech as canopy more open.

Stage III

Site 17

Kamahi shaded by beech but coppices, maybe two or three cycles.

Podocarps and rimu continue to age and may fall.

Beech increasing.

Stage IV

Site 20

Beech reaches maximum pollen production.

Podocarps and rimu at lowest production, aged and dying.

Kamahi continues to coppice.

Stage V

Site 19

Beech completes life cycle and dies.

Kamahi reaches maximum production under opening canopy but is ageing.

Rimu increases under the ageing kamahi acting as a nurse crop.

Podocarps similar to rimu.

Stage VI

Soil 6 - 13 cm

Kamahi dies.

Podocarps and rimu maturing.

Beech regeneration.

Tree ferns increase.

Stage VII

Site 14, - soil 5 cm

Kamahi not obvious at this stage.

Podocarps and rimu reach maturity.

Beech suppressed.

Discussion

With the limited time available it was only possible to collect, process and count one moss polster from each site. Again it is fully realised that the results found and the ideas developed would require extensive testing. What is presented here is an original idea and use of pollen analysis to obtain information about the present and immediate past history of some forest communities.

It is *very important* to realise that the data being graphed are an indication of *pollen production* and deposition. If it can be assumed that mature trees produce more pollen and that more trees will produce more pollen then the proportion of pollen of a species in the pollen rain may indicate not only the presence of the species but what could be called the reproductive vigour of a species. It is noted, however, that the highest percentage of kamahi pollen on any Ruapehu site occurs when the canopy is open, which agrees with the tentative findings from the Kahuterawa study and when it is obviously dying which agrees with the data from the West Tamaki site. For all species and pollen types, except rimu, maximum production is followed by a fairly rapid decline.

At no time is the pollen of any pollen type completely absent. This may be due to:

1) The regional pollen rain.
2) The uneven ages of the trees due to:
    i) A long life span for rimu and podocarps.
    ii) The coppicing habit of kamahi.
    iii) The suppression of beech until it has acquired adult foliage and a 'light pool' becomes available.

The presence of many stems of kamahi did not indicate that a high percentage of pollen would necessarily be found, this was so at sites 17 and 20.

Crops known to play a role as 'nurse crops' appear to be post mature as regards pollen production, if this indicates a decrease in vigour with possibly a reduction of root competition then this would explain why they are subsequently overtopped. This appears to be the case with kamahi succeeded by podocarps and *Dicksonia* which often serves as an epiphytic site for seedling kamahi but only when it is dying or dead.

The prime aim of this study was to gain information about the life cycle of kamahi. As the sites have been arranged it would appear that the coppicing of kamahi allows a 'stretching' of its life cycle to adjust to that of the much longer lived podocarps in *a podocarp beech forest at this altidudinal range.* Although the sites were plotted quite arbitrarily at equal intervals the proportionate life cycles do in fact fit quite well.

Validity of Results

Because this is a new approach to the study of forest communities every endeavour was made to check the data against previous work by other authors. Unfortunately there haven't been many studies made in this type of forest. Recent pollen spectra were studied by Moar at three localities in the South Island. The data from site a (i) for a *D. cupressinum* forest in the Westland National park and for a (ii) described as *Weinmannia* forest have been extracted from Moar 1970 214 Table 1. Pocknall studied relative pollen representation in relation to vegetation composition also in Westland (1978). The site description given for Snake Creek appears to be similar to that for site 18 Mount Ruapehu. A polster collected from the forest near the West Tamaki site was also analysed and compared to site 19 Mount Ruapehu. In this last case Mosimann's statistical analysis was used, the confidence interval is ± 5 - 6 percent for a woody count of 200+ grains at the confidence level of 95 percent. This data is set out in Table 8. Pocknall (1980) also investigated the sediments of Lady Lake, Westland. The graph given (279, Figure 3) appears to follow the same trend as for the rimu and kamahi on Mount Ruapehu.

A search of the literature for conflicting comments has not so far produced anything, though it is appreciated that the literature covers widely dispersed forests of this type. Comments on some points of particular interest have been grouped under the four most important species and 'forests in general'.

Table 2 6 Comparison of pollen rain for selected species from different localities

Site	%	Rimu	Kamahi	Podocarpus	*Cyathea*	*Dicksonia*
Moar (1970)	a (i)[a]	56	2	12	trace	-
Ruapehu	14 [b]	42.6	2	24.8	29.7	trace
Ruapehu Soil 16-13cm[b]		46	2	24.8	16.3	2.8
Moar (1970)	a (ii)[a]	8	39	32	16	2
Ruapehu	18 [b]	23	31	24	20	4
Pocknall (1978) Snake Creek	c	22	23	2	17	3
West Tamaki	b	29.3	29.3	10.4	16[d]	trace
Ruapehu	19 [b]	37	44.3	8.5	1.0	trace

a = % pollen sum = Total count less fern spores
b = % pollen sum = % Woody from total count 500
c = % pollen sum = Total pollen plus spores
d = origin swamp flora

i) Rimu. Franklin (1968) has collected the information available for this species in Biological Flora of New Zealand Number 3. The life history data is consistent with Figure 7.6. A comment by Cameron (1963) on the rooting habits of rimu and also Cameron (1959) on the lack of annual rings in the heartwood of this species could be taken to confirm the frequent establishment of this species on old logs, a fact which accords well with the lack of regeneration under living podocarps. Lloyd (1963) also comments on the problems of dating the annual rings of some indigenous species. There appears to be as much evidence for both a lack of young trees and the presence of young trees (Franklin 504-505). Detailed observations of one area over forty years are given by Hutchinson (1928, 1972) on the growth of young rimu.

ii) Podocarps. Robbins (1961, 67) quotes a personal communication from Chavasse on the mortality of podocarps and their replacement and the long delay before seed bearing due to the length of time required to break through the hardwood canopy. Nicholls (1956) gives evidence for the last 1000 years of podocarps becoming stabilised only under canopy breaks. The association of kamahi with both rimu and podocarps is remarked by many authors. McKelvey's (1953) remarks are typical of many. Many of the qualifications of statements formerly necessary can be explained if it is accepted that the kamahi life cycle is, as it were, stretched to fit the podocarp life cycle. It resolves the enigma of kamahi growing to maturity after establishment under ageing podocarps only to be present again when podocarps overtop it and yet trunks of kamahi show only up to 250 years growth.

iii) Beech. Druce (1957) describing succession in the Taita catchment, states that beech, unlike kamahi, is not adapted to a subcanopy environment, but to a well lit sheltered position, such as a 'light pool' formed by the death of a tree in a mature forest. He goes on to say that exposure causes die-back in young saplings until they have acquired adult foliage. The behaviour of the beech curves in the graph contrasts with all other species. In association with podocarps it can only reach maturity when the podocarps age and die. Both Nicholls (1956) and Ensor (1954) record podocarp regeneration under beech.

iv) Kamahi. Wardle *et al* has written about this species in Biological Flora of New Zealand Number 1. The establishment agrees with the graph. There are some indications of changes in the pH of the soil. Wardle quotes 'a more acidic type of mull humus'. In the Secretary Island studies Part 2 (Wardle 1963) gives a pH 6.1 (186 Table 2) for a kamahi/*Cyathea* stand. Unfortunately he does not give any examples for the rimu stands. Chavasse (1954) 'soils of pH 3.5 have been recorded in the Mahinapua forest, these once grew adequate crops of podocarps'. Does kamahi 'improve' the soil for podocarp regeneration? Poole (1937) quoted in Wardle *et al.* (1966) suggested a regeneration cycle in podocarps. Beveridge (1965) discusses the dispersal of rimu tree seed by birds resting on kamahi.

v) Forest in general. Wardle (1963) Secretary Island Studies Part 5. There appears to be a preponderance of small sized rimu when beech and kamahi are present, Stands I and IV A, (211, Table 1). In Part 9, (18) comment (c) applies, also (16 Table 1) Astelia Stream data at 1000' this site has:

a high percentage of beech trees and few young trees,
a small percentage of rimu trees and no young trees,
an equal percentage of kamahi trees to young trees (coppice?).

This site appears fairly comparable to those described in Figure 7.6 where beech is dominant. Bayliss and Mark (1963) Part 4, discussion on page 207 and the introductory comments on pages 203-204 seem to lend support.

The above references are only a small sample of the literature. A conspicuous feature of which is the continual qualification of statements made. There seems to be always some contradictory evidence. It is *very* tentatively suggested that lack of a framework into which the various seral stages can be fitted is the cause of much of this confusion. The following conclusions are offered with caution as it is fully appreciated that far more samples need to be examined to establish the validity of this hypothesis.

CONCLUSIONS

In the forest the trees may safely be left to speak for themselves by analysing the pollen produced by communities past and present. This method should give an accurate representation of forest history provided that the assumptions stated are acceptable. If accepted the following may be stated.

1) It is possible within the life span of the longest lived species, in this case *Podocarpaceae*, to discern patterns of succession in these species, also in beech and kamahi. Adjustments to the different life spans are made by,

  i) in kamahi, a coppicing stage

  ii) in beech, by stagnation of saplings until they have adult foliage and a light pool is available.

Within this infra structure tree ferns and other hardwoods also have their life cycles.

2) Indications are that some species act as 'nurse crops' for other species when they themselves are declining, and that no two species have their peak of pollen production at the same time.

3) Because the *Podocarpaceae* are so long lived and maturity depends on conditions of growth even aged stands are not produced, thus in the undisturbed forest there are always seed trees available due to the mosaic pattern which develops.

Growth reflects the interplay of many factors, edaphic, altidudinal, climatic, this further intensifies the mosaic leading to an infinite variation on the same theme.

4) It is possible that the controversy over the 'lack of podocarp regeneration' could be solved by looking in the right place, for forest in this altitudinal range that could be under the beeches.

5) It is suggested that kamahi does have a cyclic life cycle. So do podocarps, beech, *Cyathea, Dicksonia, Nestegis* and *Copromsa*, but their presence in the forest depends on the presence or absence of other species. The whole is ecologically integrated.

CHAPTER 8

OVERVIEW

The study sites

The Aranuian (postglacial) deposits of the south eastern Ruahine Range which have been investigated in this study have covered a range in altitude from 80 - 1,050 metres (Table 1) and have yielded radio carbon dates that span the whole period of approximately 14,000 years (Table 2). There is always an element of doubt until a date has been determined and one must acknowledge a certain element of good fortune in achieving such a sequence. When the date for the Taupo lapilli and the possible position of the Waimihia Ash are added the series then has seven dated points of reference and three periods of overlap. Some of the deposits, however, only afford brief glimpses of the palaeoecology of the sites. The two Ballantrae sites and that of Manawatu Gorge are short profiles covering only the period determined by the colonisation of *Leptospermum*.

All sites contain essentially forest pollen, although that present at the Delaware site must be regarded as regional. Apart from Ballantrae all other sites are still covered with native vegetation, Delaware at 1050 metres being leatherwood subalpine scrub, West Tamaki at 500 metres rimu-kamahi forest and the Manawatu Gorge at 300 metres tawa forest. It is considered that the Ballantrae sites may also have been in tawa forest or in a seral stage of this succession, before it was cleared for pastoral farming.

From the study of present day podocarp-hardwood forests between altitudes of 902-633 metres on Mount Ruapehu it was concluded that there is a cyclical succession of dominant species similar to that described by Cameron (1954).

This conclusion was reinforced by the pollen profile of the West Tamaki site with particular reference to rimu and kamahi.

The implication of this conclusion is that in considering the vegetation types as interpreted from a pollen spectrum it must be borne in mind that one may be seeing one or more seral stages in a very long term succession. It is therefore essential to have a measure for the degree of change that can be accepted as part of the variation within a population. Some criterion is required by which to assess the amount of variation that would be caused by a change in the physical environment. In this thesis the method outlined by Mosimann (1965) has been used giving a 95 percent level of confidence in the results obtained.

Climatic change

The two Ballantrae sites are particularly interesting because they are at the same altitude but separated by nearly 3000 years in time. West Ballantrae clearly shows that podocarp-broadleaf forest dominated by *Podocarpus spicatus* was present at the site as early as 13,000 ± 90 years B.P. The absence of *Dacrydium cupressinum* indicates that the climate at this time was either too dry or too cold or possibly both even at this low altitude for the survival of this species. About 3000 years later at East Ballantrae *D. cupressinum* pollen occurs at 45 percent and during the time period of this short profile *Ascarina* pollen also appears indicating an equable climate probably free from frosts and droughts (McGlone and Moar 1977).

The Manawatu Gorge site 200 metres higher and dated about 3770 years B.P. also has *Ascarina* present in a high percentage and increasing throughout the profile. *D. cupressinum* is also present at a higher percentage than all other *Podocarpus* species together. Thus at this time also the climate must have been free from frosts and droughts. About this same time or a little earlier *Ascarina* has a minor peak on the Delaware at 1050 metres. This is above its altitudinal limit according to McGlone and Moar (1977) and probably represents regional pollen whilst that at the Manawatu Gorge is presumably a local population.

The Delaware Ridge site lies close to Takapari which is the highest point in the southern Ruahines (Figure 6.3a following page 43). The most striking feature of the vegetation map (Figure 6.2 following page 42) is the almost complete absence of beech. There is just a small area of rimu-beech forest in the Makawakawa valley and some beech lies to the north of Takapari. A kāmahi-beech community starts at the northern head of the Tamaki catchment and is part of an extensive area of this type which covers much of the Pohangina catchment to the north and west (Strand 1977.22). None of the sites have beech on them at present. It is to be expected therefore that the percentage of beech at Delaware would be less than at other Ruahine fossil pollen sites (Moar 1961 and 1967) and examination of pollen diagrams show that this is so.

Licitis (1953) found that *Nothofagus* pollen was in the group of most abundant pollen types collected on atmospheric slides exposed at Napier, Rotorua, Wellington, Nelson and Christchurch, where all the rest were exotic species. He commented that *Nothofagus* indicated the spread of pollen masses in the air beyond the limits of the actual distribution of the trees. Myers (1973) found that *Nothofagus* was an important element in the pollen rain up to 60 km from the source areas thus confirming the findings of Licitis. Elder reports the information supplied by B.E. Sixtus (1965,42) that the present beech forests in the Pohangina valley are a remnant of a black beech forest which formerly covered the high ridge between the Oroua and the Pohangina Valleys.

To investigate the species of beech present in the lowest sample (90 - 100 cm) of site CML 80/1 Delaware Ridge, a count was made of the number of pores in 50 grains of *N. fusca* type, five were too crumpled to be distinguished, the results are as follows: 1 grain has 5 pores, 9 had 6, 20 had 7, 15 had 8 and no grains with 9 were seen. Cranwell (1939) found that *N. solandri* had between 6 - 8 pores of which 80 percent had 7, 0.3 percent had 5 none had 9. Although the sample was very small it does seem to indicate that the *N. fusca* type grains in the sample were most likely to be *N. solandri*. It seems reasonable to conclude that the beech pollen in the Delaware sample has been carried to the site by updraft from the forests below as suggested by Moar (1967).

Mention has been made in Chapter 4, 22 - 23 of the cause, persistence and effect of cloud in the southern Ruahines and the occurrences of the subalpine scrub species *Olearia colensoi*. Only a comparatively small percentage of the pollen in the surface samples from the moss polsters represents the many hectares occupied by this species. The fact that it is entomophilous may indicate that it represents a very local population and that the increase shown over the profile merely indicates its progressive colonisation of the bog. There is another possible explanation.

In interpreting the data from this site on page 53 the apparent link between the sharp decline in Dacrydioid pollen and the rise in *Olearia* pollen was noted as possibly indicating a change in the treeline. Calculation of an accumulation rate from the Taupo pumice to the present gives a rate of 0.03 cm per year or 1 cm in 33 years. The significant rise in *Olearia* is at the 10 cm level or about 330 years ago, assuming that deposition continued up to the cutting of the road, which would have altered the drainage conditions at the site.

Elder (1965) records the very poor state of the *Libodedrus - Dacrydium* formation in the southern Ruahines and assumes it is a relic of the much more extensive community which lies to the north. He considered that the deterioration followed a gradient of improvement with more sunshine. He noted that in the Ruahines to the south of the Pohangina valley low cloud was common. At Maharahara 67 percent of the days were cloudy while at Wharite there were only 11 percent of sunny days over a period of 13 months. An increase of *Olearia colensoi,* which Wardle (1965) regards as particularly well adapted to low insolation might indicate increased cloudiness.

Zotov (1938) concluded that in the Tararuas *Nothofagus* was absent from areas where frequent fogs reduced the radiant energy supply to such low levels that its seedlings could not compete successfully. Wardle (1964) suggested amending this hypothesis to read 'invading *Nothofagus* competes less effectively with existing vegetation where there is high rainfall or frequent fogs and therefore invades more slowly than under drier, sunnier conditions' (1964, 360). It is tentatively suggested that if the steady increase of *Olearia* pollen at the Delaware site does not represent a purely local colonisation of the bog then it may indicate a steady increase in cloudiness with a marked increase over the last 300 years or so sufficient to cause deterioration in the *Libocedrus - Dacrydium* formation. This high incidence of fog may be, as Wardle suggests, the reason for the lack of *Nothofagus* in the southern Ruahines. As has been pointed out before it is possible that the bog is of an earlier date than the Compositae wood which has been dated, the initiation of deposition at the site may have occurred as early as the change in climate recorded between the West and East Ballantrae sites. Moar suggested (1961, 353) that dates ranging from 8,000 - 12,000 years could be calculated for the two deep Mokai Patea peats. Table 27 shows a summary of the climatic indications for all sites.

Erosion.

Several workers have commented on the erosion that appears to be increasing in the southern Ruahines especially in the West Tamaki where several studies have been made. The details of these are presented in the two booklets edited by Dr V.E. Neall (1977, 1981) and have been mentioned in Chapter 5. The study of the fossil pollen sites does indicate that erosional events have been a part of the geomorphological history for the last 14,000 years. Evidence from the stratigraphic columns

Table 27 Summary of climatic indications for all sites

Date yrs B.P	Authority	Site	Altitude metres	Sample cm	Species	Climate indicated	Time	Pollen^{a} zones
13,300±200	NZ4651B	CML81/3 W. Ballantrae	80	40 - 0cm	*P. spicatus* dominant	Cooler & drier than present	14,000-10,000	1
10,540±150	Provisional only	CML81/9 E. Ballantrae	80	40 - 25cm	*D. cupressinum* increasing	Tending to warm and moist	10,000- 5,000	2
				25 - 15	*Ascarina*	Less frost & droughts		
				15 - 0	*D. cupressinum* dominant	Warm and moist		
8400 ± 130	NZ5274	CML 80/1 Delaware	1050	100 -70	Podocarp - broadleaf forest % *Olearia* small	*Possibly* less cloud than present	5,000 - present	3
3770 ± 90	NZ5231C	CML81/5 Manawatu Gorge	300	30 - 0cm	*D. cupressinum* *Ascarina*	Less frost & drought than present	b	
3420 ± 70	Waimihia Ash	CML80/1 Delaware	1050	87 cm	*Olearia* begins to increase	*Possibly* cloud increasing		
ca3200	Calculated rate	"		70	*Ascarina*	Less frost & drought than present		

Table 27 continued

Date yrs B.P	Authority	Site	Altitude metres	Sample cm	Species	Climate indicated	Time	Pollen[a] zones
		CML80/1 Delaware		65	*Ascarina* declines *Olearia* increasing	*Possibly* cloud increasing		
1819 ± 17	Taupo lapilli	"		55	*Olearia* increasing	"		
770 ±	NZ 4547C	CML80/2 West Tamaki	500	2 - 0	*D. cupressinum* *Metrosideros* *W. racemosa*	Same as present		

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a = Pollen zones McGlone and Topping (1977)

b = Agrees with McGlone and Moar (1977)

of both Ballantrae sites suggests a change in conditions due to the creation of a new channel and both profiles are terminated by deposition of gravel which could only be carried by fast moving water. The close proximity of the fault to the sites may have been a cause of these changes in the stream bed. This cannot be proved on the present evidence. Marden (1981,16) noted that 'Failure within the colluvium mantle results in *debris avalanches.'* Later he stated 'All forms of slope failure identified within the southern Ruahine Range are often found in association with faults. However, one form of slope failure *slumps,* shows a consistent relationship with known fault zones.' (Marden 1981,17). It is of interest that the layer of colluvium at the East Ballantrae site is thicker than that at the higher West Ballantrae site.

At the Manawatu Gorge site several large logs are embedded at an angle in the layered silts, it was not possible to discover the cause of their destruction or if this was the reason for the very large meander that now encompasses the swamp between the two greywacke ridges. The largest erosional event is that recorded by Hubbard and Neall (1980). They suggest that the very large alluvial fan formed following erosion in the Whiteywood creek caused the eastern valley to be blocked by gravel thus forming the swampy area at which CML 80/2 is located.

Inter-relationships between plants and land

The role of forest vegetation in helping to retain soil of sloping land was investigated by O'Loughlin and Pearce (1976). Grant (1981) in describing alternating periods of erosion and tranquil intervals stated that in the former vegetation on a wide range of sites is severely depleted or destroyed. During the latter revegetation of slopes occurs widely and sediment quantities decrease. Four of the five sites record these events. As has been shown they resulted from erosional events and they faithfully record the revegetation stages, and the stabilising of the ground.

The Ballantrae and Manawatu Gorge sites were colonised by *Leptospermum*. The steepness of the rise in the percentage of this species is due to its prolific seed bearing, its flowering and producing viable seed when the seedlings themselves are only 5 cm high and the early fastigate growth habit which prevents most other species from entering the dense stand of plants. The decline which can also be abrupt as seen in the profiles is due to the fact that as a light demander it rapidly succumbs once over topped by taller species (Cockayne 1928) (Grant D.A. 1966).

The sequence of events at the West Tamaki site was quite different. New ground was not exposed by disturbance of land by erosion but was actually created by swamp plants themselves trapping sediment from the surface of the surrounding hills. These clay and sand particles together with pollen and the organic debris from the plants formed nearly three metres of organic deposit in the short space of 770 years. The swamp plant at present on the site is *Cortaderia toetoe*. Esler (1978) records a comment by Kettle (1842) that *Phormium* increased after drainage of swamps. Esler concludes from this that toetoe occupied wetter sites than *Phormium* (flax). He goes on to say that while it is well known that toetoe can grow in very wet soil there are now insufficient undisturbed swamp areas to verify this point. His account was confined to the Manawatu on the west of the Ruahine Range. It seems likely therefore that the toetoe at West Tamaki has in fact been responsible for the transformation of the former narrow valley into a broad flat area of swamp. There is a high proportion of Gramineae pollen throughout the profile. If indeed such swamps are rare it could prove a useful area for an ecological study of this species.

The life cycle of *Weinmannia racemosa* (kamahi)

The last objective listed in the introduction was to attempt to discover details of the life cycle of the kamahi and it was extremely fortunate that the pollen profile at CML 80/2 provided such a clear representation of rising percentage of pollen being contributed by the kamahi population and its subsequent decline. With additional information contributed by the study of modern pollen rain on Mount Ruapehu it was possible to establish that the decline was in fact a natural one and not induced by browsing of oppossums.

Using the accumulation rate previously calculated for site CML 80/2 of 1 cm in 2.7 years it is possible to estimate that a time period of approximately 200 years (70 cm of the profile) is required for kamahi at this altitude to reach a peak of pollen production. Observations of a stand of podocarps and kamahi that produced the highest percentage of pollen at any site on Ruapehu showed that kamahi was in fact in an unhealthy state. This was site 19 which is noted by the Park board as a succession site with podocarps overtopping the kamahi. It seems likely therefore that a single life cycle would approach the span of 250 years, the maximum recorded in the data on growth in Wardle *et al* (1966). It was apparent that on Mount Ruapehu under some conditions kamahi coppices and these appeared to be when beech was also involved in the succession. As noted before, beech only occurs in the head waters of this catchment and was not seen on the site although the pollen is recorded in the profile. Dispersal ability of beech pollen has been dealt with in discussion of the Delaware site.

Comparison with other studies

Some points of comparison with the northern and western sites investigated by Moar (1961, 1967) have been made. There is, however, an interesting contrast in the apparently complementary variation between *Nothofagus* and *Podocarpus* curves which is remarkably precise in some of the pollen diagrams. There may be a technical explanation. Moar himself merely mentions the fact that marked fluctuations do occur. They do not occur at the Delaware site which is more remote from the sources of beech pollen. These fluctuations are regarded with interest in view of the successional patterns derived from the pollen rain studies on Mount Ruapehu.

In comparing the results found here with those of McGlone and Topping (1973, 1977) for Tongariro also in the North Island it can be seen that at some points they closely resemble each other. The West Ballantrae site would fall within their first zone and East Ballantrae within the second as set out on page 11 of this thesis. The marked period of a more equable climate between the Waimihia and Taupo eruptions is also indicated by *Ascarina* as found by McGlone and Moar (1977).

Commenting on the findings from South Island sites Moar (1971) found that forest seems to have become established in the South

Island about 10,000 years B.P. but that the spread was not synchronous. McGlone and Topping (1973) found that 13,800 years B.P was the earliest date for forest, this was at 600 metres so the earlier date of 13,300 years B.P. seems reasonable for the West Ballantrae at 80 metres. In the South Island the slow spread of *Nothofagus* into areas from which it is presumed to have been eliminated during the Pleistocene glaciations has been attributed to the limited range of the dispersal of the seed. Holloway (1954) states that this can only be carried downstream and hence the development of riverine beech forests with slow uphill spread from there. The shape of the rimu-beech forest in the Makawakawa valley certainly seems to illustrate this point. There is no indication on the Quaternary Geological map (NZGS 1973) that glaciation occurred on the Ruahines and Willett (1950) suggested periglacial conditions. Soons (1979) has, however, suggested that the cooling may have been much less only 4.5°C as against Willett's (1950) 6°C for the South Island. Other factors which may limit the spread of beech, especially the high incidence of fog, have been suggested by Wardle (1964).

Elder (1965) states that the beech community is aggressive at its southern border in the Ruahines and all the pollen sites record the increase in the percentage of beech pollen over that of *Podocarpus* pollen throughout the last 8000 years and maybe as far back as 12,000 years. If the beech was already present on the top of the range then it seems curious that it has not spread further along the broad plateaux of the Ruahines because Holloways restriction would not apply here. McGlone and Topping only suggest a cooling of 2 - 3°C for their first pollen zone for *P. spicatus* dominated forest and *Nothofagus* is stated by Holloway to spread in drier cooler conditions. The question is poised. Was *Nothofagus* eliminated from the crests of the Ruahines? Was it ever there? The answer would seem to lie in further studies of the pollen rain in areas dominated by *Olearia colensoi* to determine the dispersal range of this pollen.

Three species are worthy of special comment at this stage. *Ascarina*. Apart from the peaks mentioned on the three fossil sites this pollen was also recorded consistently in all counts of the West Tamaki profiles though always in small amounts. It was also recorded in 5 out of 8 samples of modern pollen rain on moss polsters from the Kahuterawa valley and in several samples from Mount Ruapehu. *Quintinia*. Elder does not list this genus in his report of 1965. It occurs first at the top of the East Ballantrae profile but only as a trace at the Manawatu Gorge site. It is present consistently below the 25 cm level in the Delaware sites and also as traces in the lower 45 cms of the West Tamaki. It was not identified in any of the modern pollen rain samples. *Dactylanthus* was recorded at the 20 -30 cm level on the West Tamaki site and at the 20 -21 cm level in the Delaware Ridge CML 81/6.

Conclusions

1) The palynological techniques used in this thesis have provided data for analysis and interpretation of organic deposits at the 95 percent confidence level.

2) Information obtained from the series of five dated sites indicates the following changes in climate over the last 13,300 years in the S.E. Ruahines.

i) Between 13,300 and 10,650 (provisional) a change from a cooler drier climate to a moister warmer one.

ii) About the 3200 - 3770 years a more equable climate existed with less frosts and droughts.

3) These findings support those of other workers on other postglacial sites.

4) There appears to be a succession of dominant species in the podocarp - broadleaf forests of Mount Ruapehu.

5) The decline of *Weinmannia racemosa* at site CML 80/2 was part of a natural cycle.

SUMMARY PART II

The field, laboratory and statistical methods have been described to together with the presentation of data. Testing of the data from two sites on the Delaware Ridge by Mosimann's method (1965) indicated the validity of the data base. Six profiles from five sites were sampled. The altitude range was from 80 - 1050 metres and dates spanned the last 14,000 years.

The geomorphology, stratigraphy and vegetation of each site was discussed and the percentages of pollen derived from several pollen sums was presented in a series of pollen diagrams; this pollen data was then analysed, interpretations were suggested and the relevance to pollen zones examined. Where relevant modern pollen rain derived from moss polsters at the sites were similarly investigated.

In an investigation into modern rain in the Kahuterawa Valley and on Mount Ruapehu information was obtained which assisted in determining the life cycle of one species *Weinmannia racemosa*. It was also possible to derive a succession of dominant species within the podocarp - broadleaf forests on Mount Ruapehu between altitudes of 633 - 902 metres. These results and conclusions were applied in interpreting the changes in the pollen curves for the fossil pollen sites.

In the final chapter all the sites have been reviewed as a series covering Aranuian time from 14,000 years B.P. Possible changes in climate were discussed and determined. In general findings agree with those of Moar (1961, 1967), (McGlone and Topping 1973, 1977) and McGlone and Moar (1977). The geomorphology of the sites as they relate to erosional events and the role of plants in the revegetation of the sites was discussed, in terms of the colonisation and stabilisation of the land.

Two new procedures developed during analysis were described, the use of pollen rain and soil samples to investigate a succession of species in a forest and the use of a scale of deterioration in the preservation of spores of *Cyathea smithii* type to determine changes in the preservation conditions at the site. Notes on the occurrence of three species have been made. Finally a list of conclusions has been presented.

APPENDIX

METHOD FOR THE PREPARATION OF FIELD SAMPLES FOR POLLEN ANALYSIS

1. Treatment with Potassium Hydroxide

A small quantity of the field sample is removed and placed in a Nalgene (plastic) centrifuge tube. 5 mls of 10 percent Potassium Hydroxide are added. A set of 8 samples is carried through each process. The 8 tubes are transferred to a 250 ml beaker which serves as a waterbath. The waterbath is kept just below boiling for 10 minutes and the contents of the tubes are stirred with long glass rods.

2. Sieving

Pouring the contents of the tubes through a 100 mesh sieve removes most of the extraneous material.

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

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

3) Pour the contents of a tube through the sieve, rinse twice with distilled water collecting all washings into a numbered beaker.

4) Repeat all the above for each of the 8 tubes.

5) All the filtrate must be centrifuged and decanted so that only the pollen remains in the tube. Centrifuge at 2000 revolutions/minute for 4 minutes.

3. Treatment with Hydrofluoric acid

The pollen remaining in the centrifuge tube is washed into a Tripor beaker with a small quantity of 70 percent alcohol.
ALL STEPS IN THIS SECTION MUST NOW BE CARRIED OUT IN A FUME CUPBOARD. THE OPERATOR MUST WEAR FULL PROTECTIVE CLOTHING, (acid proof apron, rubber boots, long rubber gloves and a face shield). THE SAFETY

OFFICER SHOULD BE INFORMED WHEN HYDROFLUORIC ACID IS BEING USED. GREAT CARE IS ESSENTIAL.

A small quantity of Hydrofluoric acid is added to each sample when it has been placed on a suitable waterbath in a fume cupboard. The amount to be added can be judged on the quantity of sand or silt in the sample and adjusted accordingly. The fume cupboard is shut down and not opened for at least 20 minutes. After this time (and wearing full protective gear) the beakers may be gently agitated using tongs to handle the beakers. The samples must be agitated from time to time and are ready when only a very small amount of liquid remains and all the sediment has gone, if some remains the process must be repeated. The beakers are removed and ALL the pollen rinsed out with 10 percent Hydrochloric acid the beakers are handled with tongs and plunged into a large quantity of water after the pollen has been removed. This pollen is rinsed with 10 percent HCl into clean centrifuge tubes for the next stage.

4. Flocculation

The tubes are now placed in a 250 ml beaker of warm water and heated gently but not allowed to boil. The silicates will pass into solution and the supernatant fluid will turn green, at the same time the precipitate will flocculate and circulate up and down the tube. This is a critical test, if this does not occur the tubes are centrifuged and fresh 10 percent HCl added and they are warmed again until flocculation is achieved.

5. Bleaching

The tubes are centrifuged to remove the HCl.

1) Add distilled water, stir and centrifuge again.

2) Add Bleach (recipe supplied) up to 3 cm below top of tube.

THIS REQUIRES CARE, BLEACH CONTAINS GLACIAL ACETIC AND SULPHURIC ACID. The tubes are left up to an hour and stirred from time to time, appearance should then be of finely divided material of a lighter brown. Centrifuge, decant into running water in sink.

6. Acetolysis

1) Add 3 mls of Glacial acetic acid to each tube. Stir, centrifuge, decant.

2) Share equally between the 8 tubes the acetolysis mixture which must be freshly prepared as follows:
Using extreme care, pour 1.5 mls of concentrated Sulphuric acid into 13 mls of Acetic Anydride, agitate very gently to mix.

3) Transfer the tubes to the 250 ml beaker waterbath which must be boiling, and heat for exactly 4 minutes stirring all the time. Remove from the heat.

4) Centrifuge and decant into running water in sink.

5) Add 5 mls Glacial acetic acid, stir, centrifuge and decant.

7. Staining

1) Add 10 mls distilled water to each tube, stir, centrifuge, decant.

2) Add 10 mls of distilled water and 3 drops of 10 percent Potassium hydroxide to each tube, stir, centrifuge and decant.

3) Add diluted Basic Fuchsin stain to each tube. Stir, leave approximately 10 minutes. Adjust depth of stain to quantity of pollen. Stir occasionally during this period. Centrifuge and decant.

4) Add 10 mls distilled water, stir, centrifuge and decant.

8. Mounting

Use rectangular cover slips size 40 x 22 mm.

1) Stir pollen gently. Use a new disposable pipette for each tube. Place two drops on slide, add two drops of warm Glycerine jelly and stir very gently into a dumbell shape with a sterile toothpick, warm gently on hot plate. Discard toothpick.

2) Using sterile forceps gently lower cover slip onto the slide. The film of jelly and pollen must be thin and without air bubbles and not too deeply stained.

Preparation of Bleach for treating fossil pollen

To make 500 ml.

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

Add 75.5 g of Sodium Chlorate.

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

Stir until Sodium Chlorate is dissolved.

If an electric stirrer is used, cover the container or the Chlorine and Glacial acetic acid content will be reduced by evaporation.

Preparation of Glycerine jelly

Dissolve 42 g of gelatine in 114 ml of warm distilled water, add 6 g of phenol crystals and 157 ml Glycerine (AR). Complete dissolving by gentle warming. When dissolved centrifuge in large tubes to remove insoluble residue. Bottle the jelly. If made correctly, it should set to a firm consistency. After the jelly has been heated a number of times (in order to prepare slides) it will become darker in colour, noticeably more sticky and less firm. At this stage it should be discarded.

Source

Dr M.S. McGlone and Miss Julie Shand of the Palynological Laboratory Botany Division, D.S.I.R., Lincoln.

THE MASSEY UNIVERSITY REFERENCE POLLEN SLIDE COLLECTION LIST OF SLIDES

Serial No:	Herbarium No:	Name	Authority of specimen
1	CML 116	*Parsonsia heterophylla*	A. Cunn.
2	CML 117	*Melicytus ramiflorus*	J.R. et G. Forst.
3	CML 87	*Laurelia nova zelandiae*	A. Cunn.
4	CML 100	*Brachyglottis repanda*	J.R. et G. Forst.
5	CML 152	*Myoporum laetum*	Forst. f.
6	CML 93	*Rubus cissiodes*	A. Cunn.
7	CML 28	*Macropiper excelsum*	(Forst f.)
8	CML 90	*Metrosideros diffusa*	(Forst. f.)
9	CML 106	*Podocarpus dacrydioides*	A. Rich.
10	CML 186	*Phyllocladus alpinus*	Hook. f.
11	MPN 004832	*Nothofagus fusca*	Hook. f. Oerst.
12	CML 188	*Phormium tenax*	J.R. et G. Forst.
13	MPN 005081	*Dodonaea viscosa*	Jacquin.
14	MPN 10139	*Cordyline australis*	(Forst. f.)
15	CML 180	*Leptospermum scoparium*	J.R. et G. Forst.
16	MPN 003437	*Podocarpus halli*	Kirk.
17	MPN 005113	*Neopanax arboreum*	(Muir)
18	MPN 001744	*Coprosma australis*	(A. Rich.)
19	MPN 005070	*Alectryon excelsus*	(Gaertn.)
20	MPN 13736	*Podocarpus nivalis*	Hook.
21	MPN 10007	*Potomogeton cheesmanii*	A. Benne.
22	CML 27	*Genisotoma ligustrifolium*	A. Cunn.
23	CML 126	*Cotula coronopifolia*	L.
24	CML 85	*Plagianthus betulinus*	A. Cunn.
25	CML 160	*Corynocarpus laevigatus*	J.R. et G. Forst.
26	CML 103	*Pittosporum crassifolium*	Banks et Sol.
27	CML 182	*Gaultheria crassa*	Allan nom. nov.
28	CML 205	*Discaria toumatou*	Raoul.
29	CML 176	*Cyathodes fraseri*	(A. Cunn.)
30	CML 25	*Hebe speciosa*	(A. Cunn)
31	MPN 004539	*Hoheria populnea*	A. Cunn.

Serial No.	Herbarium No.	Name	Authority of specimen
32	MPN 006307	*Elytranthe colensoi*	(Hook. f.)
33	MPN 003385	*Dacrydium colensoi*	Hook.
34	MPN 005729	*Coprosma areolata*	Cheesem.
35	MPN 00653	*Myrsine australis*	(A. Rich.)
36	MPN 004436	*Eugenia maire*	A. Cunn.
37	MPN 12676	*Pennantia corymbosa*	J.R. et G. Forst.
38	MPN 005209	*Griselinia lucida*	Forst. f.
39	MPN 004860	*Nothofagus solandri*	(Hook. f.) Oerst.
40	MPN 004854	*Nothofagus menziesii*	(Hook. f.) Oerst.
41	MPN 13930	*Carpodetus serratus*	J.R. et G. Forst.
42	MPN 003907	*Muehlenbeckia australis*	(Forst f.)
43	MPN 003681	*Ascarina lucida*	Hook. f.
44	MPN 005097	*Schefflera digitata*	J.R. et G. Forst.
45	MPN 003992	*Tupeia antartica*	(Forst. f.)
46	MPN 004980	*Loranthus micranthus*	(Hook. f.)
47	MPN 004076	*Myriophyllum species*	
48	MPN 003819	*Drosera arcturi*	Hook.
49	MPN 004579	*Weinmannia racemosa*	Linn. f.
50	CML 227	*Eucalyptus species*	
51	CML 189	*Bulbinella angustifolia*	(Kn. et Laing)
52	CML 96	*Coriaria arborea*	(Lindsay)
53	MPN 12780	*Fuchsia colensoi*	Hook.
54	MPN 10963	*Olearia colensoi*	Hook.
55	MPN 005636	*Nestegis cunninghamii*	Hook.
56	MPN 10960	*Olearia avicenniaefolia*	(Raoul)
57	MPN 001713	*Aciphylla colensoi*	Hook.
58	CML 198	*Dracophyllum acerosum*	Bergg.
59	CML 203	*Anisotome aromatica*	Hook.
60	MPN 004801	*Sophora microphylla*	Ait.
61	MPN 003862	*Colobanthus apetalus* *var. alpinus*	(Labill.) (Kirk.)
62	MPN 000163	*Carmichaelia odorata*	Col. ex Hook.
63	MPN 005204	*Griselinia littoralis*	Raoul.

Serial No:	Herbarium No:	Name	Authority of specimen
64	CML 233	*Pinus radiata*	
65	MPN 004817	*Nothofagus cliffortioides*	(Hook. f)
66	MPN 004875	*Nothofagus truncata*	(Col.)
67	MPN 002406	*Podocarpus spicatus*	R.B. ex Mirbel
68	MPN 002354	*Lycopodium volubile*	Forst. f.
69	MPN 002880	*Leptolepia novae selandiae*	(Col.)
70	MPN 003494	*Phyllocladus trichomanoides*	D. Don. in Lamb
71	MPN 002670	*Dicksonia fibrosa*	Col.
72	MPN 001829	*Knightia excelsa*	R. Br.
73	MPN 004102	*Fuchsia excorticata*	(J.R. et G. Forst.)
74	MPN 005615	*Myrsine divaricata*	A. Cunn.
75	MPN 004479	*Elaeocarpus dentatus*	(J.R. et G. Forst.)
76	MPN 002681	*Cyathea colensoi*	(Hook. f)
77	MPN 002647	*Gleichenia cunninghamii*	Heward ex Hook.
78	MPN 003502	*Pseudowintera axillaris*	(J.R. et G. Forst.)
79	MPN 003867	*Stellaria gracilenta*	Hook.
80	MPN 003563	*Hedycarya arborea*	J.R. et G. Forst
81	MPN 004529	*Entelia arborescens*	R. Br.
82	MPN 002575	*Lycopodium scariosum*	Forst.
83	MPN 004570	*Ackama rosaeifolia*	A. Cunn.
84	MPN 006355	*Pseudowintera colorata*	(Raoul)
85	MPN 000669	*Metrosideros robusta*	A. Cunn.
86	MPN 000711	*Typha muelleri*	Rohrb.
87	MPN 001775	*Quintinia serrata*	A. Cunn.
88	MPN 11015	*Olearia rani*	(A. Cunn)
89	MPN 11223	*Gentiana patuala*	(Kirk)
90	MPN 005333	*Hydrocotyle elongata*	A. Cunn.
91	MPN 000660	*Pentachrondra pumila*	(J.R. et G. Forst.)
92	MPN 005422	*Pernettya nana*	Col.
93	MPN 005064	*Dysoxylum spectabilis*	(Forst. f.)
94	MPN 002451	*Euphrasia cuneata*	Forst. f.
95	MPN 006005	*Cassinia fulvida*	Hook. f.

Serial No.	Herbarium No.	Name	Authority of specimen
96	MPN 005576	*Epacris pauciflora*	A. Rich.
97	MPN 002531	*Lycopodium billardieri*	Spring
98	MPN 005119	*Neopanax anomalum*	(Hook)
99	MPN 004657	*Acaena microphylla*	Hook.
100	CML 241	*Magnolia denudata*	
101	MPN 10308	*Spargarium subglossum*	Morong.
102	MPN 13318	*Tmesipteris tannensis*	Bernh.
103	MPN 002510	*Psilotum nudum*	(L)
104	MPN 002218	*Phymatodes diversifolium*	(Willd.)
105	MPN 003531	*Beilschmedia tawa*	(A. Cunn.)
106	MPN 12086	*Amoracia rusticana*	
107	MPN 001305	*Leucogenes grandiceps*	(Hook. f.)
108	MPN 12673	*Senecio lyalli*	Hook. f.
109	MPN 00678	*Celmisia spectabilis*	Hook. f.
110	MPN 003167	*Blechnun discolor*	(Forst. f.)
111	MPN 002138	*Polystichum vestitum*	(Forst. f.)
112	MPN 006982	*Gnaphalium collinum*	Labill.
113	MPN 10896	*Helichrysum glomeratum*	(Raoul)
114	CML 237	*Cupressus macrocarpa*	
115	CML 247	*Ulex europaeus*	
116	CML 243	*Juncus bufonius*	
117	CML 291	*Taraxacum officinale*	
118	CML 292	*Plantago lanceolata*	
119	MPN 10281	*Sporodanthus traversii*	(F. Meull.)
120	CHR 108946	*Carex virgata*	Sol. en Hook.f.
121	CHR 2447	*Ranunculus insignis*	Hook. f.
122	CHR 100990	*Nertera balfouriana*	CKn.
123	CHR 202520	*Epilobium wilsonii*	Petrie.
124	CHR 1762080	*Histiopteris incisa*	(Thunb.)
125	CML 284	*Pyrrosia serpens*	(Forst. f.)

Sources:

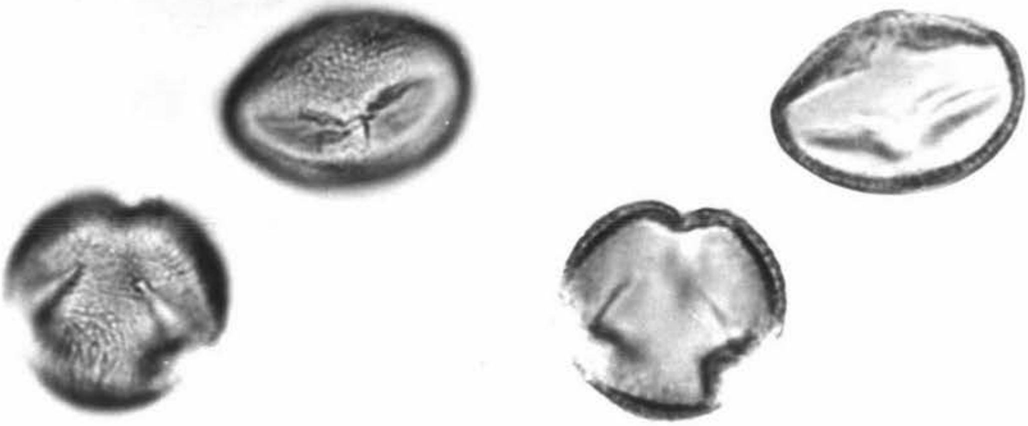
Flora of N.Z. Vol. 1. (1961) H.H. Allan
Flora of N.Z. Vol. 2. (1970) L.B. Moore & E. Edgar

PHOTOGRAPHS OF POLLEN GRAINS AND SPORES

These photographs were taken at the New Zealand Geological Survey Palynology Laboratory under the instruction of Dr I.J. Raine. A Carl Zeiss photo microscope (675) was used. The film was 35mm, Pan F 18 din. exposure 1 second. Objective oil immersion x 54, eyepiece x 12.5 giving a magnification of x 675. The film and prints were processed by the Central Photographic Unit of Massey University. The film was enlarged either x 2.5 or x 5 depending on the size of the pollen grain.

Ref. No.	Species	Magnification
Plate A		
11	*Nothofagus fusca*	x 3375
40	*Nothofagus menziesii*	x 1688
54	*Olearia colensoi*	x 3375
31	*Hoheria populnea*	x 1688
73	*Fuchsia excorticata*	"
41	*Carpodetus serratus*	x 3375
43	*Ascarina lucida*	"
35	*Myrsine australis*	"
Plate B		
67	*Podocarpus spicatus*	x 1688
64	*Pinus radiata*	"
87	*Quintinia serrata*	x 3375
8	*Metrosideros diffusa*	"
98	*Neopanax anomalum*	"
76	*Cyathea colensoi*	"
71	*Dicksonia fibrosa*	x 1688

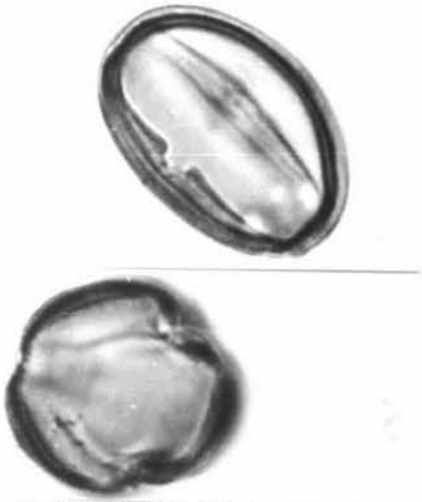
Ref.No.	Species	Magnification
Plate C		
6	*Rubus cissoides*	x 3375
72	*Knightia excelsa*	"
42	*Meuhlenbeckia australis*	"
63	*Griselinia littoralis*	"
80	*Hedycarya arborea*	"
Plate D		
84	*Pseudowintera colorata*	x 3375
13	*Dodonaea viscosa*	"
47	*Myriophyllum* sp.	"
55	*Nestegis cunninghamii*	"
10 - 15 cm	West Ballantrae Unknown	"
Plate E		
20 -,30 cm	West Tamaki general view.	x 2363
20 - 30 cm	Monolete A *Histiopteris*	x 3375
124	*Histiopteris incisa*	"
111	*Polystichum vestitum*	"



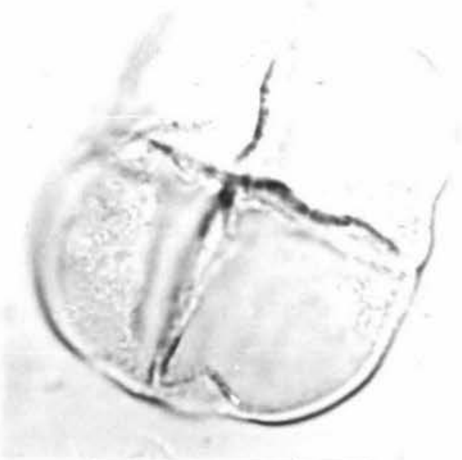
Rubus cissoides

Knightia excelsa

Muehlenbeckia australis

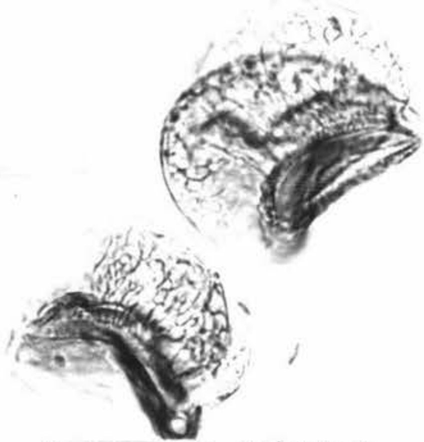


Griselinia littoralis



Hedycarya arborea

Plate A



Podocarpus spicatus

Pinus radiata

Quintinia serrata

Metrosideros diffusa

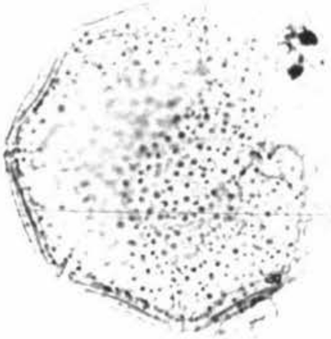
Neopanax anomalum

Cyathea colensoi

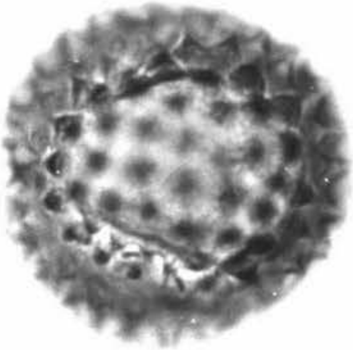
Dicksonia fibrosa

Plate B

Nothofagus fusca

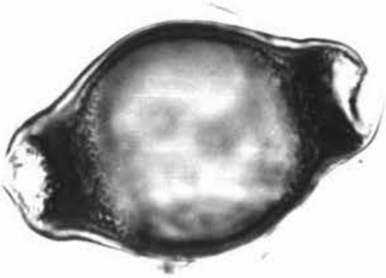


Nothofagus menziesii

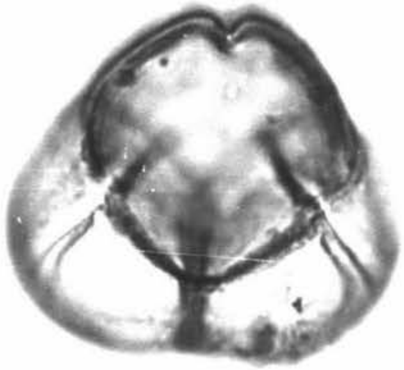


Olearia colensoi

Hoheria populnea



Fuchsia excorticata

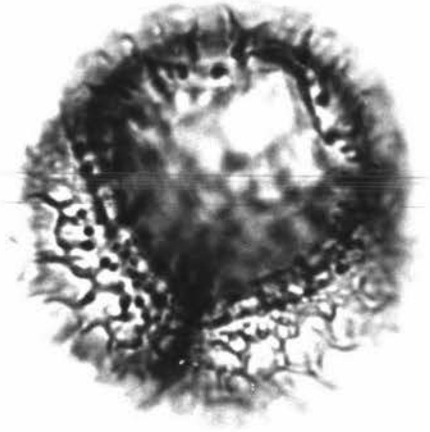


Carpodetus serratus

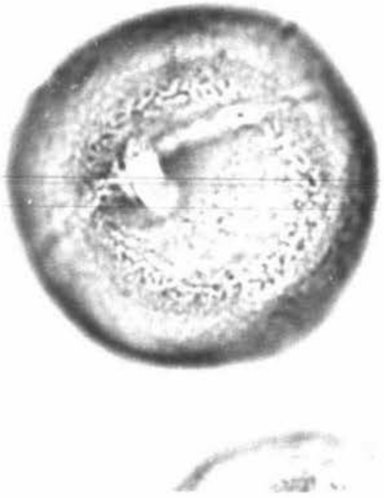
Myrsine australis

Ascarina lucida

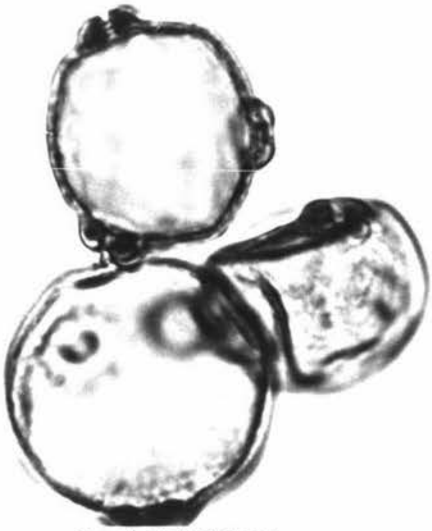
Plate C



Pseudowintera colorata



Dodonaea viscosa

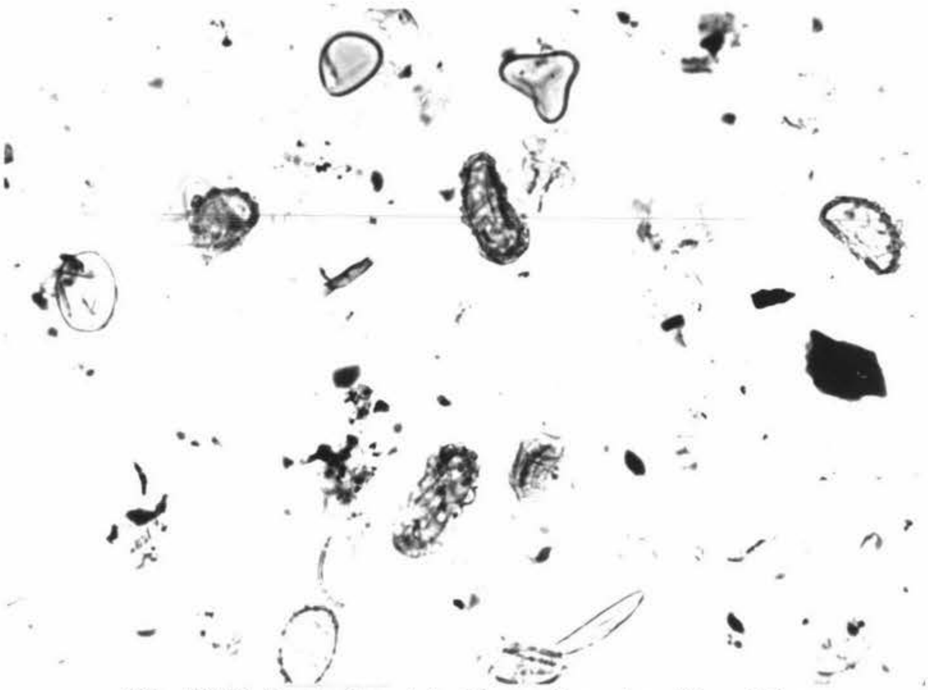


Myriophyllum

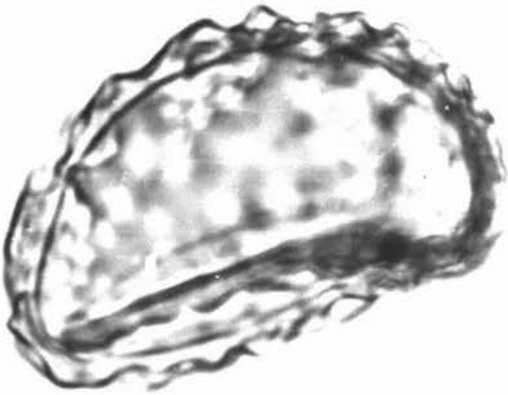
Nestegis cunninghamii

West Ballantrae Sample 10 - 15 cm. Unknown

Plate D

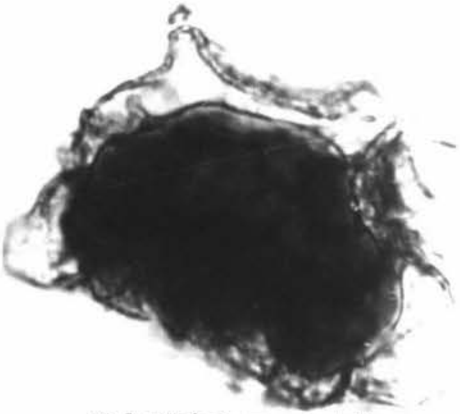


CML 80/2 West Tamaki River Sample 20 - 30cm.



Monolete A *Histiopteris type*

Histiopteris incisor



Polystichum vestitum

Plate E

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