Palaeoecology By Palynology: A Palaeoecological Study of the Vegetation of the Tongariro Volcanic Centre, New Zealand, Immediately Prior to the c. 232 AD Taupo Eruption.

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ABSTRACT.

The usual source of pollen for analysis has been from within deposits of peat from lakes, bogs and mires. Soils have not generally been considered a potentially useful pollen source. Under some circumstances, however, (such as volcanic eruptions) a soil may be buried so rapidly that the pollen it contains will be more or less completely preserved in the resulting palaeosol. Studies of such volcanically buried palaeosol pollen have been made overseas.

The last eruption from the Taupo Volcanic Centre occurred approximately 1800 years ago. The culminating phase of the eruption ejected *ca* 30 cubic kilometres of ignimbrite as a very hot and fluid pyroclastic flow which covered an area with a radius of 70-90 km centred on Lake Taupo. This deposit is known as the Taupo Tephra. The purpose of the present investigation was to examine peats and palaeosols directly beneath the Taupo Tephra from a variety of sites within the Tongariro area and to analyse any pollen preserved. Samples were taken from a total of 42 sites at various altitudes and distances from the eruptive source, and pollen extracted. Each sample taken, therefore, was from a buried soil or peat directly below the Taupo Tephra. The pollen contained within these samples and contains pollen deposited immediately prior to the eruption. An initial qualitative investigation indicated that the ignimbrite acts as an effective filter in preventing any contemporary pollen and spores from percolating through into underlying layers.

The preservation of pollen was reasonably good at most sites allowing some conclusions to be drawn as to the structure and composition of the pre-eruption forests of the Tongariro area. Beech forest was widespread throughout, especially at higher altitudes, although mixed conifer associations were also evident, particularly in the west.

At those sites where pollen preservation was poor, some alternative conclusions can be drawn about preservation environments within palaeosols. The pH value is particularly important, and pollen and spores are not well preserved when the soil pH value is in excess of 6.0. The possibility of differential preservation within the New Zealand flora is also examined.

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CHAPTER ONE: INTRODUCTION

1.1 Aims of the investigation

The Volcanic Plateau of the central North Island of New Zealand is dominated by Lake Taupo and the three andesitic volcanoes to the south of the lake - Ruapehu, Ngauruhoe, and Tongariro (Appendix E, Map of Tongariro National Park). These volcanoes are a part of the Tongariro Volcanic Centre, which also includes within its southern region the Pihanga massif, the small eroded centres Maungakatote and Hauhungatahi, and the two satellite vents of the Pukeonake scoria cone and Ohakune Craters (Donoghue *et al* 1995, Cole *et al* 1986).

Within the area to the south of the lake and around the volcanoes of the Tongariro National Park a significant feature of the landscape is a characteristic white layer of unwelded pumice material that is the Taupo Ignimbrite. This material is the result of a pyroclastic flow which was the culminating phase of the last eruption from the Taupo Volcanic Centre nearly 1800 years ago.

Beneath the layer of tephra clearly defined palaeosols can be seen in many outcrops and road cuttings. While the pyroclastic flow which inundated the area so dramatically and completely must have been a truly spectacular sight, the purpose of this study was to investigate the possibility that pollen and spores from the vegetation which existed up to the eruption might have been preserved within these palaeosols. It would then be possible to establish a generalized over-view of the vegetation of the area at a variety of altitudes and sites within the region. By studying the palynology of the region at a number of sites, some conclusions might be drawn as to the palaeoecology of the area prior to the eruption, where palaeoecology, as defined by Colinvaux (1993), literally means the ecology of the past.

A total of 42 samples were taken from 40 sites around the mountains to the south of Lake Taupo, ranging from just south of Waiouru to as far north as the Rangipo Prison Farm, and at altitudes ranging from just over 400 metres above sea level to just under 1300 metres (Appendix E, Map of Tongariro National Park). The sample taken at each site was from a buried soil, peat, or weathered allophanic material observed to be immediately below the Taupo Tephra, that is directly below the contact between the overlying pumice and underlying soil or peat. This represents the surface where the latest pollen was deposited prior to the eruption. The quality of the preservation of pollen and spores within these samples might also be used to draw conclusions as to the status of palaeosols as a preserving environment in those situations where suitable peat sites are unavailable.

1.2 Stratigraphy of the Tongariro Volcanic Centre

"The complexity and size of this eruption preclude accurate forecasting of the size, nature and return period of the inevitable next eruption from the Taupo Volcanic Centre." (Wilson and Walker 1985).

The volcanic landforms of the central North Island reach from the coast of the Bay of Plenty to the Tongariro region south of Lake Taupo. These landforms mark the subduction zone of the oceanic Pacific tectonic plate beneath the margin of the continental Indo-Australian plate. This subduction has caused melting of the plunging basaltic ocean floor and of the immediately overlying siliceous continental rock (mainly greywacke), and formation of magma chambers at great depth along a line running north-eastward from below the andesitic mountains of the Tongariro Ecological Region to the Bay of Plenty (Nicholls 1985). This line marks the Taupo Volcanic Zone which has been the source of countless, often very violent eruptions over the last 800 000 years. The three major eruptive centres in this zone are the Taupo Volcanic Centre and the Okataina Volcanic Centre in the central North Island, and the Tongariro Volcanic Centre to the south of the zone.

The Tongariro Subgroup of tephras is defined by Donoghue *et al* (1995) as those tephras erupted from the Tongariro Volcanic Centre over the last 10,000 years, including the Pahoka Tephra as the base unit. The interbedded Taupo Tephra lies within the Tongariro Subgroup immediately above the Mangatawai Tephra and below the Ngauruhoe Formation. Donoghue *et al* (1995) define the Ngauruhoe Formation as all andesitic tephras, including currently accumulating tephras, erupted from Mt. Ngauruhoe and Mt. Tongariro and overlying the rhyolitic Taupo Tephra Formation (dated *c.* 1,850 years B.P.) with the upper contact of the formation being the present soil surface. The Ngauruhoe Formation is described as very dark grey to dark brown fine ash and medium ash. The same authors define Mangatawai

Tephra as andesitic tephra which conformably underlies Taupo Tephra and overlies Papakai Formation, the upper contact being with Taupo Tephra and the basal contact being defined by the lower limit of the black ash beds. The base of Mangatawai Tephra contains beech leaves which have been radiocarbon dated (Donoghue *et al* 1995) at 2,500 +/- 200 years B.P. This gives the formation a maximum age of accumulation of *c.* 680 radiocarbon years. At the type section Mangatawai Tephra is described as 0.79 m of dark brown fine ash over 0.51 m of dark grey and very dark grey medium ash containing beech leaves (Topping 1973).

1.3 The Taupo Eruption

"It is evident that were the Taupo eruption to be repeated today, the devastation caused would equal or exceed that produced by the worst eruption in historical times." (Wilson and Walker 1985).

The Taupo Volcanic Centre in the central North Island of New Zealand has a long history of volcanic eruptions. Rhyolitic eruptions have occurred at least 28 times in the past *c.* 25 000 years (Wilson 1993), with the most recent occurring in AD 232 +/-15 yr (Sparks *et al* 1995). This event was characterised by a series of eruptions which generated a great variety of pyroclastic deposits: two plinian pumice falls, three phreatomagnetic ashes and several ignimbrite flow units (including some of the intraplinian type), and was one of the largest explosive eruptions in the world within the past 7000 years (Wilson & Walker 1985). The Taupo Tephra Formation (previously named as the Taupo Pumice Formation by Grange in 1931) comprises five distinct members - Taupo Ignimbrite, Taupo Lapilli, Rongotaio Ash, Hatepe Ash, and Hatepe Lapilli (Froggatt & Lowe, 1990).

The series of eruptions which make up the total event may have occurred over a few days or over several months. Most of the airfall deposits of the early stages were distributed to the east of the current lake, presumably as a result of westerly winds. The culminating eruption, however, ejected *ca.* 30 cubic kilometres of ignimbrite which is extremely widespread, covering a large area with a radius of 70-90 km centred on Lake Taupo. Evidence from buried *Phyllocladus alpinus* trees suggests that this final phase occurred in late summer or autumn, as the outermost growth ring is incomplete with little or no late wood (Palmer *et al* 1988). This is supported by the macrofossil evidence from the buried forest at Pureora, where Clarkson *et al* (1988) noted the seeding and fruiting of collected species to be consistent with that season of the year.

The site of the vent itself is on the lake bed within *ca.* 3 km of the modern Horomatangi Reefs (Wilson 1993). It has been suggested (Wilson & Walker 1985) that the parent flow to the Taupo Ignimbrite was erupted over roughly 400 seconds as batches of material which gradually coalesced, so that from *ca.* 40 km outwards the flow was a single wave of material. This flow moved at high velocities over a locally mountainous landscape at speeds which probably exceeded 250-300 metres per second near the vent and remained high (locally more than 100 metres per second) to the outer limits of the flow (Wilson & Walker 1985). An indication of the speed of the flow is that Taupo Ignimbrite occurs on Mt. Tongariro at 1500 m above sea level. This represents a world record for height climbed by a pyroclastic flow (Walker *et al* 1980). Further from the source the flow streamed off ridges and was strongly channelled through valleys leaving thick deposits of pumice in lower points of the landscape, as described by Nicholls (1985). South of Mt. Ruapehu there are no deposits of the ignimbrite visible between Tangiwai and Horopito on SH 49 as the flow was deflected around the sides of the mountain.

The ignimbrite deposited close to the source is physically significantly different from normal ignimbrite (NI). The term "fines-depleted ignimbrite" (FDI) was proposed as a descriptive term for this variant by Walker *et al* (1980). In this ignimbrite most clasts are coarser than about 2 mm and are clast-supported. In NI, clasts are always matrix-supported, and there is an even distribution of fragments smaller and larger than 2 mm. At some sites a phase transitional between NI and FDI, which shows a decreased content only in the finest size class, is described by the same authors as "weakly depleted ignimbrite" (WDI). Deposits of the Taupo FDI are found close to the source of the eruption, generally between about 15 and 24 km from the vent (Walker *et al* 1980). The Taupo FDI is characteristically unwelded.

A comparison of the effect of the pyroclastic Taupo eruption with the much smaller pyroclastic flow which resulted from the eruption of Mt. St. Helens on May 18, 1990, reveals that in the latter event the blast carried lithic ash and lapilli in a devastating hurricane over a northward sector of an arc of nearly 180 degrees, 30 km across from west to east and extending outward more than 20 km from the volcano's summit (Christiansen 1980). The result of this blast was the destruction of virtually everything within the inner area of just under 10 km. No trees remained in an area which had previously been covered with dense forests. Beyond this zone, almost to the limit of the blast, nothing remained standing, while at the outer limit the trees were seared by the heat. The much larger Taupo eruption is considered to have destroyed vegetation over a radius of about 50 km (Elder 1963), with charred fragments of vegetation being recorded 65-80 km from the approximate centre of the eruption (Grange 1931; Cunningham 1964).

The characteristic white layer of the Taupo Tephra is clearly visible in road cuttings and outcrops in the region. At some sites the upper section has a salmon pink colouring indicating the presence of haematite formed by heat generated from within the flow as it cooled after deposition. There are also sites where the force of the moving flow was sufficient to rip up the underlying soil and redeposit it within the ignimbrite. The charcoalized remains of the preexisting vegetation can be seen within the Taupo Tephra at many of the sites sampled, implying that even towards the distal edges of the flow the ignimbrite was still sufficiently hot to burn vegetation. McKelvey (1963) considered that the eruption destroyed hundreds of thousands of hectares of forest with at least an equivalent area being severely modified. Clarkson *et al* (1992) record forests flattened by the shock wave preceding the pumice flow and completely buried by tephra as far away from the vent as Mangapehi, 70 km north-west of Taupo.

1.4 Palynology

"There is only one fact in pollen analysis that always holds true: a pollen grain of a plant species came from a specimen of that species. What has happened between the time it left the anther until it was recovered on a microscope slide may be anything from just dropping down to a complicated story of transport and deposition and possibly redeposition." (Faegri and Iversen 1989).

Pollen grains are produced in the anthers of a flower and are the means by which male gametes are transferred to the female parts (the stigma) of the same or another flower wherein fertilisation of the ovule takes place. Pollen is chiefly transported from anther to stigma either by the wind (anemophilous pollination), or by insects (entomophilous pollination), although birds (ornithophilous pollination) are the pollinators of a number of species in the New Zealand flora.

Under certain circumstances those pollen grains which have not reached a stigma may fall to the ground and become trapped in the soil or various sediments within lakes or bogs. In a suitably preserving environment they may survive virtually unchanged for considerable periods of time. Traverse (1988) describes such an environment as usually being one which is acid rather than alkaline, reducing rather than oxidising, quiet rather than energetic, and especially, exclusive of oxygen. The outer layer of a pollen grain, the exine, is formed from a compound known as sporopollenin which is one of the most extraordinarily resistant materials known in the organic world (Faegri and Iversen 1975). The outer walls of the spores produced in the life cycle of pteridophytes are also composed of sporopollenin. The amazing resistance to decay of this organic compound means that it has been found in Palaeozoic rocks even when all other fossils have been destroyed, making pollen and spores the most widely known of plant fossils (Brooks *et al* 1971, Faegri and Iversen 1975, Traverse 1988).

The morphology of pollen grains and spores varies greatly from one species to another. Not only are grains a wide variety of different shapes, but the structure of the exine also varies greatly. This variety, combined with an amazing resistance to decay, means that both pollen grains and pteridophyte spores form good microfossils which can be identified by their shape and ornamentation with a relatively high degree of precision (Large and Braggins 1991), often even to species level.

The first modern percentage pollen analyses were presented by Lennart von Post in 1916, and since the middle of the 1920's pollen analysis has been the dominant method for investigation of late-Quaternary development of vegetation and climate (Faegri and Iversen 1975). In New Zealand, the first attempt to identify pollen grains from the native flora was made by Gunnar Erdtman in 1924 in a brief report on pollen analysis of peats from the Chatham Islands and from Otago (Moar 1993). Much of the early description of the pollen grains of New Zealand plants was done by Lucy Cranwell who published her descriptions of the southern beech pollens (*Nothofagus*) in 1939, the New Zealand conifers in 1940, and the monocotyledons in 1952. The first detailed pollen diagrams were published somewhat earlier in 1936 by Cranwell and von Post.

The actual quantity of pollen from any particular species which may be deposited within a specific area will be dependent on a number of factors as outlined by Faegri and Iversen (1989). These factors include the frequency of the species within the region, the absolute pollen production of the species, and the pollen dispersal mechanism of the species.

The total pollen deposited at a site has come from a source which may be immediately local, from a short distance, or from a considerable distance. Jacobson and Bradshaw (1981) describe pollen influx as local if the source is within 20 m, extra-local if it is from plants growing between *c.* 20 - 300 m distance, and regional when from plants more than 300 m away.

The lack of certainty as to the origin of pollen from a particular species also causes problems in the interpretation of site data when attempting to reconstruct the probable vegetation assemblage of the past. Cole (1996) considers the two most important and critical assumptions of palynological palaeoecology to be the influence of extra-local pollen and the representative quality of fossil pollen as a proxy index for historic plant population density. Faegri and Iversen (1989), however, conclude that the quantity of pollen produced by local vegetation is generally so immense that the quantities deriving from long-distance transport are relatively insignificant despite their absolute magnitude.

The pollen spectrum obtained from a particular site can provide a record of the vegetation within a certain area. However, this must be interpreted with care since differences in productivity, transport, and preservation of pollen between species mean that there is not a one-to-one correlation between the original representation of a species in the vegetation cover and its frequency in the recovered pollen spectrum (Faegri and Iversen 1989). Studies of contemporary pollen rain in New Zealand have also supported this statement (Pocknall 1978, Bussell 1988, Horrocks and Ogden 1994, McGlone and Wilson 1996, Elliott 1999).

1.5 Pollen in soils.

"At least as much, and normally more, pollen must fall upon a unit of dry ground as upon an equivalent bog surface, yet the fate of this pollen has aroused little interest." (Dimbleby 1957).

The usual source of pollens for palynological analysis has been from aquatic deposits of peat from lakes, bogs and mires. Soils were not considered potentially useful as it had been generally assumed that pollen would be broken down by microbial activity in aerated soils. Even if pollen were to survive, it was expected that the activity of soil organisms would serve to mix it with the organic substrate so that any stratification would be lost (Moore and Webb 1978). Despite these obvious potential shortcomings some use may be made of pollen deposited in soils. Dimbleby (1961) noted earlier work done in this area and cites authors such as Beijerinck in 1933, Dewers in 1936, and Erdtman in 1943. Dimbleby (1957), also noted that there are many areas where peats or sedimentary deposits are lacking and even the broadest conclusions produced by a study of soil pollen may be of great interest. He was able to show very high frequencies of nearly 1.5 million pollen grains per g of oven-dry soil from mineral layers, although raw humus also gave high counts.

An important difference between soils and peats as a source of pollens for analysis is the actual origin of the grains recovered at a particular site. In soil pollen analyses it is the vegetation growing on the site which contributes the bulk of the pollen, and such a site can not be expected to give a picture of the regional pollen rain (Dimbleby 1961). Within a forest canopy the influence of outside pollen is very limited; Dimbleby estimates it to be less than 3 per cent of the tree pollen. This filtering effect can also be expected to apply to scrub and shrub types of vegetation such as manuka scrub, but not to open grass or tussock country where the effect of distant pollen transport will be greater.

A further complication in the interpretation of soil pollen diagrams is caused by movement of pollen grains down through the soil profile. Peat or lake deposits accumulate progressively, and once incorporated within the deposit the pollens at a particular level can be assumed to have been deposited at the same time, as in general movement up or down within the profile does not occur (Faegri & Iversen 1975, Dimbleby 1985). The situation is very different in soils where grains may percolate down through the profile. This possibility implies that soil pollen analyses are not reliable when registering vegetational successions (Faegri & Iversen 1975), although they may give important information on changes in the local vegetation (Dimbleby 1961).

There are a number of other specific problems in studies of soil palynology. Firstly, the sporopollenin present in the exine is very readily oxidised and pollen grains are consequently rapidly degraded under aerobic conditions. However, the spores and pollen of different taxa have conspicuously different rates of corrosion. One of the most sensitive spores to corrosion is the fern spore *Polypodium* , while *Lycopodium* spores are particularly resistant, whereas pollen grains from conifers and various angiosperms being more easily degraded (Havinga 1971, Traverse 1988).

Where many grains in a sample are degraded or corroded it is then possible to conclude that active breakdown is occurring. Havinga (1971) has described a qualitative grading system where the sample is graded as largely unaffected, intermediately affected, or severely affected, based on the proportion of damaged grains in each sample. Where most grains were whole and entire the sample is regarded as largely unaffected, but where there is some degree of superficial corrosion, or loss of distinctive characteristic features, the sample is classed as intermediately affected. Those samples which are dominated by severely damaged and fragmented grains are considered severely affected. Dimbleby (1957) presumes that the converse may also hold: if few grains are in a decomposed state breakdown is not very active. Corrosion and breakdown of pollen exines and spore walls seems to occur especially in aerated circumstances as well as in alkaline conditions, with the possibility of some micro-organisms also being able to attack some exine types (Faegri and Iversen 1989).

In the second case there is also the problem of bioturbation by soil organisms. Earthworms and some millipedes are the main agents of soil mixing but they avoid acidic soils with low pH values (pH 4.5) which favour the preservation of pollen (Lees 1987). The importance of soil pH values in preservation of soil pollen has been determined by Dimbleby (1957) who concludes that soils whose pH is above 6 are virtually useless for pollen analysis, those between a pH range of 5 to 6 have small numbers of pollen present, while those below pH 5 have frequencies "of the same order as, and even in much excess of, the counts obtained on peats." Forest types such as beech and podocarp which produce characteristically moroid profiles, where acid organic matter often occurs as distinct layers concentrated at the surface of the soil (McLaren and Cameron 1996), are therefore potentially suitable for pollen analysis. Studies of the vertical stratification of pollen in a soil profile (Dimbleby 1957) show a decrease in total pollen content with increasing depth, and the main concentration near the surface. Since this upper zone is usually the area which is most biologically active, pollen preservation will be influenced by the soil pH with better preservation in more acid soils. Where soil pH increases pollens will be degraded and thus the records will be biased towards more resistant types (Traverse 1988).

The third aspect is that of pollen grains being removed down through the profile by the process of downwash. Dimbleby (1957) demonstrated a decrease in total pollen content as soil depth increases, with the main concentration of grains being near the surface, and pollen in countable frequencies seldom being found below a depth of 1 ft (30 cm). He also observed pollen grains frequently embedded in humic matter, which may have mitigated the effect of downwashing (Lees 1987). In general however, (Dimbleby 1985), the bulk of recent pollen is in the top 4 cm of the profile, although some grains will have percolated well down. At the same time, the bulk of the ancient pollen is in the lower layers, although some does still remain higher up the profile. Pollen of an intermediate age is spread over the profile, with its peak abundance between the other two.

In this study it is necessary to consider the possibility that pollen may percolate into or through the Taupo Tephra into the underlying palaeosol or peat, or even have been deposited within the flow at the time of the eruption. Although deposition is unlikely, due to the very high temperature of the ignimbrite flow, there is a possibility that ground water moving down through the tephra might carry post eruption pollens down to the palaeosol. The porous nature of the tephra may, however, act as a filter and trap pollens, in the same way as pumice lapilli in the Aokautere Ash have been observed to entrap minor illuviated silts and clays (Wallace 1987).

The thick deposits of the Taupo Ignimbrite, which so suddenly devastated the area around Lake Taupo during the eruption, can be seen to have buried and preserved the underlying soils at a number of outcrops in the region. Buried soils have been defined by Dimbleby and Speight (1969) as "a once-exposed geological substrate in which biological activity has taken place and which is now under a later deposit." Molloy (1988) gives a similar definition of a palaeosol as "a soil which formed at the land surface and subsequently was buried by other material." The overlying material may have been deposited by a variety of natural forces such as wind, water, or gravity induced mass movement of hillsides, as well as by anthropogenic action.

Some palaeosols resulting from burial by volcanic action have been examined previously in New Zealand, and several New Zealand palynologists have extracted pollen from these buried soils in different areas. McGlone and Topping (1983) found well preserved pollen in dark brown palaeosols below the Kawakawa Tephra (*c.* 22 590 yr BP) at a number of sites in the south-west Taupo region. Lees (1987) has also analysed pollen sampled from late Holocene buried soils between tephric and laharic layers from exposed roadsides and farm drains in the Taranaki region. Dimbleby (1985) also cites an intriguing overseas example with the work of Professor Wilhelmina Jashemski in the buried gardens of Pompeii.

1.6 Vegetation history of the Tongariro region.

"Modern pollen rain studies are the essential first step to the accurate interpretation of historical pollen spectra." (McGlone and Moar 1997).

The Tongariro region at present has a cool-temperate climate with an annual average temperature at 600 m of c. 10°C (de Lisle 1962). Snow is common over the winter months and may fall to 800 m, although it does not normally lie for long at lower altitudes. Frosts are common in winter. The annual rainfall is 1800-2500 mm, and droughts are rare although water deficits may occur in summer. The Tongariro Volcanic Centre includes the major andesitic volcanoes of Mts. Ruapehu (2797 m), Ngauruhoe (2291 m) and Tongariro (1968 m) which are sufficiently high to cause a rainshadow effect from the prevailing north westerly winds, resulting in reduced precipitation on their eastern flanks (McGlone and Topping 1977). The present climatic limit to tree growth on the Volcanic Plateau is at *c.* 1500 m (McGlone and Topping 1977).

During the last glaciation the climate in the Tongariro area was harsh, as it was certainly colder, and possibly drier, with annual temperatures being up to 6°C lower than at present; while Tongariro itself was extensively glaciated between 20 000 and 14 300 yr BP, with glacial retreat beginning before 14 000 yr B.P. (McGlone and Topping 1977). During the glacial maximum the Tongariro area probably supported a thin or discontinuous, rather depauperate vegetation cover (Rogers and McGlone 1989). McGlone and Topping (1977) summarise climate changes over the last 14 000 years as follows (Table 1.1):

Table 1.1: Climatic changes in the Tongariro region.

Years B.P.	Climate
14 000 - 10 000	Colder (up to 3° C lower annual temperature) and drier
10 000 - 5 000	Warmer and wetter than the present, but with marked fluctuations
5 000 - 3 500	Cooler and drier; possibly approaching present conditions
3 500 - 1 800	A recovery to slightly wetter and perhaps milder conditions
1 800 - 0	No reliable data

McGlone and Topping (1977) recognize three major post-glacial pollen zones. Botanical nomenclature is from Allan (1961) with revisions from Connor and Edgar (1987) and Webb *et al.* (1988) as cited in Poole and Adams (1990).

i) 14 000 - 10 000 yr B.P. *Prumnopitys taxifolia* (matai) forest was dominant. Annual temperatures may have been 2 -3 degrees lower than at present, but the climate was substantially drier.

ii) 10 000 - 5 000 yr B.P. *Dacrydium cupressinum* (rimu) forest was dominant and the climate much wetter and milder than at present.

iii) 5 000 yr B.P. - present. Return of *Prumnopitys taxifolia* -dominant forest, increase of *Nothofagus*, and a general trend away from the mild climates of the previous pollen zone to a more drought- and frost-prone climate.

Pollen evidence from bogs cored to the east of the Tongariro National Park in the nearby northern Ruahine Ranges at Reparoa and Three Kings (Rogers and McGlone 1989) shows a late glacial shrubland-low forest initially dominated by *Halocarpus bidwillii* (bog pine), then by *Phyllocladus asplenifolius* var. *alpinus* (mountain toatoa), with an increasing abundance of *Libocedrus bidwillii* (kaikawaka or pahautea). Beech forest of the *Nothofagus fusca*-type began expanding in the area at c. 8000 years B.P., although the shrubland-low forest association probably persisted at higher altitudes above the upper limit of *Nothofagus*. The vegetation immediately prior to the Taupo eruption was dominated by *N. fusca*-type (65%) with significant quantities of *D. cupressinum* (10%) and *Prumnopitys taxifolia* (15%).

Pollen analysis of mires in the Pureora region to the west of Lake Taupo indicates that the dryland vegetation in the area prior to the eruption was predominantly a *Phyllocladus trichomanoides* (tanekaha), and *Dacrydium cupressinum* forest (Clarkson *et al* 1986). A very thorough description of the pre-eruption vegetation using macrofossils such as leaves, trees and wood from the buried forest at Pureora (Clarkson *et al* 1988) also supports this forest composition. The forest reconstruction described by these authors is of a dense canopy, up to 30 m tall dominated by *P. trichomanoides* and *D. cupressinum,* with other podocarps also present including *P. taxifolia, P. ferruginea* (miro), *Podocarpus totara* (totara), and *Dacrycarpus dacrydioides* (kahikatea). Other species such as *Myrsine, Nestegis, Elaeocarpus, Metrosideros,* and *Libocedrus* occurred only very occasionally. The shrub layer, in order of abundance, was composed mainly of *Pseudowintera, Neomyrtus, Cyathea smithii* (katote), *Dicksonia, Pseudopanax, and Coprosma,* while *Blechnum discolor* (piupiu) was the most common ground cover species. Also interesting is the absence of a number of species common in the area today such as *Beilschmiedia tawa* (tawa), *Weinmannia racemosa* (kamahi), *Melicytus ramiflorus* ssp. *ramiflorus* (mahoe), and *Asplenium bulbiferum* (hen and chicken fern), as well as the presence of species which are now not in the area such as *Freycinetia baueriana* ssp. *banksii* (kiekie), *Gahnia xanthocarpa* (cutty grass), *Libocedrus sp.*, and *Cyathea colensoi.*

Within the study area, Wilmshurst and McGlone (1996) noted the presence of pollen from forest taxa at Wairehu including *D. cupressinum, Prumnopitys taxifolia, P. ferruginea,* and *N. fusca*-type. In the 5000 years leading up to the Taupo eruption there was a slight recovery in the ratio of *D. cupressinum,* and an increase in the *N. fusca*-type as well as in scrub and swamp tree species, with an overall change to forest more like that of the present (McGlone and Topping 1977). The same authors suggest that the gradual dwindling of species such as *D. cupressinum, Ascarina lucida* (hutu), *Dodonaea viscosa* (akeake), and *Alectryon excelsus* (titoki) during this period, combined with the previously mentioned forest changes, imply a climate trend towards the conditions of today. Steel (1989) comments that the Wairehu record indicates that *Nothofagus* forest, specifically *Nothofagus* *solandri*, was the dominant vegetation in the West Ruapehu region 2000 years ago. Horrocks and Ogden (1998b) also obtained very high *Nothofagus fusca*-type values (up to 48%) from the Erua swamp and suggest the presence of extensive regional forests further supporting Steel (1989) and Horrocks (1994).

Forest changes reflecting climate change are also supported by Ogden *et al* (1997) in a study of subalpine forest on Mt. Hauhungatahi, where increases in *Nothofagus*, *Libocedrus* and *Pteridium*, combined with decreases in species indicative of more stable forest association such as *Cyathea smithii*-type were noted. Pollen analysis from Gibson's Swamp, 5 km north west of Ohakune and just outside the area covered by the Taupo ignimbrite, indicates that the southern Ruapehu forests were tall podocarp forests with *Libocedrus* as a dominant canopy emergent (Horrocks and Ogden 1998a).

The area devastated by the eruption was once again covered in tall forests within 300 years of the eruption (Stevens *et al* 1988, Rogers and McGlone 1989). These forests were of a different composition from those destroyed by the eruption. In the west Taupo mires of the Pureora area Clarkson *et al* (1986) note that both beech and *Libocedrus* became rare after the eruption, while the previously unrepresented *Beilschmiedia tawa* became a more significant component of the vegetation.

McKelvey (1963) and Wardle (1991) have given a detailed description of the post-Taupo conifer/broadleaf (podocarp/hardwood) associations as they existed in historic times, and as remnants today. These associations were widespread throughout the lowland and montane regions of not only the Taupo basin, but also Bay of Plenty and Hawke's Bay. The general description of these forests is one where emergent podocarp trees (*Dacrydium cupressinum, Prumnopitys taxifolia, Prumnopitys ferruginea, Podocarpus totara,* and *Dacrycarpus dacrydioides*) tower above a canopy of flowering dicotyledonous trees such as (*Beilschmiedia tawa, Weinmannia racemosa, Knightia excelsa* - rewarewa, *Elaeocarpus dentatus* - hinau, *Nestegis spp.*, and *Quintinia serrata* - tawheowheo). Beneath the canopy, small trees (*Griselinia littoralis* - kapuka, *Alectryon excelsus, Carpodetus serratus* - putaputaweta, and *Coprosma spp.*) form a subcanopy with tree ferns (*Cyathea spp.*, and *Dicksonia spp.*). Climbers (*Passiflora tetranda* - kohia, *Clematis spp., Freycinetia baueriana* subsp. *banksii, Ripogonum scandens* - kareao, and *Rubus spp.*) and epiphytes (*Astelia solandri* - kowharawhara, and *Collospermum spp.*) occur throughout the tiers of the forest, while shrubs and ferns (*Pseudopanax spp., Melicytus spp., Myrsine spp., Aristotelia spp., Fuchsia excorticata* - tree fuchsia, *Brachyglottis repanda* - rangiora, *Coriaria arborea* - tutu, *Coprosma spp.* and *Pteridium esculentum*-aruhe) are found in light wells, clearings, and along forest margins.

Beech distribution within the eruptive area is irregular and somewhat reduced. Wilmshurst and McGlone (1996) note that at higher altitudes the montane and subalpine areas of the North Island axial ranges are dominated by structurally simple and species-poor *Nothofagus* forest. The five New Zealand representative taxa are *Nothofagus menziesii* (silver beech) and the four taxa of the *Fuscospora* subgenus, *N. fusca* (red beech), *N. truncata* (hard beech), *N. solandri, var. solandri* (black beech) and *N. solandri var. cliffortioides* (mountain beech), and they occur in this region in both mixed and pure stands. Within the nearby Kaimanawa and Raukumara ranges beeches can also occur in a mixed forest association with other broadleaved trees and podocarps.

In the northern section of the area studied in the current thesis, near Turangi on the Kakaramea, Pihanga and Tihia mountains, the most extensive beech forest is between 900 and 1050 m. Here it is close to the timberline, but descends in some areas to 750 m (Wardle, 1984). Some smaller islands of beeches also occur within other forest types, and most of these forests are dominated by red beech with occasional mountain beech and *Libocedrus bidwillii*. However, as described by Wardle (1984), silver beech is equally dominant with red beech on the northern and western slopes of Mt. Pihanga, although silver beech tends to be the more common species at higher altitudes, with red beech more common lower down. The sub-canopy species in these forests are usually *Podocarpus hallii* (Hall's totara), *Griselinia littoralis*, and *Pseudopanax spp.* with an understorey dominated by *Pseudowintera colorata* (mountain horopito), *Coprosma foetidissima* (stinkwood), *Microlaena avenacea* (bush rice grass) and *Blechnum spp.* At around 750 m altitude, both here on Mt Pihanga and on slow draining terrain in the area west of Mt Tongariro and Mt Ngauruhoe, on the Waimarino Plateau, the forest is a complex of podocarp and beech species where mainly mountain beech, but also red beech, intermingle with *Libocedrus bidwillii, Podocarpus hallii, Prumnopitys ferruginea, P. taxifolia, Weinmannia racemosa, Dacrydium cupressinum*, with frequent *Lagarostrobus colensoi* (silver pine).

The forests south of Turangi and to the west of Mts. Tongariro, Ngauruhoe, and Ruapehu, are dominated by beech species, especially red beech, silver beech and mountain beech, with black beech somewhat more limited. Wardle (1984) describes the Mt Ruapehu forests as mostly beech-softwood, often giving way to pure beech at higher levels, and with an irregular timberline of mountain beech which is the highest in the North Island, reaching 1510 m in places. Associated species forming an understorey at higher altitudes are *Phyllocladus asplenifolius* var. *alpinus* (mountain toatoa), *Coprosma pseudocuneata* , *Podocarpus nivalis* (snow totara), and *Gaultheria depressa* (snowberry). *Halocarpus biformis* (pink pine), and *Libocedrus bidwillii* usually appear below 1400 m, and from 1250 m, may co-dominate with mountain beech, especially on more gentle slopes. *Dacrydium colensoi* and *Podocarpus hallii* may also be present with an understorey usually of *Pseudopanax simplex* (haumakaroa), *Griselinia littoralis, Phyllocladus asplenifolius* var. *alpinus, Coprosma foetidissima, C. pseudocuneata, Leucopogon fasciculatus* (mingimingi), *Neomyrtus pedunculata* (rohutu), *Gahnia procera* and *Astelia nervosa.*

Silver beech is present in these forests, appearing at about 1220 m, and together with red beech both species dominate the canopy on the south side of the mountain below 1065 m (Wardle, 1984). Mountain beech is still present, but at these lower altitudes its distribution is restricted to stream margins, areas of poor drainage, and ridges. This association of red and silver beech forest usually has an understorey of *Griselinia littoralis, Pseudopanax crassifolius* (horoeka), *P. simplex, Carpodetus serratus, Podocarpus hallii, Myrsine divaricata* (weeping mapou), and *Coprosma foetidissima.* The forest floor is usually dominated by *Blechnum discolor.* At the lowest altitudes in the area, *Dacrydium cupressinum, Prumnopitys ferruginea,* and *P. taxifolia,* co-dominate with red and silver beech.

The distribution of beech species in the forests on the western side of Mt Ruapehu is one where both red and silver beech become scattered, and then fade out altogether towards the north of the mountain. The forests down to approximately 975 m (Wardle, J. 1984) are pure mountain beech, although in some areas *Libocedrus bidwillii* and *Dacrydium biforme* occur in the association. Mountain beech and black beech are still important below this level on sites where the drainage is poor, but the forest becomes dominated by *Dacrydium cupressinum* with *Prumnopitys ferruginea,* and *P. taxifolia,* and the associated hardwoods *Elaeocarpus dentatus, E. hookerianus*(pokaka), and *Weinmannia racemosa*. On well drained sites the beeches are almost entirely excluded.

At the time of the first colonising of the area by Polynesian settlers 800 - 1000 years ago, forest had once again covered the land devastated by the Taupo eruption. Various authors have since noted the beginning of a widespread and sustained anthropogenic destruction by fire of the forests which commenced c. 650-560 B.P. (Horrocks and Ogden 1998a, Rogers and McGlone 1989, Wilmshurst and McGlone 1996). When European settlers arrived after 1840 much of these forests had been destroyed, almost entirely as a result of uncontrolled burning by the Maori. What remained was extensively milled up until the 1960's (Nicholls 1985), so that today the only sizable area of remaining podocarp forest within the Tongariro Volcanic Centre is the stand on the lower flanks of Mt Pihanga. Current land use within the Tongariro region is centred on exotic forestry and farming in the west, although much of the area sampled in this study is currently within the boundaries of the Tongariro National Park. Extensive tussock grassland west of the Desert Road is within the park boundary, but the New Zealand army controls the area to the east.

CHAPTER TWO: METHODS

2.1 Site selection criteria and procedure

"When spores are deposited in sediments, in addition to microbiological and chemical alterations, there are three main physico-chemical factors that cause changes to occur; temperature, time and pressure." (Brooks 1971)

Prospective sites for sampling were chosen on the following criteria:

1. Sites were selected around the central North Island volcanoes (the Tongariro Volcanic Centre) at a variety of altitudes and distances from the eruptive source near the modern Horomatangi Reefs on the bed of Lake Taupo.

2. The covering layer at each site is the Taupo Tephra, that is the unwelded ignimbrite which represents the culminating phase of the Taupo eruption.

3. The current flood plains of rivers and streams in the area were avoided because of the risk of redeposition or contamination under fluvial deposits.

4. The sample taken at each site was from a peat, palaeosol or highly allophanic clay loam unit immediately below the Taupo Tephra. At those sites which are within the Ruapehu ring plain this represents the uppermost level of the Mangatawai Tephra, and indicates a sequence which is unlikely to have been disturbed or redeposited. At many sites the lower few centimetres of pumice was characterised both by slightly coarser granules of pumice than those higher in the layer, as well as by the presence of thread-like streaks of charcoalized material which presumably represent vegetation overcome by the volcanic deposit. The presence of this layer, particularly in some western sites where the Mangatawai tephra was absent, was also taken as an indication that the sequence had not been disturbed.

5. Sites within 15-25 km of the source of the eruption were chosen carefully as in this area the Taupo Tephra is in the form of fines-depleted ignimbrite (FDI) as described by Walker *et al* (1980). The

resulting deposit of coarse, unwelded pumice can be seen to be easily penetrated by roots which could allow the potential translocation of modern pollens down through the profile.

2.2 Site sampling procedure

Once a suitable site had been selected, a spade was used to clean current vegetation from the face of the profile back to a point where there was no sign of contemporary root penetration or bioturbation.

Each sample taken was from immediately below the contact between pumice and underlying soil or peat, as this represents the the latest pollen deposited prior to the eruption. A slice approximately one centimetre deep, ten centimetres long and three centimetres broad was removed and sealed in a labelled airtight plastic bag. The samples were then frozen and stored before processing.

A total of 42 samples were taken from 41 sites around the Central North Island volcanoes, from south of Waiouru at the southern limit of the Taupo Tephra, to the southern end of Lake Taupo (Appendix E, Map of Tongariro National Park). No suitable sites were found directly to the south of Mt. Ruapehu between Tangiwai and Horopito on SH 49, where the bulk of the volcano had obviously deflected the initial flow of the Taupo Tephra. Many suitable sites were found very conveniently in roadside cuttings or drainage ditches, but others were in stream banks or other naturally eroding physical features of the landscape.

2.3 Site locations and altitudes

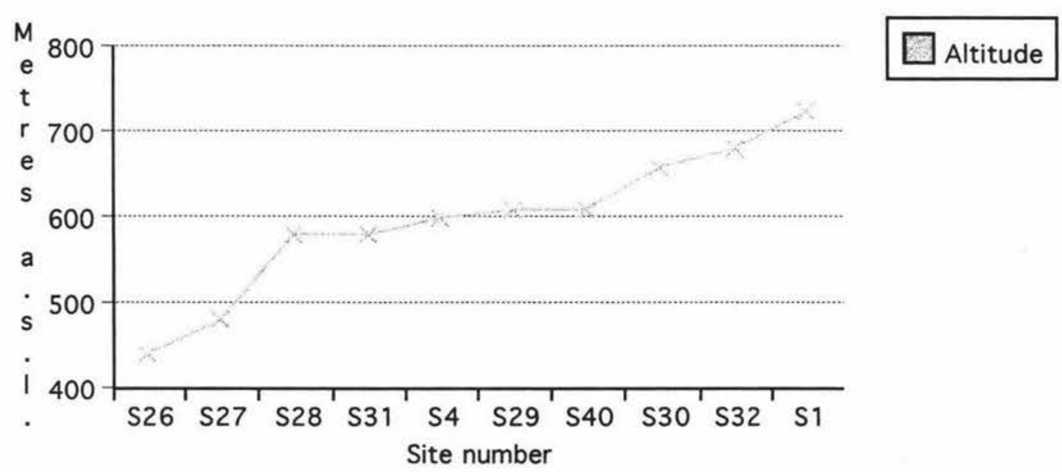
At each site a full description of the location was taken. This included a grid reference (GR), and the altitude in metres above sea level as indicated by the contours on the topographic map, as well as a description of the surrounding vegetation. The full stratigraphy of each sequence was also measured and described in detail.

Geographically, the sites can be clustered together in four groups as:

i) Northern group (10 sites north of Mt Tongariro and either on or north of State Highway 47 to the east).

Site 1 - West Ketetahi (GR: T19/400343), 725 m altitude
Site 4 - McDonnell's Redoubt Road (GR: T19/485323), 600 m altitude
Site 26 - Burma Road (GR: T19/569388), 440 m altitude
Site 27 - Hautu Road (GR: T19/569350), 480 m altitude
Site 28 - Te Ponanga Saddle Road (GR: T19/438391), 580 m altitude
Site 29 - Otukou Quarry (GR: T19/396386), 610 m altitude
Site 30 - Mangaparuparu Stream (GR: T19/343438), 660 m altitude
Site 31 - Mangahouhounui Stream (GR: T19/516319), 580 m altitude
Site 32 - Papakai (GR: T19/350363), 680 m altitude
Site 40 - Wairehu Canal (GR: T19/401398), 610 m altitude

Figure 2.1: Altitude range of sites in northern group.

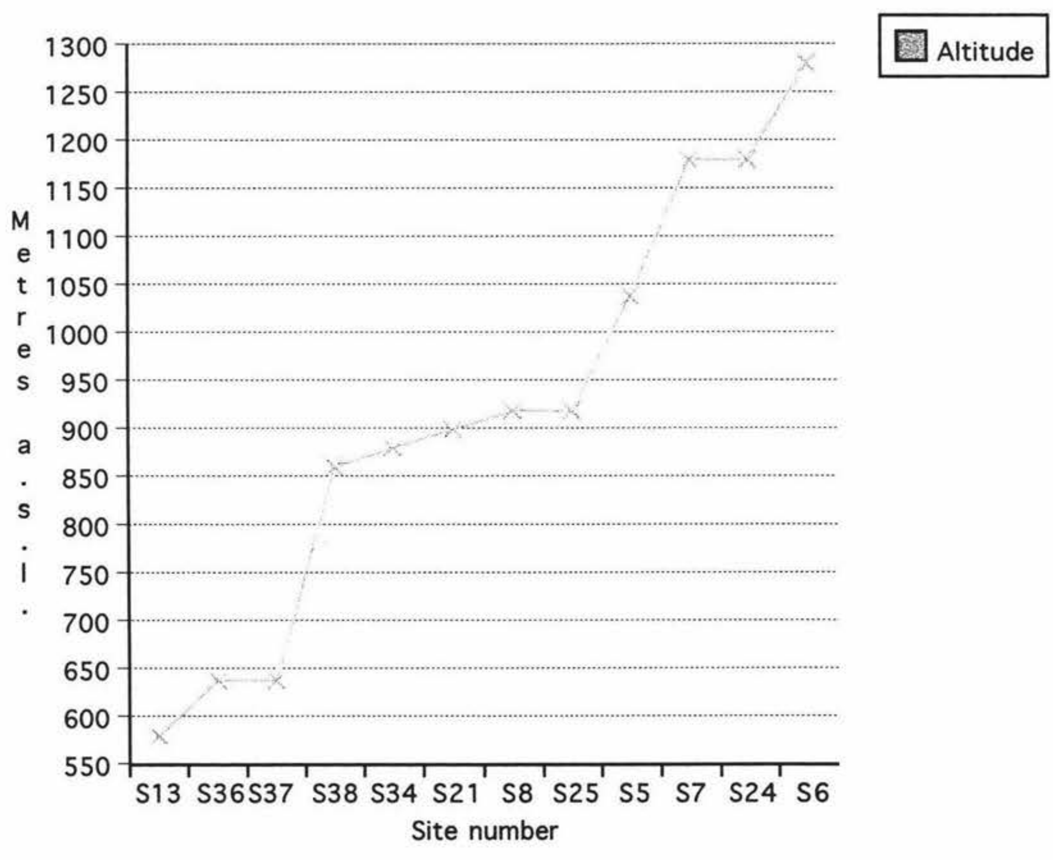


ii) Eastern group (12 sites on the eastern side of the volcanoes but north of Waiouru and south of the Rangipo Prison Farm)

Site 5 - Desert Road (tank crossing) (GR: T20/451050), 1040 m altitude
Site 6 - Upper Tukino Road (GR: T20/404118) 1280 m altitude
Site 7 - Lower Tukino Road (GR: T20/416105) 1180 m altitude
Site 8 - Waipakihi Road (GR: T20/498154) 920 m altitude
Site 13 - Poutu Canal (GR: T19/ 533294) 580 m altitude
Site 21 - Waihohonu Stream (GR: T20/480185) 900 m altitude

Site 24 - Upper Karioi Forest (GR: T20/379046) 1180 m altitude
Site 25 - Lower Karioi Forest (GR: T20/391986) 920 m altitude
Site 34 - North Waiouru (GR: T20/414955) 880 m altitude
Site 36 - Umukarikari Track (GR: T19/546257) 640 m altitude
Site 37 - Kaimanawa Road (GR: T19/524282) 640 m altitude
Site 38 - Mangatawai Stream (GR:T19/493236) 860 m altitude

Figure 2.2: Altitude range of sites in eastern group.



iii) Southern group (5 sites near Waiouru to the south east of Mt.Ruapehu)

Site 19 - West Waiouru (GR: T21/394893) 800 m altitude
Site 20 - Waitangi Stream (GR: T21/357894) 720 m altitude
Site 22 - South Waiouru (GR: T21/400852) 800 m altitude
Site 23 - Bates' Farm (GR: T21/377893) 730 m altitude
Site 41 - Makiokio Stream (GR: T20/407918) 810 m altitude

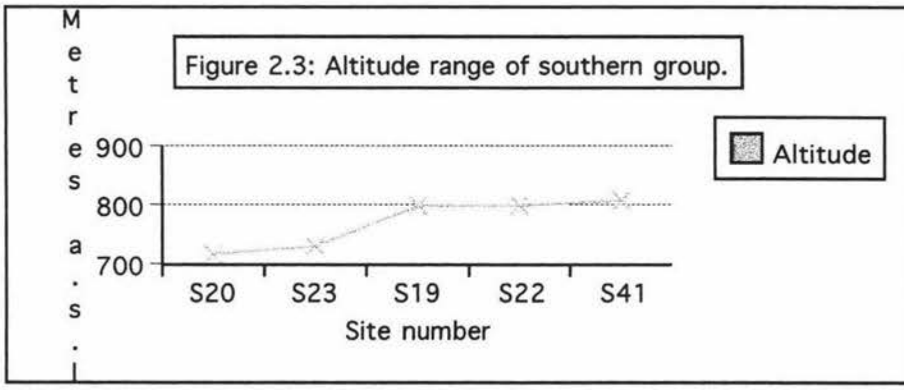
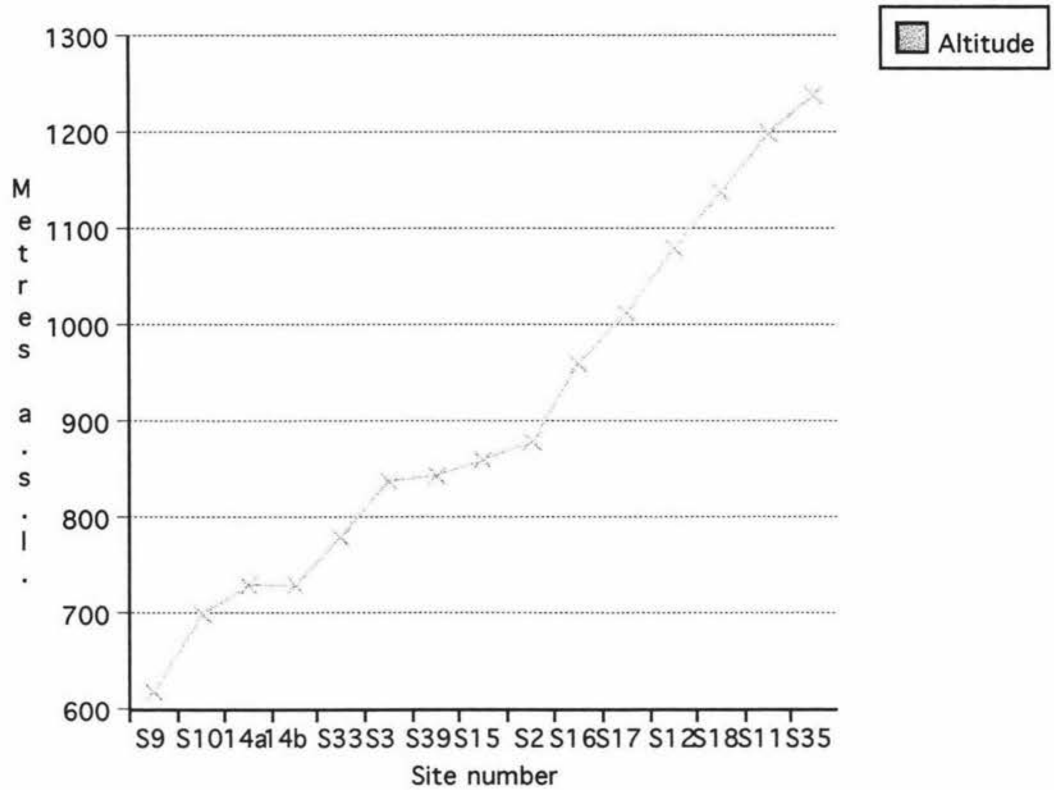


Figure 2.3: Altitude range of southern group.

iv) Western group (15 sites west of the volcanoes from Erua in the south to the Mangatepopo Stream in the north)

Site 2 - Whakapapa Intake Road (GR: S19/288286) 880 m altitude
Site 3 - Whakapapanui Bridge (GR: S19/266256) 840 m altitude
Site 9 - Okupata Intake Road (GR: S19/284368) 620 m altitude
Site 10 - Okupata Drop Shaft (GR: S19/287351) 700 m altitude
Site 11 - Pukeonake (GR: T19/321255) 1200 m altitude
Site 12 - Mangatepopo Valley (GR: T19/325261) 1080 m altitude
Site 14a - Erua Road (GR: S20/165171) 730 m altitude
Site 14b - Erua Road (GR: S20/160170) 730 m altitude
Site 15 - Whakapapaiti Bridge (GR: S19/236225) 860 m altitude
Site 16 - Lahar Mounds (GR: S19/265230) 960 m altitude
Site 17 - Whakapapa Road (GR: S19/283215) 1015 m altitude
Site 18 - Skotel, Whakapapa Village (GR: S20/297197) 1140 m altitude
Site 33 - North National Park (GR: S19/172253) 780 m altitude
Site 35 - Silica Springs Track (GR: S20/194181) 1240 m altitude
Site 39 - East National Park (GR: S19/189221) 845 m altitude

Figure 2.4: Altitude range of western group.



2.4 Extraction of pollen from palaeosols

"Pollen is relatively easy to extract from soils, and in most cases the presence of soil material does not seriously interfere with identification." (Dimbleby 1957).

The major problem encountered during this study was the presence of considerable quantities of volcanic glass throughout the samples, but this was overcome with the use of a liquid mount which permitted the rotation and displacement of grains.

The pollen extraction procedure outlined by Dimbleby (1957) for use with soils was used for both the peats and palaeosols sampled.

1. The samples were each placed in separate aluminium foil trays and air

dried for several days. Each tray was covered with a paper cover in order to prevent contamination with modern pollens during the drying time.

2. Once thoroughly dry, each sample was ground lightly with a mortar and pestle to break up any large aggregates, before being passed through a 1 mm sieve in order to remove coarse particles of pumice.

3. A standard weight of 1 g from each site was then processed with an added tablet of *Lycopodium* marker spores (batch no. 201890) (Stockmarr 1971), which had been dissolved in 2 ml of a 10% solution of hydrochloric acid. Each sample was placed in a 50 ml polypropylene centrifuge tube with 10 ml of a 10% solution of potassium hydroxide.

4. The sample tubes were then placed in a boiling water bath within a fume hood, and treated for 20 minutes in order to break down any humic aggregates. During this process each sample was occasionally stirred with a glass rod to assist in breaking up the material. Where necessary, samples were topped up with distilled water to keep the KOH concentration at 10%.

5. The material remaining was washed with distilled water, centrifuged at 3000 rpm for 3 minutes, and decanted. The residue was passed through a 125 micron sieve, washed in distilled water, centrifuged and decanted again. This washing, centrifuging, and decanting process was repeated twice more.

6. After the final decanting, the residue was then taken up in 5 ml of a 1:1 mixture of glycerine and water to which a 0.5 per cent alcoholic solution solution of safranin had been added at the rate of 1 ml per 50 ml. Each sample was then stored in a glass, screw-topped vial.

2.5 Counting procedures

"Pollen grains are always difficult to identify, whether from illustrations or from a key." (Faegri and Iversen 1975).

Two drops of each prepared sample were pipetted onto a slide and examined under a microscope at x40 magnification under a Zeiss microscope. The samples almost all contained considerable quantities of small shards of volcanic glass which were generally in the order of 1 -10 microns in length. The use of the previously described water and glycerol mount simplified identification of pollens and spores, in that by applying pressure to the coverslip of the slide, these shards could be moved away when they obscured a grain. It was also possible to roll grains over to assist in their identification.

i) Qualitative

Once processed, an initial qualitative assessment was carried out for each site. This involved scanning one slide per site identifying and recording the species present, the relative frequency of *Lycopodium* marker spores, and the general state of preservation of pollens and spores in the sample. Each site was qualitatively graded as largely unaffected (1), intermediately affected (2) or severely affected (3) using the rating system described by Havinga (1971).

ii) Quantitative

A second set of samples was prepared using the same methods and a quantitative assessment undertaken. At least two slides were counted from each sample, and a minimum total of 300 grains counted per sample. Each slide was scanned with consideration for the distribution of grains under a coverslip as outlined by Brookes and Thomas (1967). Counting was continued to the end of the slide once the requisite number had been reached to compensate for any differential movement under the coverslip (Dimbleby 1957).

The pollen sum of a sample defines the plant community from which the data will be interpreted (Faegri & Iversen 1975). As most sites sampled were of palaeosols rather than peats - only Site 2 (Whakapapa Intake Road), Site 3 (Whakapapanui Bridge), Site 10 (Okupata Drop Shaft), and 14a (Erua Road), are peat samples - the pollen count represents localised dry land assemblages with a minimum contribution of regional pollen rain. Under these circumstances the representation of pteridophyte spores is a relevant feature of the total pollen sum, as their inclusion is an indication of the vegetation type growing at each site prior to the Taupo Eruption. Percentages were therefore based on the total count of all taxa in each sample, following the principle of counting the requisite number of grains of the species or groups which are of interest (Dimbleby 1957). The peat samples were subjected to the same procedure to maintain consistency, and this also provided an opportunity to contrast their quality of preservation with the palaeosols.

The pollen grains and spores present in each sample were identified as completely as possible with only whole and entire grains being counted. Grains were identified as accurately as possible at least to genus level, although many were identifiable only to family or to type status. Where this was impossible the grain was recorded as unidentified. Many of the Podocarpaceae grains in particular were frequently difficult to identify beyond family level as distinguishing features of cappa and sacci were not well preserved at many sites. (Appendix A, Figure 5

Pteridophyte spores were not generally recorded more specifically than as a spore type, that is, as monolete, trilete and as fern allies (others) types, except where they provided some information as to the vegetation assemblage in the sample. These exceptions included *Cyathea smithii*-type, *Pteridium*, *Gleichenia*, and *Hymenophyllum*.

The initial qualitative analysis had indicated considerable differences in the state of preservation in each sample. Following the system described by Havinga (1971), the preservation status of each sample was qualitatively described as to whether pollen and spores were largely unaffected, intermediately affected, or severely affected. Those sites where most grains were whole and entire with little corrosion or fragmentation, and where the count of unidentified pollen and spores was low were classed as largely unaffected. Where there were frequent collapsed, folded, torn or corroded grains, generally matched with slightly higher unidentified counts, the site was classed as intermediately affected. Severely affected sites were those where preservation had been poor with very few grains in good condition, and where the count of unidentified pollen and spores was often very high. These ratings were expressed numerically as 1 (largely unaffected), 2 (intermediately affected), and 3 (severely affected).

Pollens and spores were identified by comparison with the Massey University set of pollen reference slides, from photographs kindly supplied by Dr. M. Elliott, from Moar (1993), Large and Braggins (1991), Cranwell (1952), McIntyre (1963), and Pocknall (1981a, 1981b, 1981c). Botanical nomenclature is from Allan (1961) with revisions from Connor and Edgar (1987) and Webb *et al.* (1988) as cited in Poole and Adams (1990). Some examples of common pollen and spores encountered in this study are reproduced in Appendix A, Figures 1-4.

2.6 Pollen percolating through pumice profiles

There is a possibility that pollen may percolate into or have been deposited within the Taupo Tephra. Although deposition is unlikely, due to the very high temperature of the ignimbrite flow, there is a possibility that ground water moving down through the tephra might carry post eruption pollens down to the palaeosol.

To investigate this possibility, continuous samples of the Taupo Tephra were taken from Site 5 (Tank Crossing) on the Desert Road. This particular site was chosen as the overlying deposits of the Taupo Tephra were known to be sufficiently deep to allow for sampling at intervals to ascertain how far pollen grains might infiltrate pumice, and also because the palaeosol had already been sampled (9/1/98) and found to contain pollen during the initial qualitative analysis. The sampled profile is at GR: T20/ 451050 (1040 m altitude) on the eastern side of the Desert Road. It is situated on the south side of a small dry gully flowing to the east at the green roadside marker pole No.5, on the south west side of a tank crossing site. The vegetation of the area is tussock grassland in association with *Calluna vulgaris.*

The site was revisited on 30/8/98 and the overlying layers above the pre-Taupo palaeosol (including the Taupo ignimbrite) were continuously sampled in order to provide data on the possible downwards translocation of pollen through the profile. A 1.72 m vertical column of the ignimbrite and overlying material was divided into six representative areas and each one was sampled. Samples 5.1 to 5.3 represent post Taupo deposits, while 5.4 to 5.6 represent the full depth of the Taupo Tephra deposit at this site. (Table 2.1)

The six samples obtained were air dried over several days and then treated by the standard soil pollen analysis procedure (Dimbleby 1957, 1985).

Initially a qualitative analysis was carried out. This involved using 1-2 cubic centimetres of material from each subset of the profile and leaving it to deflocculate for three days in a 5% detergent solution. After several rinses in distilled water followed by centrifuging the samples were then digested in the standard potassium hydroxide (KOH) digestion procedure. In order to eliminate, (or at least reduce), the possibility of pollen and spore loss in the detergent froth, a few drops of glacial acetic acid were added to each sample to break up the bubble raft which had formed. After repeated rinsing and centrifuging, the residue was taken up in the standard 5 ml of a 1:1 mixture of glycerine and water with 0.5 per cent alcoholic solution of safranin.

Table 2.1: Desert Road (Site 5) profile of Taupo Tephra.

Sample	Depth	Description
	0 - 0.47 m	Current topsoil (not sampled)
5.1	0.47 - 0.58 m	Mixed Ngauruhoe Ash and organic matter
5.2	0.58 - 0.70 m	Brown allophanic weathered tephra
5.3	0.70 - 0.80 m	A mixed layer of the brown allophanic material and the underlying Taupo ignimbrite with some root penetration
5.4	0.80 - 1.10 m	Pink Taupo ignimbrite
5.5	1.10 - 1.33 m	Grey Taupo ignimbrite
5.6	1.33 - 1.72 m	Grey Taupo ignimbrite enriched with charcoal over the basal 0.08 m
	1.72 - 1.94 m	Pre-Taupo palaeosol (not sampled on this occasion)

Two slides were prepared from each site sample and scanned for pollen under the microscope. The upper three zones (5.1 to 5.3) were found to contain plentiful pollen and spores, but no pollen was found in layers 5.4 to 5.6 (Table 3.1).

A second set of samples was also prepared for a quantitative analysis with the addition of *Lycopodium* marker spore tablets immediately before the initial KOH digestion. A minimum of 250 marker spores were counted in each sample.

2.7 pH testing of samples

"It has been shown that acid tropical soils may contain considerable quantities of pollen, a point which, taken together with the high values in temperate soils, suggests that the normal aerobic microbiological processes of acid soils are not so destructive of pollen as might be thought." (Dimbleby 1957).

The initial qualitative analysis indicated that samples from the northern and southern groups tended to be less well preserved than the western and eastern groups. Within both the northern and southern groups there were more pollens which were too degraded for accurate identification, while there were also higher counts of *Lycopodium* marker spores which indicated that fewer pollens and spores were present at these sites. This was particularly so of the southern group. Both groups, especially the northern group, were also characterized by high numbers of pteridophyte spores, which were recognizable as such even though further identification was not possible as the spores were often damaged and superficially degraded.

The stratigraphy of the southern sites around Waiouru differs from the other areas in that the volcanic deposits are relatively thin over the underlying sedimentary rocks. Where the terrain has marked relief as in stream and river valleys, these underlying mudstones and limestones may be exposed at the surface on higher ground. In general, the landscape of the area shows a mantling of volcanic deposits which are restricted to low lying areas. This feature raises the possibility of rainfall and percolating groundwater becoming less acidic as it moves over the sedimentary rocks, and thereby raising the pH values of the deposits beneath the Taupo Tephra as it flows down into the rivers and streams.

Dimbleby (1957), as previously discussed, when working on soil pH as it relates to the preservation of pollen, has concluded that soils whose pH is above 6 are virtually useless for pollen analysis, those between a pH range of 5 to 6 have small numbers of pollen present, while those below pH 5 have frequencies "of the same order as, and even in much excess of, the counts obtained on peats."

The standard New Zealand Soil Bureau procedure to test for soil pH (Blakemore *et al* 1981), uses a 1:2.5 ratio of soil to deionised water, with 20 *gm* of soil providing a sufficiently large sample. This is read after overnight standing which allows for the extraction of more partially soluble carbonates.

The initial sampling of each site had been restricted to very small amounts as required for pollen analysis, but sufficient material had been obtained from 18 sites to allow pH testing to take place. These samples were air dried and a 20 gm dry weight sample was taken. Following the procedure as outlined by Blakemore *et al* (1981) this was mixed with 50 ml of deionised water and left to equilibrate over 24 hours. A MeterLab PHM 201 portable pH meter was calibrated to standard pH 4 and pH 7 solutions before recording the results from the available sites.

There was sufficient material available for pH testing from 18 sites (Table 3.2). These sites were Site 1(West Ketetahi), Site 2 (Whakapapa Intake Road), Site 9 (Okupata Intake Road), Site 10 (Okupata Drop Shaft), Site 12 (Mangatepopo Valley), Site 19 (West Waiouru), Site 20 (Waitangi Stream), Site 22 (South Waiouru), Site 23 (Bates' Farm), Site 24 (Upper Karioi Forest), Site 25 (Lower Karioi Forest) Site 27 (Hautu Road), Site 29 (Otukou Quarry), Site 30 (Mangaparuparu Stream), Site 38 (Mangatawai Stream), Site 39 (East National Park), Site 40 (Wairehu Canal) and Site 41 (Makiokio Stream).

CHAPTER THREE: RESULTS

3.1 Pollen percolating through pumice profiles

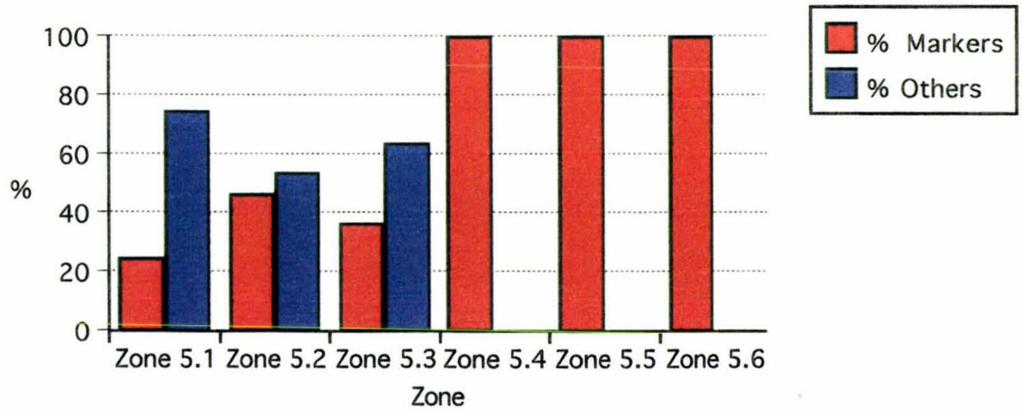
In order to investigate the possibility of modern pollen being translocated through the Taupo Tephra and into the underlying palaeosol, continuous samples of the Taupo Tephra were taken from Site 5 (Tank Crossing) on the Desert Road. A 1.72 m vertical column of the ignimbrite and overlying material was divided into six representative zones and each one was continuously sampled. Samples 5.1 to 5.3 represent post Taupo deposits, while 5.4 to 5.6 represent the full depth of the Taupo Tephra deposit at this site (Table 3.1).

Table 3.1: Zonal counts at Site 5 - Desert Road (tank crossing).

Zone	Marker spores	Other spores and pollen	Total	Marker spores %	Other spores and pollen %
5.1	270	824	1094	25	75
5.2	268	309	577	46	54
5.3	268	471	739	36	64
5.4	282	0	282	100	0
5.5	276	0	276	100	0
5.6	250	0	250	100	0

The results demonstrate (Fig. 3.1) that the three zones above the Taupo Tephra, Zones 5.1 - 5.3, did contain considerable quantities of post Taupo pollen as well as lesser quantities of *Lycopodium* marker spores. Conversely,

Figure 3.1: Comparison of marker spores with other pollen and spores.



the three zones within the Taupo Tephra, Zones 5.4 - 5.6, yielded only the *Lycopodium* marker spores.

3.2 pH results

"Recent work has shown that in acid soils pollen may be preserved for very long periods and that from the distribution of the various pollen types in the soil a general picture of past vegetational change - often indicating change of treatment - may be built up." (Dimbleby 1961).

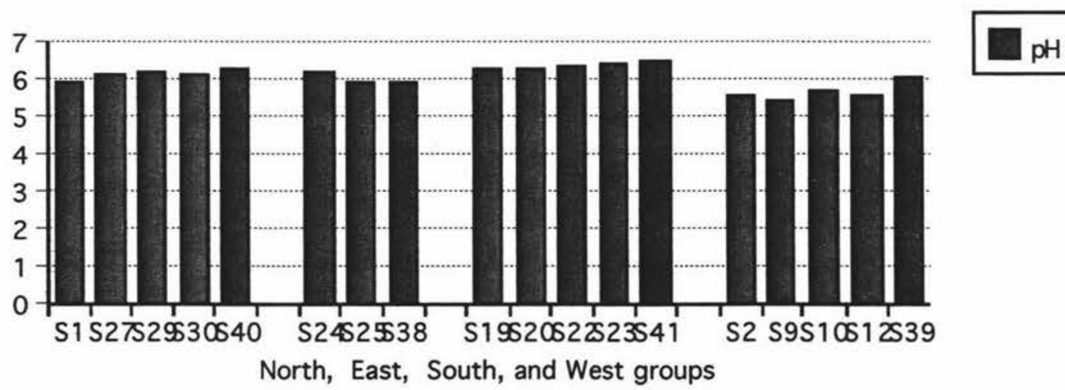
Of the 18 sites for which sufficient material was available for pH testing, 11 were found to be above a pH of 6.0. These included all tested sites from the southern group, and all but Site 1 from the northern group (Table 3.2).

Table 3.2: Site pH results.

Northern group		Eastern group		Southern group		Western group	
Site	pH	Site	pH	Site	pH	Site	pH
S1	5.9	S24	6.2	S19	6.3	S2	5.5
S27	6.1	S25	5.9	S20	6.3	S9	5.4
S29	6.2	S38	6.0	S22	6.4	S10	5.7
S30	6.1			S23	6.4	S12	5.6
S40	6.3			S41	6.5	S39	6.1

The pH results were generally lower in the eastern and western groups, with only Site 39 in the west and Site 24 in the east being above pH 6.0 (Fig. 3.2).

Figure 3.2: pH values of samples.



3.3 Site results

3.3.1 Site 1: West Ketetahi

GR: T19/400343   Altitude: 725 m   Date sampled: 28/6/97 and 11/1/98.

The site is located on SH 47, 850 m west of the Ketetahi turnoff, on the northern side of the road, at the eastern end of an extensive road cutting. The surrounding vegetation is manuka (*Leptospermum scoparium*) and kanuka (*Kunzea ericoides*) scrubland.

Table 3.3: Site 1 - West Ketetahi pollen count.

SITE 1: West Ketetahi		
	Total	%
Trees		
Libocedrus bidwillii	2	1
Podocarpus totara	2	1
Prumnopitys taxifolia	2	1
Dacrycarpus dacrydioides	1	1
Dacrydium cupressinum	10	3
Podocarpaceae	12	4
Nothofagus fusca-type	122	39
Nothofagus menziesii	44	14
Small trees and shrubs		
Melicytus	1	1
Ferns and fern allies		
Cyathea smithii-type	25	8
Blechnum species	9	3
Monolete fern spores	23	7
Trilete fern spores	21	7
Other	28	7
Unidentified	17	5
Lycopodium marker spores	6	2
Total	325	
Taxa values		
Trees	195	60
Small trees and shrubs	1	0
Ferns and fern allies	106	33

The pre-Taupo palaeosol at this site is overlain by 1.0 m of unwelded Taupo ignimbrite, the lower *c.* 0.30 m or so containing extensive charcoal (especially bracken rhizomes up to 0.12 m long and 0.15 m in diameter). There is a sharp boundary between the ash and underlying darkly organic palaeosol which remained damp even during summer when the site was revisited but not sampled.

Figure 3.3: Site 1 - West Ketetahi total pollen values.

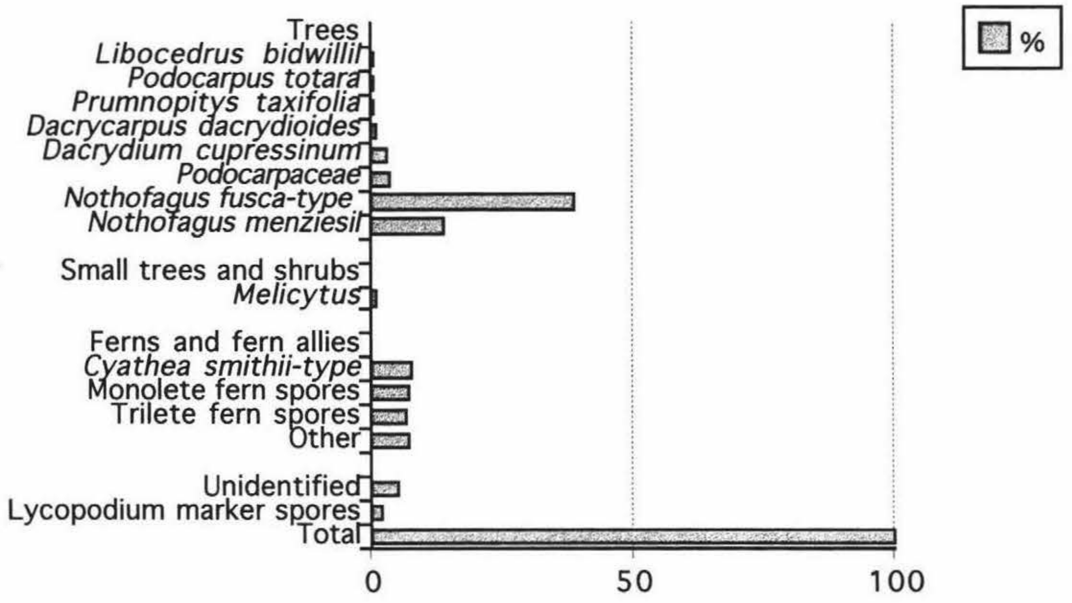
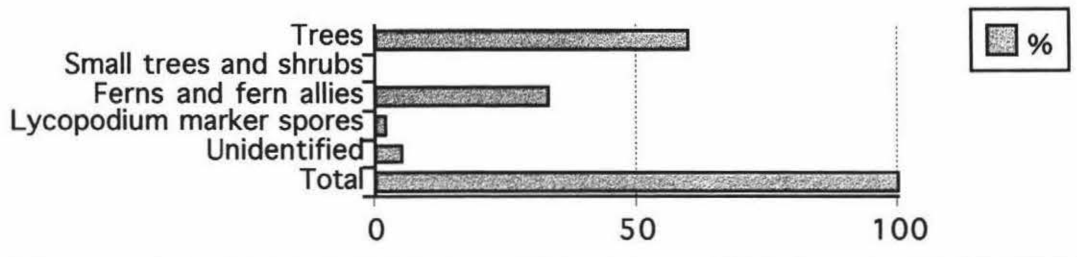


Figure 3.4: West Ketetahi taxa values.



The pollen and spores extracted from the palaeosol at this site are largely unaffected, with most grains entire and only 5% unable to be identified. The site is also relatively rich as in a total count of 325, only 2% of these were the *Lycopodium* marker spores. Sufficient material was available for pH testing with a result of 5.9.

3.3.2 Site 2: Whakapapa Intake Road

GR: S19/288286 Altitude: 880 m Date sampled: 28/6/97 and 11/1/98

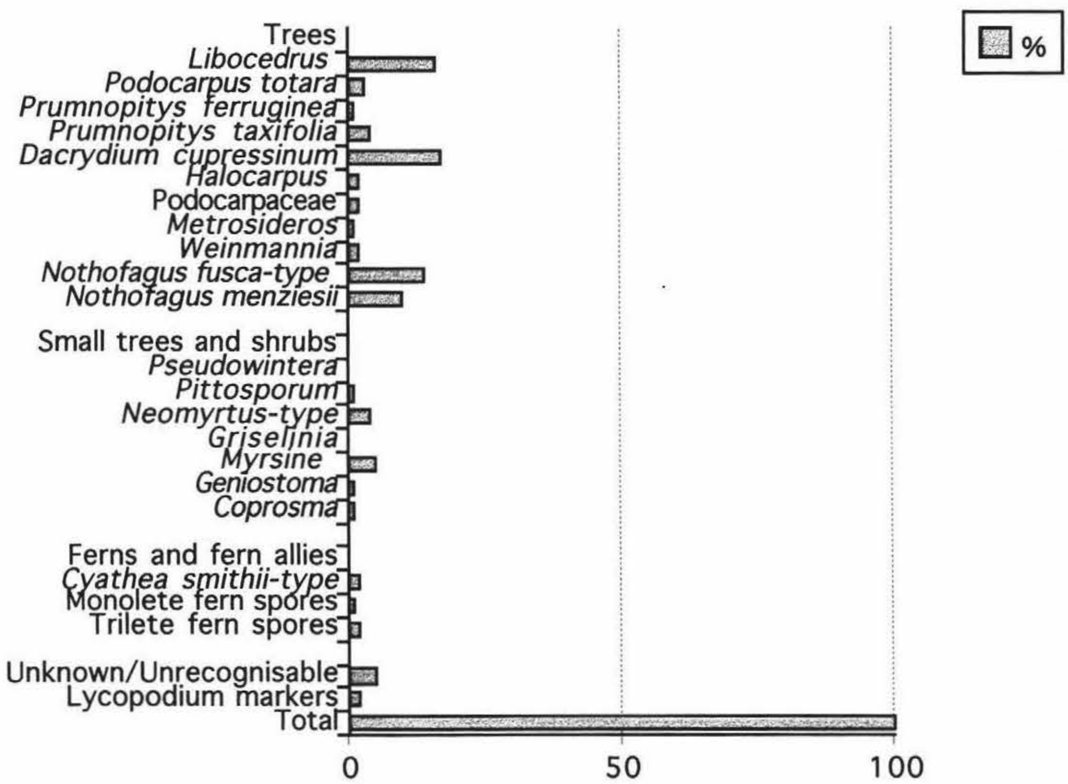
This site is located in a road cutting on the eastern side of the road on SH 47, approximately 200 m east of the Whakapapa Intake Road (Access Road No. 1). The surrounding vegetation is composed of manuka and kanuka scrub, with neighbouring pine forest.

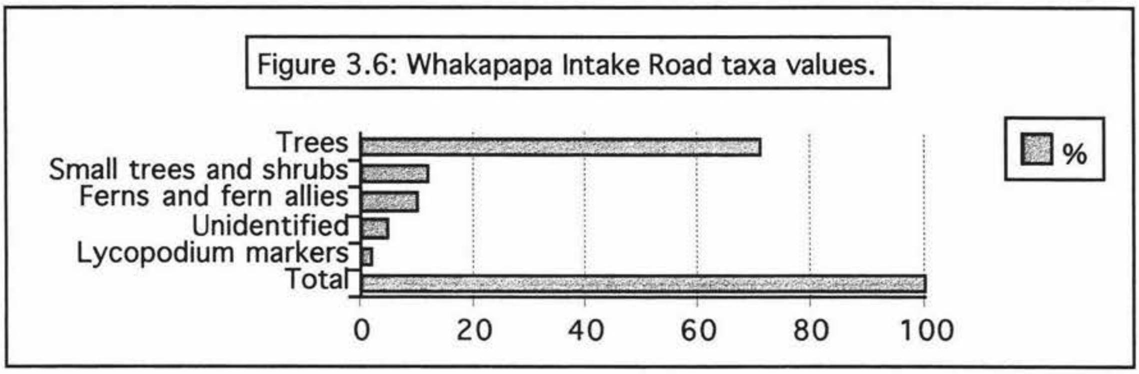
Table 3.4: Site 2 - Whakapapa Intake Road pollen count.

SITE 2: Whakapapa Intake Rd.		
	Total	%
Trees		
Libocedrus bidwillii	29	9
Podocarpus totara	19	6
Prumnopitys taxifolia	3	1
Dacrydium cupressinum	45	14
Podocarpaceae	39	12
Nothofagus fusca-type	67	20
Nothofagus menziesii	32	10
Metrosideros	1	0
Small trees and shrubs		
Epacridaceae	1	0
Neomyrtus-type	7	2
Myrsine	11	3
Quintinia	9	3
Coprosma	2	1
Ferns and fern allies		
Cyathea smithii-type	6	2
Monolete fern spores	6	2
Trilete fern spores	12	4
Others	5	2
Unidentified	16	5
Lycopodium marker spores	19	6
Total	329	100
Taxa values		
Trees	235	71
Trees and shrubs	30	9
Ferns and fern allies	29	9

The underlying peat is covered by 2.0 m of an undulating, unwelded Taupo ignimbrite layer, with evidence of iron staining. Charcoalised logs 1.2 - 1.5 m in length and up to 0.28 m diameter are present in the ash as are some fossil plant roots. The contact boundary is generally planar and sharp. Occasional logs up to 0.10 m in diameter can be seen in the peat. Even in summer (when the site was revisited but not sampled) both the pumice and the underlying peat remained very wet.

Figure 3.5: Site 2 - Whakapapa Intake Road total pollen values.





This site represents a peat rather than a palaeosol and lies within the FDI zone. There is a good state of preservation, with most grains being largely unaffected. Only 5% of the total 329 counted were recorded in the unidentified category, and with only 2% of marker spores recorded the sample appears to be relatively rich in pollen and spores. Sufficient material was available for pH testing with a result of 5.5.

3.3.3 Site 3: Whakapapanui Bridge

GR: S19/266256 Altitude: 840 m Date sampled: 28/6/97 and 11/1/98

The site is located in a cutting on the southern side of the road on SH 47, 100 m west of the Whakapapanui Bridge. The surrounding vegetation is predominantly heather (*Calluna vulgaris*) with some toetoe (*Cortaderia* spp.) and flax (*Phormium* spp.).

Table 3.5: Site 3 - Whakapapanui Bridge pollen count.

SITE 3: Whakapapanui Bridge		
	Total	%
Tall trees		
Libocedrus bidwillii	3	1
Dacrydium cupressinum	26	8
Podocarpus totara	6	2
Phyllocladus	1	0
Podocarpaceae	9	3
Metrosideros	2	1
Nothofagus fusca-type	165	54
Nothofagus menziesii	29	9
Small trees and shrubs	19	6
Ascarina	1	0
Coriaria	1	0
Plagianthus	1	0
Quintinia	1	0
Griselinia lucida	1	0
Myrsine	12	4
Geniostoma	2	1
Ferns and fern allies	22	7
Cyathea smithii-type	3	1
Monolete fern spores	3	1
Trilete fern spores	16	5
Unidentified	17	6
Lycopodium marker spores	6	2
Total	305	100
Taxa values		
Trees	241	79
Small trees and shrubs	19	6
Ferns and fern allies	22	7

The underlying peat is covered by a 2.3 m layer of unwelded Taupo ignimbrite which contains charcoalized logs and is coarser towards the base. Iron staining is evident throughout the pumice. Vertical columns up to 30 mm in diameter occur in the top two thirds of the deposit. The boundary between the peat and the Taupo ignimbrite is sharp and undulating with about 0.20 m relief. There are some organic macrofossils evident within the peat. Even in summer when the site was revisited but not sampled both the pumice and peat remained very wet.

Figure 3.7: Site 3 - Whakapapanui Bridge total pollen values.

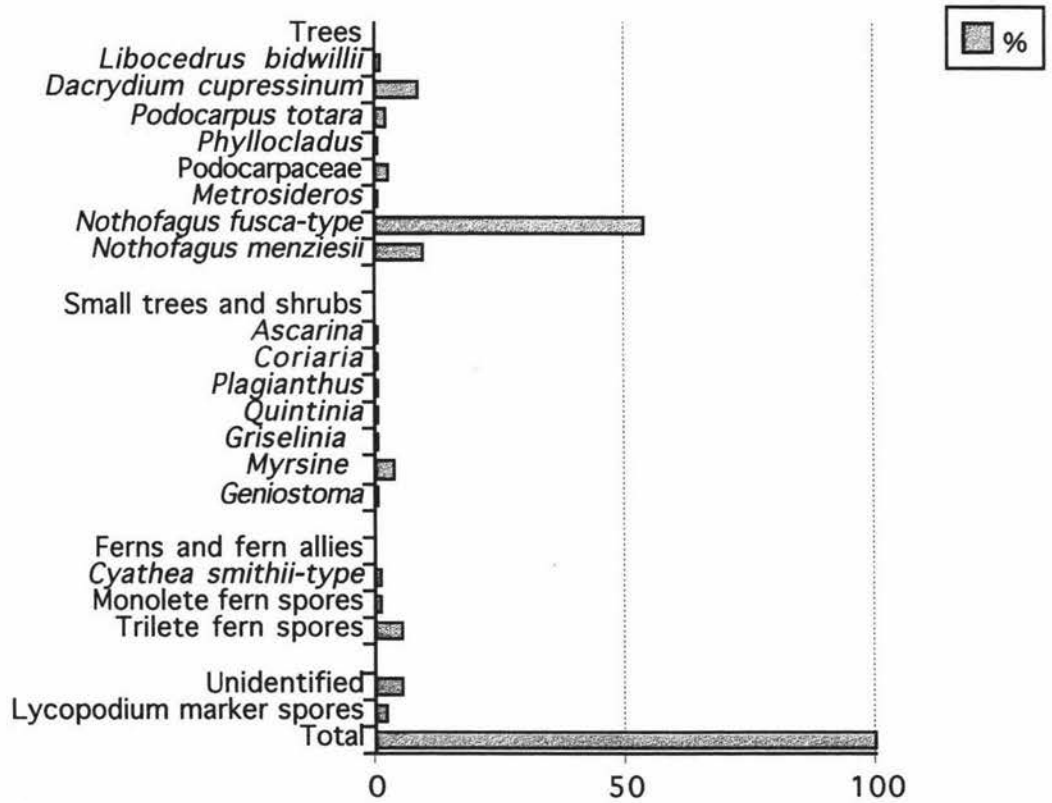
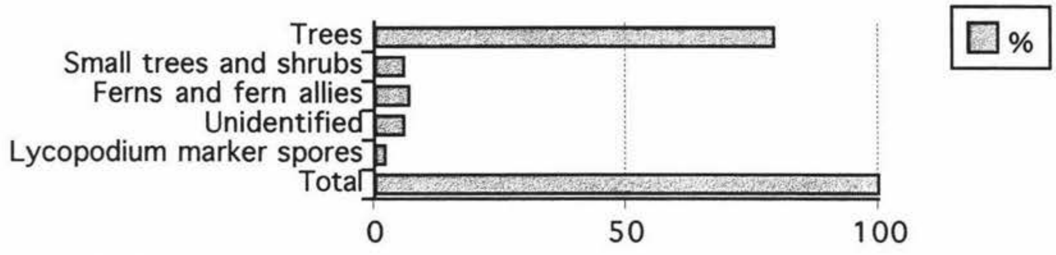


Figure 3.8: Whakapapanui Bridge taxa values.



The sample is a peat and contains pollen and spores which are largely unaffected as they are generally well preserved and intact with 6% unidentified in a total count of 305 grains. The low count (only 2%) of *Lycopodium* marker spores implies that the site also has a high frequency of pollen and spores.

3.3.4 Site 4: McDonnell's Redoubt Road

GR: S19/485323 Altitude: 600 m Date sampled: 11/12/97 and 11/1/98

This site is located on SH47 about 500 m east of McDonnell's Redoubt Road, 100 m east of a fault, in a small road cutting on the south side of road. The surrounding vegetation is predominantly manuka scrub and nearby pine (*Pinus* spp.) forest.

Table 3.6: Site 4 - McDonnell's Redoubt Road pollen count.

SITE 4: McDonnell's Redoubt Road		
	Total	%
Trees		
Libocedrus bidwillii	2	1
Dacrydium cupressinum	9	3
Podocarpaceae	2	1
Nothofagus fusca-type	22	7
Nothofagus menziesii	17	6
Small trees and shrubs		
Lophomyrtus	2	1
Myrsine	3	1
Ferns and fern allies		
Cyathea smithii-type	24	8
Monolete fern spores	6	2
Trilete fern spores	186	61
Other	8	3
Lycopodium marker spores	9	3
Unidentified	17	6
Total	307	100
Taxa values		
Tall trees	52	17
Small trees and shrubs	5	2
Ferns and fern allies	224	73

A darkly organic pre-Taupo palaeosol is covered by 1.0 m of fines-depleted (FDI) unwelded Taupo ignimbrite, with a sharp, gently undulating contact between the strata. Over summer the palaeosol remained damp rather than wet.

Figure 3.9: Site 4 - McDonnell's Redoubt Road total pollen values.

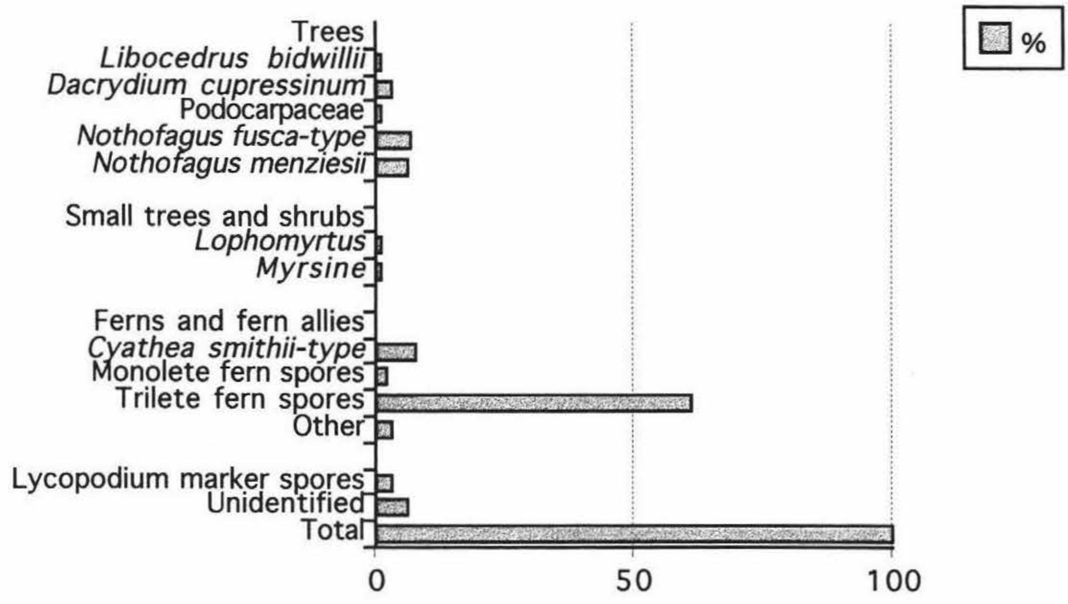
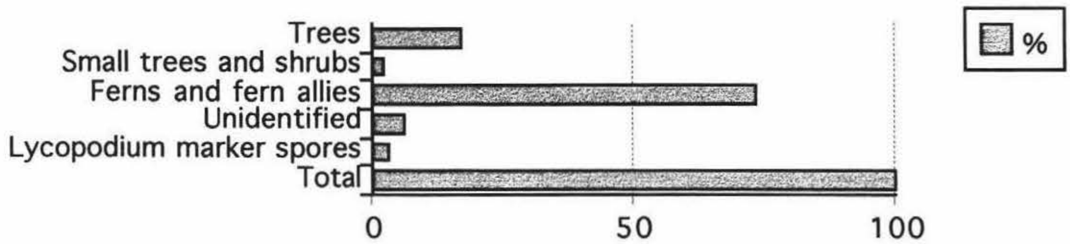


Figure 3.10: MacDonnell's Redoubt Road taxa values.



Preservation of pollen and spores at this site was severely affected as analysis showed a great many fragmented grains. However, the site also appears to be reasonably rich in pollen as *Lycopodium* marker spores were only 3% of the total pollen count of 307 grains. The highest scoring group was fern spores (73%), many of which showed some signs of degradation. Unidentified pollen accounts for only 6% of the total and the site lies within the FDI zone.

3.3.5 Site 5: Desert Road (tank crossing)

GR: T20/ 451050 Altitude: 1040 m Date sampled: 9/1/98

This site is located on the eastern side of the Desert Road and on the south side of a small dry gully flowing to the east at the green roadside marker pole No. 5. The sampled profile is on the south west side of a tank crossing cutting. The surrounding vegetation is tussock grassland with heather.

Table 3.7: Site 5 - Desert Road (tank crossing) pollen count.

SITE 5: Desert Road (tank crossing)		
	No.	%
Tall trees		
Libocedrus	1	0
Podocarpus totara	3	1
Podocarpus hallii	1	0
Prumnopitys taxifolia	5	1
Dacrydium cupressinum	33	9
Halocarpus	27	7
Phyllocladus	30	8
Podocarpaceae	9	2
Nothofagus fusca-type	163	44
Nothofagus menziesii	51	14
Small trees and shrubs		
Epacridaceae-type	1	0
Myrsine	4	1
Ferns and fern allies		
Monolete fern spores	1	0
Trilete fern spores	4	1
Gleichenia	5	1
Others	6	2
Unidentified	19	5
Lycopodium markers	6	2
Total	369	100
Taxa values		
Trees	323	88
Small trees and shrubs	5	1
Ferns and fern allies	16	4
Ferns and fern allies	16	4

The palaeosol at this site is covered by 1.0 m of Taupo Tephra with charcoal evident in the lower 0.30 - 0.40 m. The upper 0.30 m of the tephra is pink in colour. There is a sharp boundary between the ignimbrite and the palaeosol which both remained wet even in summer. The palaeosol forms a 0.22 m thick layer that grades into the underlying Mangatawai Tephra. The upper 10 -70 mm of the palaeosol is noticeably darker in colour.

Figure 3.11: Site 5 - Desert Road total pollen values.

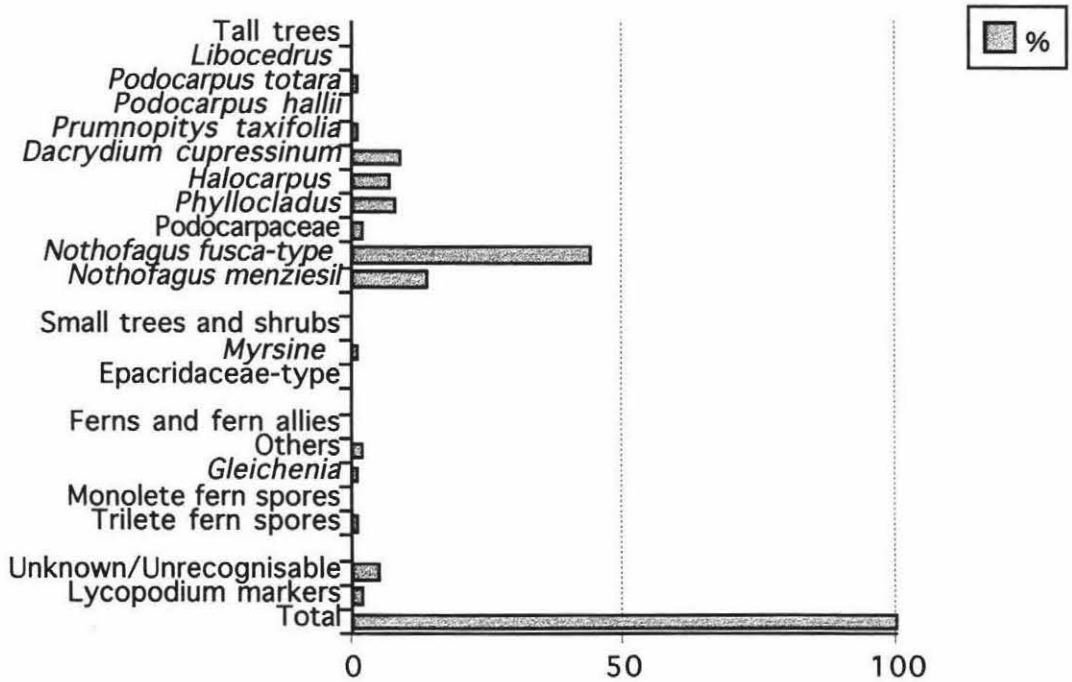
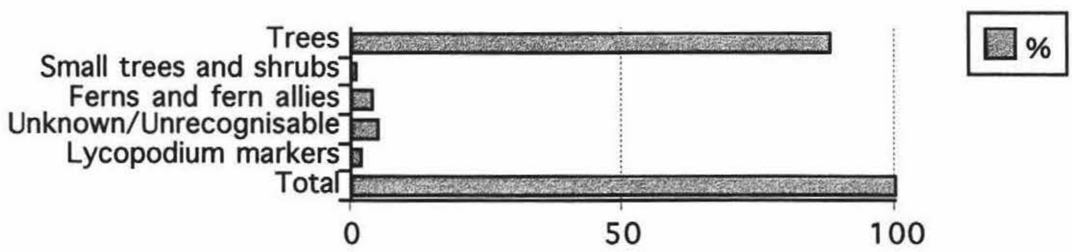


Figure 3.12: Desert Road taxa values.



There was a good degree of preservation at this site with most pollen being largely unaffected with very little sign of degradation evident and only 5% unidentified. With only 2% of marker spores recorded from a total count of 334 it is also a relatively rich site in terms of pollen abundance.

3.3.6 Site 6: Upper Tukino Road

GR: T20/404118 Altitude: 1280 m Date: 9/1/98

Site location: On an eroded outcrop which forms a pedestal off the northern side of the upper part of the Tukino Road. The pedestal sampled was the middle pedestal on an interfluve off from the base of the rise in the track leading up to the monitoring hut at the barrier near the Round The Mountain Track. The surrounding vegetation is tussock grassland and herbfield.

Table 3.8: Site 6 - Upper Tukino Road pollen count.

SITE 6: Upper Tukino Road		
	Total	%
Tall trees		
Libocedrus	2	1
Dacrydium cupressinum	16	5
Podocarpus hallii	7	2
Podocarpaceae	10	3
Nothofagus fusca-type	144	45
Nothofagus menziesii	102	32
Small trees and shrubs		
Neomyrtus-type	4	1
Ferns and fern allies		
Cyathea smithii-type	3	1
Trilete fern spores	3	1
Other	1	0
Lycopodium marker spores	5	2
Unidentified	21	7
Total	318	100
Taxa values		
Trees	281	88
Small trees and shrubs	4	1
Ferns and fern allies	2	1

The site is covered by undulating Taupo tephra from 0.60 to 0.80 m thick and containing charcoal. There is a sharp boundary with the underlying darkly organic palaeosol which remained wet even in summer.

Figure 3.13: Site 6 - Upper Tukino Road total pollen values.

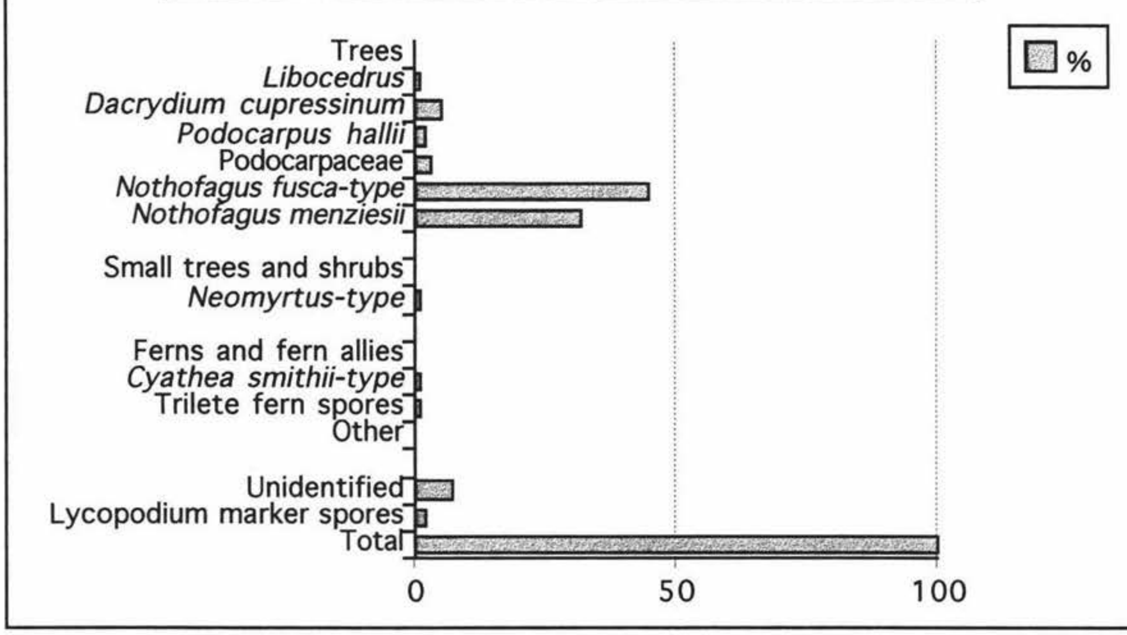
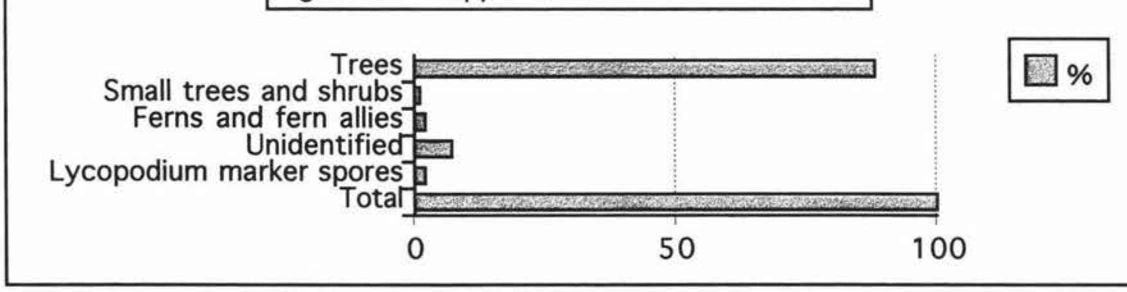


Figure 3.14: Upper Tukino Road taxa values.



This site was relatively rich in pollen and spores with only 2% of *Lycopodium* marker spores recorded in a total count of 318. The degree of preservation within the palaeosol was also largely unaffected with few degraded or fragmented grains observed and only 7% unidentified.

3.3.7 Site 7: Lower Tukino Road

GR: T20/416105 Altitude: 1180 m Date sampled: 9/1/98

The site is located in an eroded outcrop in a small gully off the south western side of Tukino Road. The surrounding vegetation is tussock and herbfield.

Table 3.9: Site 7 - Lower Tukino Road pollen count.

SITE 7: Lower Tukino Road.		
	Total	%
Trees		
Prumnopitys taxifolia	3	1
Dacrydium cupressinum	6	2
Halocarpus	3	1
Podocarpaceae	14	4
Nothofagus fusca-type	204	62
Nothofagus menziesii	76	23
Small trees and shrubs		
Myrsine	2	1
Ferns and fern allies		
Cyathea smithii-type	2	1
Trilete fern spores	4	1
Unidentified	7	2
Lycopodium marker spores	8	2
Total	329	100
Taxa values		
Trees	306	93
Small trees and shrubs	2	1
Ferns and fern allies	6	2

The site is on the side of a gully under 0.65 m of compacted Taupo Tephra. Even in summer the pumice and soil were both damp. Fine strands of twiggy charcoal up to 20 mm long are present in the pumice along the contact zone, as well as larger branches and logs. The palaeosol is reasonably dark.

Figure 3.15: Site 7 - Lower Tukino Road total pollen values.

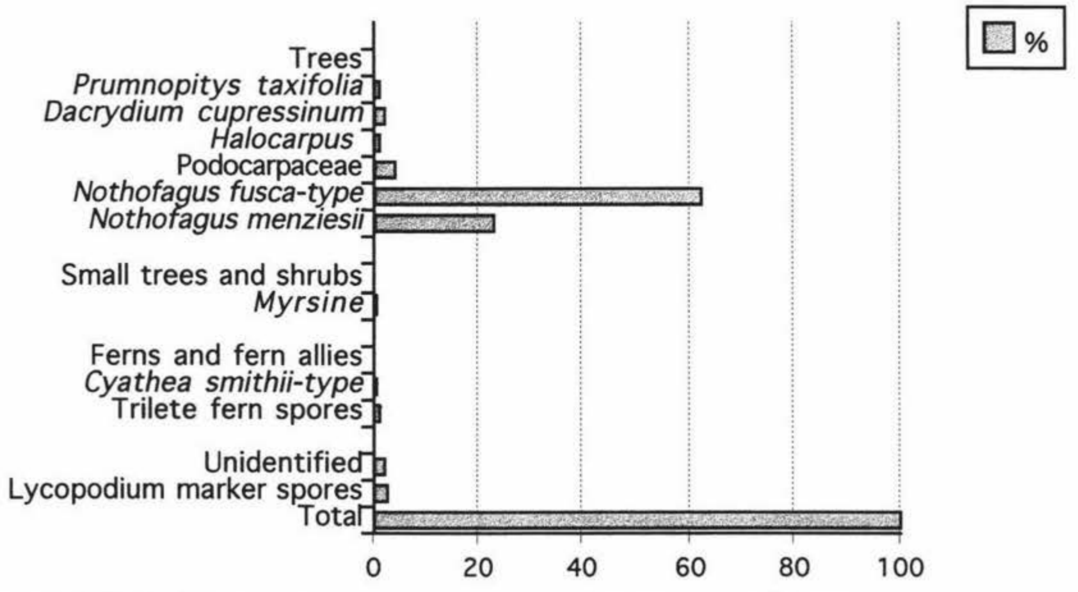
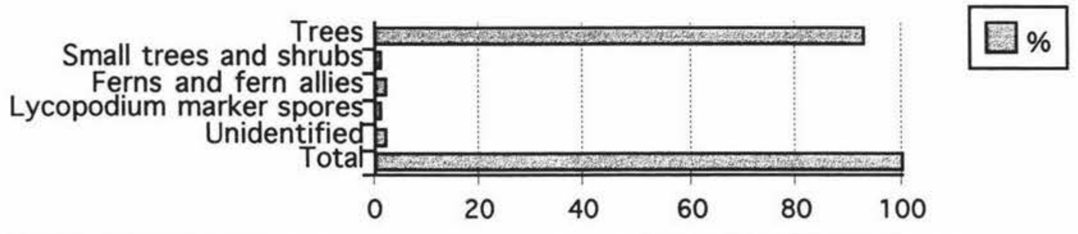


Figure 3.16: Lower Tukino Road taxa values.



There was a good degree of preservation at this site with largely unaffected pollen and spores present, and only 2% unable to be identified. The site was also a relatively rich one in that only 2% of the total count of 329 grains were of the *Lycopodium* marker spores.

3.3.8 Site 8: Waipakihi Road

GR: T20/498154 Altitude: 920 m Date sampled: 9/1/98

The site is located on Waipakihi Road, in a road cutting on the side of the river valley, at the headwaters of the Upper Waikato Stream. The surrounding vegetation is beech forest and some roadside manuka scrub.

Table 3.10: Site 8 - Waipakihi Road pollen count

SITE 8: Waipakihi Road		
	Total	%
Trees		
Prumnopitys taxifolia	2	1
Dacrydium cupressinum	4	1
Halocarpus	1	0
Podocarpaceae	5	2
Nothofagus fusca-type	193	61
Nothofagus menziesii	86	27
Metrosideros	2	1
Small trees and shrubs		
Ferns and fern allies		
Cyathea smithii-type	2	1
Trilete fern spores	6	2
Unidentified	12	4
Lycopodium marker spores	3	1
Total	316	100
Taxa values		
Trees	293	93
Small trees and shrubs	0	0
Ferns and fern allies	8	3

The site is under 1.0 m of tephra, which is pink on top, on the side of the river valley. Charcoal is obvious and abundant in the tephra, and there is a sharp boundary between that and the palaeosol. The ignimbrite and the soil both remained wet even in summer. Although the site has been reworked on top for roading and there is some anthropogenic overburden of road spoil, the lower sequences remain undisturbed. The Taupo tephra becomes much thicker immediately down slope from this site, and this thickened sequence probably reflects valley fill from the original eruption.

Figure 3.17: Site 8 - Waipakihi Road total pollen values.

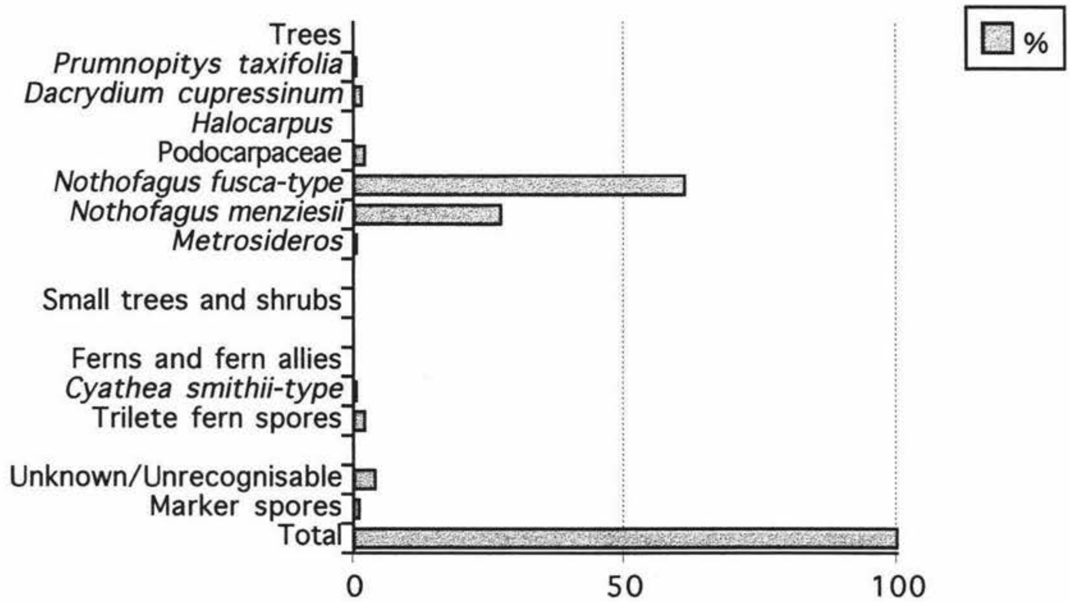
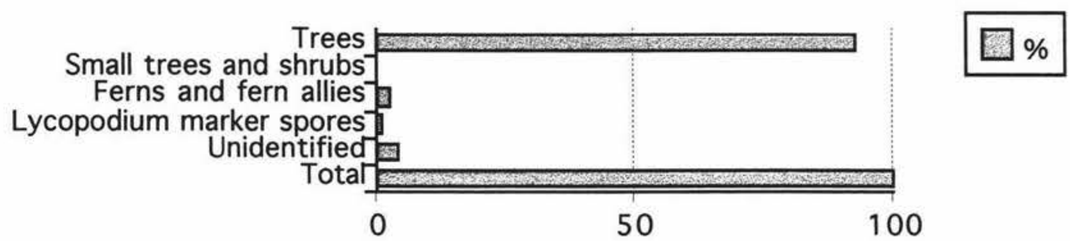


Figure 3.18: Waipakihi Road taxa values.



The pollen and spores analysed at this site were largely unaffected as they were generally whole and entire with very little evidence of fragmentation or degeneration. This is indicated by the relatively low count of unidentified grains - only 4% of the total 316 grains. It was also a very rich site with only 1% of *Lycopodium* marker spores being recorded.

3.3.9 Site 9: Okupata Intake Road

GR: S19/284368 Altitude: 620 m Date sampled: 10/1/98

The site is located on John McDonald's Road, leading in to the Okupata Intake, and is about 500 metres south west from the Okupata Caves. The site is in a small terrace on the valley edge, on the south west side of a road cutting, 100 m west of a culvert with a bush walk track and small picnic table. The surrounding vegetation is eucalyptus plantation (*Eucalyptus*) and podocarp broadleaf forest with regenerating scrub of manuka, lancewood, and toetoe on the terrace.

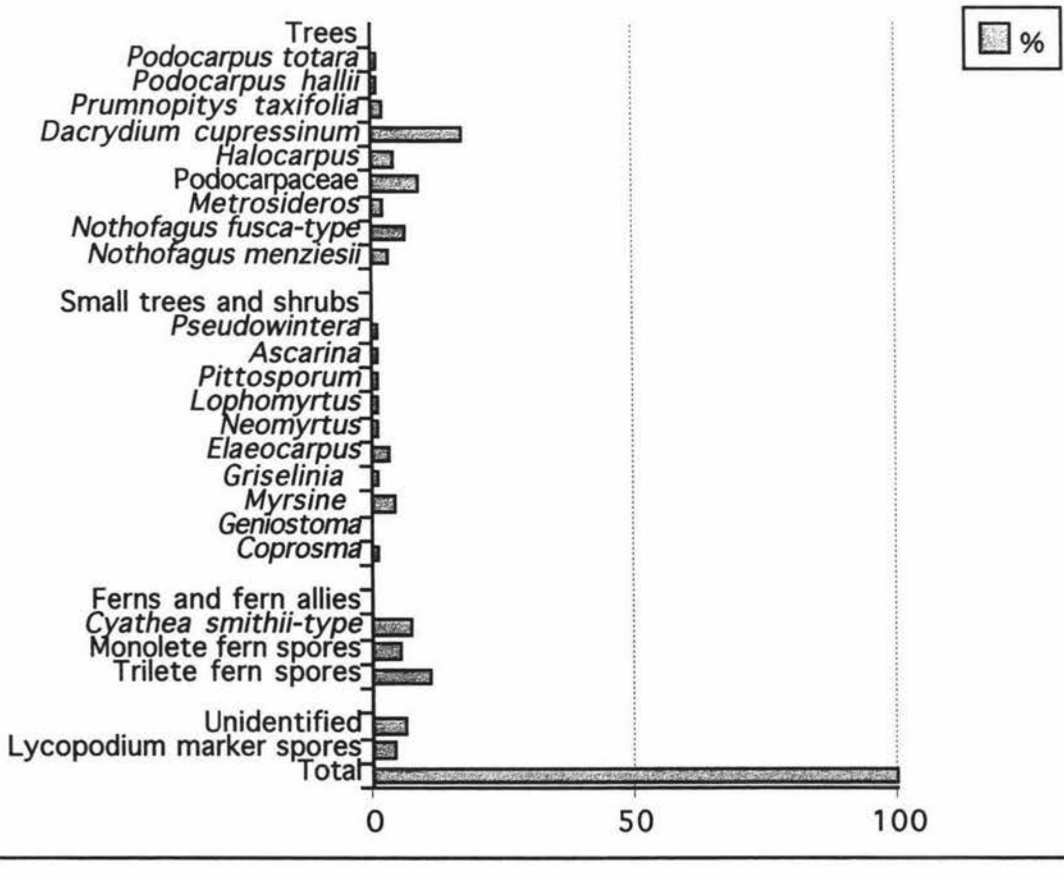
Table 3.11: Site 9 - Okupata Intake Road pollen count (continued on following page).

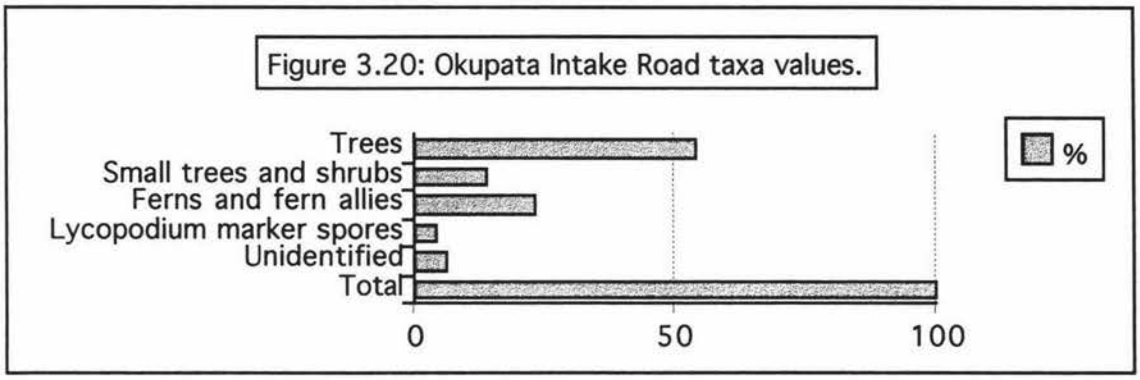
SITE 9: Okupata Intake Road		
	Total	%
Trees		
Libocedrus bidwillii	31	10
Podocarpus totara	3	1
Podocarpus hallii	2	1
Prumnopitys taxifolia	6	2
Dacrydium cupressinum	53	17
Halocarpus	12	4
Podocarpaceae	29	9
Metrosideros	5	2
Nothofagus fusca-type	20	6
Nothofagus menziesii	10	3
Small trees and shrubs		
Pseudowintera	3	1
Ascarina	3	1
Pittosporum	2	1
Lophomyrtus	3	1
Neomyrtus	3	1
Elaeocarpus	8	3
Griselinia	3	1
Myrsine	14	4
Geniostoma	1	0
Coprosma	4	1
Ferns and fern allies		
Cyathea smithii-type	23	7
Monolete fern spores	16	5
Trilete fern spores	35	11

(Table 3.11 continued)	Total	%
Unidentified	18	6
Lycopodium marker spores	12	4
Total	319	100
Taxa values		
Trees	171	54
Small trees and shrubs	44	14
Ferns and fern allies	74	23

This is a wet site with sphagnum moss and peat overlying the Taupo Tephra, and some reworked pumice from roading deposited on top of the peat. There is some lateral root penetration of the palaeosol below the contact with the ignimbrite (which was avoided in sampling), but there was no visible vertical penetration through the contact itself. The primary deposit of the Taupo Tephra is 0.60 - 0.62 m thick with charcoal present, and coarser pumice at the base of the layer. The boundary between the ignimbrite and the palaeosol is sharp and gently undulating, and both layers were very wet.

Figure 3.19: Site 9 - Okupata Intake Road total pollen values.





The sample at this site is an organic rich palaeosol which is classed as intermediately affected as it contains many fragmented and relatively degraded grains. The overall state of preservation is reasonable, as is indicated by a total count of 6% of unidentified pollen and spores, although there was sufficient degeneration evident on much of the Podocarpaceae pollen to make species identification impossible in a considerable number of cases. There is also a relatively low score of *Lycopodium* marker spores (4%) which reflects the abundance of pollen and spores at the site. Sufficient material was available from this sample for pH testing with a result of 5.4.

3.3.10 Site 10: Okupata Drop Shaft

GR: S19/287351 Altitude: 700 m Date sampled: 10/1/98

The site is located at the Okupata drop shaft, in a small excavated cutting leading down to the pool immediately upstream of the drop shaft. The surrounding vegetation is manuka and bracken scrub with toetoe and weeds, with nearby exotic conifers as well as mixed broadleaf and podocarp forest.

Table 3.12: Site 10 - Okupata Drop Shaft pollen count (continued on following page).

SITE 10: Okupata Drop Shaft		
	No.	%
Trees		
Libocedrus bidwillii	19	6
Podocarpus totara	7	2
Podocarpus hallii	1	0
Prumnopitys taxifolia	5	1
Dacrycarpus dacrydioides	7	2
Dacrydium cupressinum	84	24
Halocarpus sp	18	5
Phyllocladus	1	0
Podocarpaceae	29	8
Metrosideros	7	2
Nothofagus fusca-type	18	5
Nothofagus menziesii	12	3
Small trees and shrubs		
Ascarina	3	1
Kunzea	1	0
Neomyrtus	8	2
Elaeocarpus	3	1
Epacridaceae	1	0
Weinmannia	3	1
Myrsine	35	10
Coprosma	3	1
Ferns and fern allies		
Cyathea smithii-type	9	3
Hymenophyllum	4	1
Blechnaceae	1	0
Lycopodium	5	1
Monolete fern spores	6	2
Trilete fern spores	30	9

Table 3.12 continued	No.	%
Unidentified	18	5
Lycopodium marker spores	6	2
Total	345	100
Taxa values		
Trees	208	60
Small trees and shrubs	58	17
Ferns and fern allies	55	16

The site was very wet and was presumed to have originally been swamp or wetland. There are some woody remains *in situ* poking up into the surrounding deposits of ignimbrite. There is also charcoal present in the pumice which is 1.05 m thick with a sharp undulating contact with the underlying peats. The lower 0.45 m of the Taupo Tephra is iron stained and very wet.

Figure 3.21: Site 10 - Okupata Drop Shaft total pollen values.

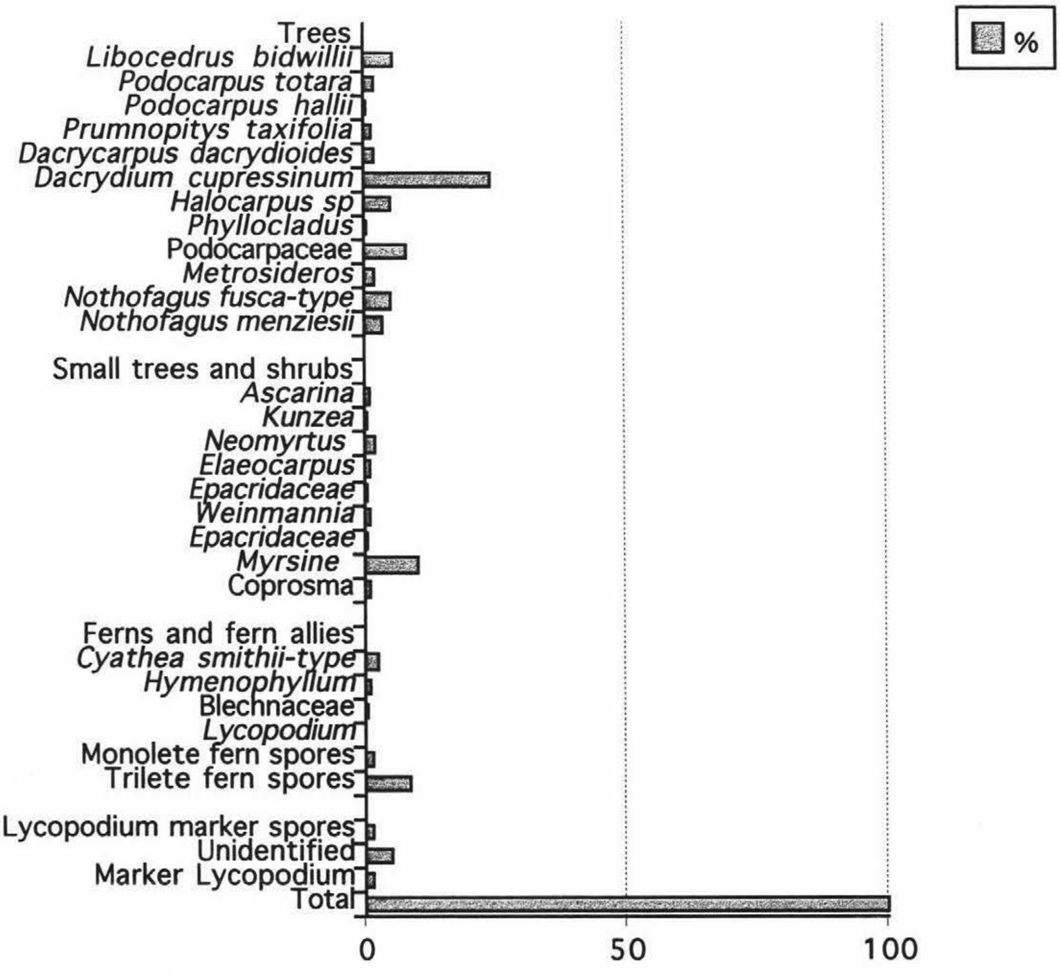
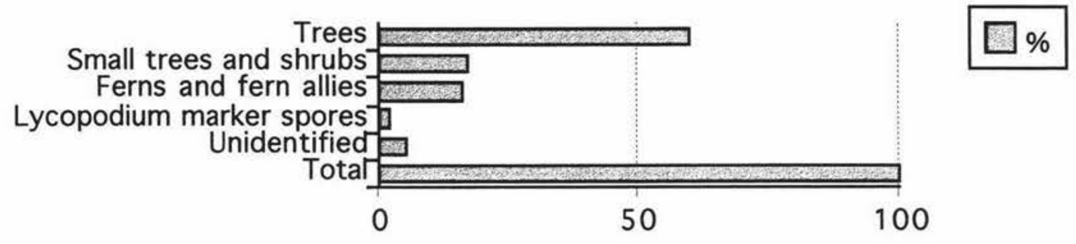


Figure 3.22: Okupata Drop Shaft taxa values.



The sample at this site was taken from a peat and sufficient material was available for pH testing with a result of 5.7. Some grains were fragmented or degraded, but the general state of preservation was sufficiently good to grade the site as largely unaffected. Only 5% of the total of 345 grains counted were unidentified, and the site was also relatively rich in pollen and spores as indicated by a count of only 2% of marker spores.

3.3.11 Site 11: Pukeonake

GR: T19/321255 Altitude: 1225 m Date sampled: 10/1/98

This site is located on the south east side of the summit of Pukeonake. The surrounding vegetation is tussock, with some leatherwood (*Olearia* spp.), and alpine herbs.

Table 3.13: Site 11 - Pukeonake pollen count.

SITE 11: Pukeonake		
	Total	%
Trees		
Libocedrus bidwillii	5	2
Podocarpus totara	1	0
Prumnopitys taxifolia	2	1
Dacrydium cupressinum	10	3
Halocarpus	13	4
Podocarpaceae	8	3
Nothofagus fusca-type	86	27
Nothofagus menziesii	160	50
Small trees and shrubs		
Coprosma	1	0
Ferns and fern allies		
Lycopodium	2	1
Pteridium	2	1
Monolete fern spores	7	2
Trilete fern spores	6	2
Unidentified	13	4
Lycopodium marker spores	3	1
Total	319	100
Taxa values		
Trees	285	89
Small trees and shrubs	1	0
Ferns and fern allies	17	5

The Taupo Tephra outcrops on the summit of Pukeonake are 0.46 m thick, and the underlying palaeosol was damp even in summer. Charcoal fragments are frequent in the ignimbrite, which is iron stained as well as coarsely fractured and jointed. The underlying Mangatawai Tephra contains obvious preserved beech leaves. There is occasional horizontal penetration of coarse root material up to 2 mm in diameter (which was avoided in sampling) along the boundary into the palaeosol, but the pumice does not appear to have been penetrated from above by the current root mass.

Figure 3.23: Site 11 - Pukeonake total pollen values.

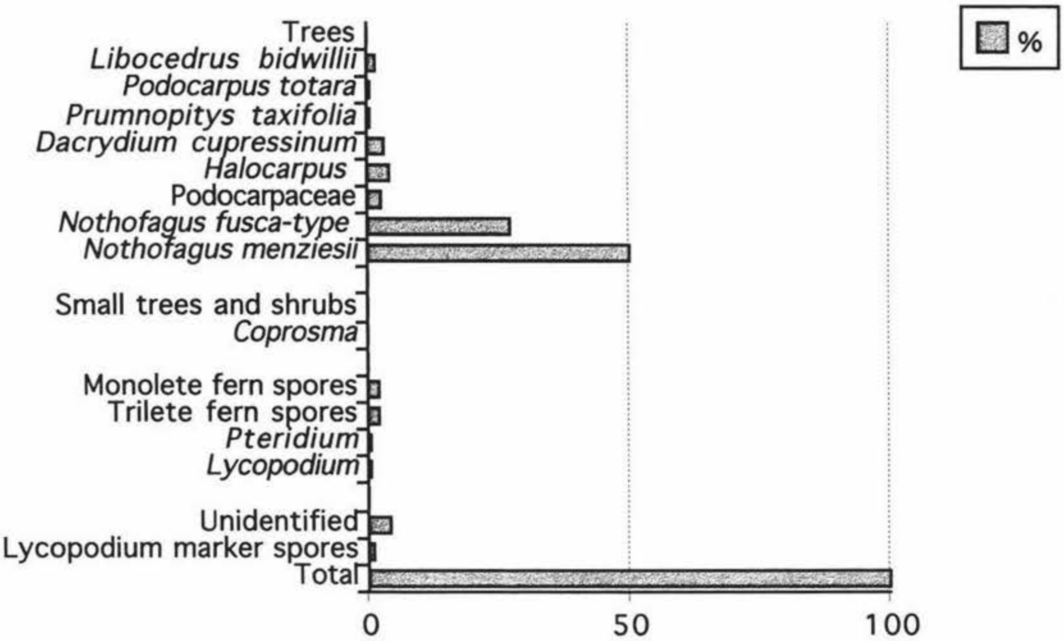
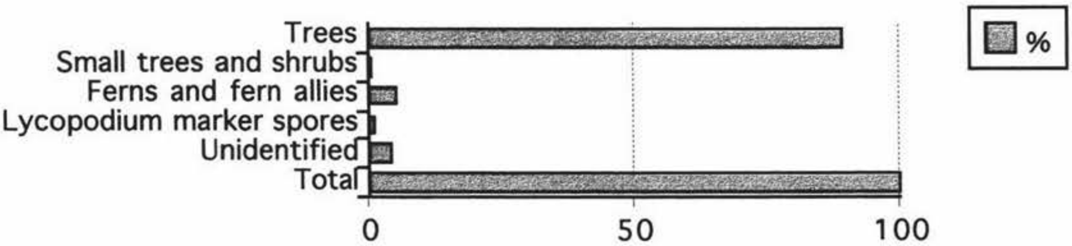


Figure 3.24: Pukeonake taxa values.



The degree of preservation at this site was very good with most grains largely unaffected, allowing for the identification of all but 4% of the total 319 grains counted. It was also a very rich site with only 1% of marker spores recorded.

3.3.12 Site 12: Mangatepopo Valley

GR: T19/325261 Altitude: 1080 m Date sampled: 10/1/98

The site is located at the intersection of a small stream with the Mangatepopo Valley Road, close to the road end. The site is on the true left side of a scoured "gully" on the south west side of the road, about 1 km from the road end. The surrounding vegetation is heather and tussock grassland.

Table 3.14: Site 12 - Mangatepopo Valley pollen count.

SITE 12: Mangatepopo Valley		
	No.	%
Trees		
Libocedrus bidwillii	7	2
Podocarpus totara	1	0
Prumnopitys taxifolia	4	1
Dacrydium cupressinum	9	3
Halocarpus	5	2
Podocarpaceae	15	5
Nothofagus fusca-type	111	34
Nothofagus menziesii	134	41
Small trees and shrubs		
Elaeocarpus	2	1
Myrsine	3	1
Ferns and fern allies		
Cyathea smithii-type	7	2
Monolete fern spores	4	1
Trilete fern spores	5	2
Lycopodium	1	0
Unidentified	15	5
Lycopodium marker spores	7	2
Total	330	100
Taxa values		
Trees	286	87
Small trees and shrubs	5	2
Ferns and fern allies	17	5

The Taupo Tephra is 1.0 m thick and contains large charcoalized logs up to 60 mm in diameter. The contact zone is sharp, and the palaeosol was damp rather than wet, but not darkly organic in appearance.

There was no root penetration evident in the tephra or the palaeosol.

Figure 3.25: Site 12 - Mangatepopo Valley total pollen values.

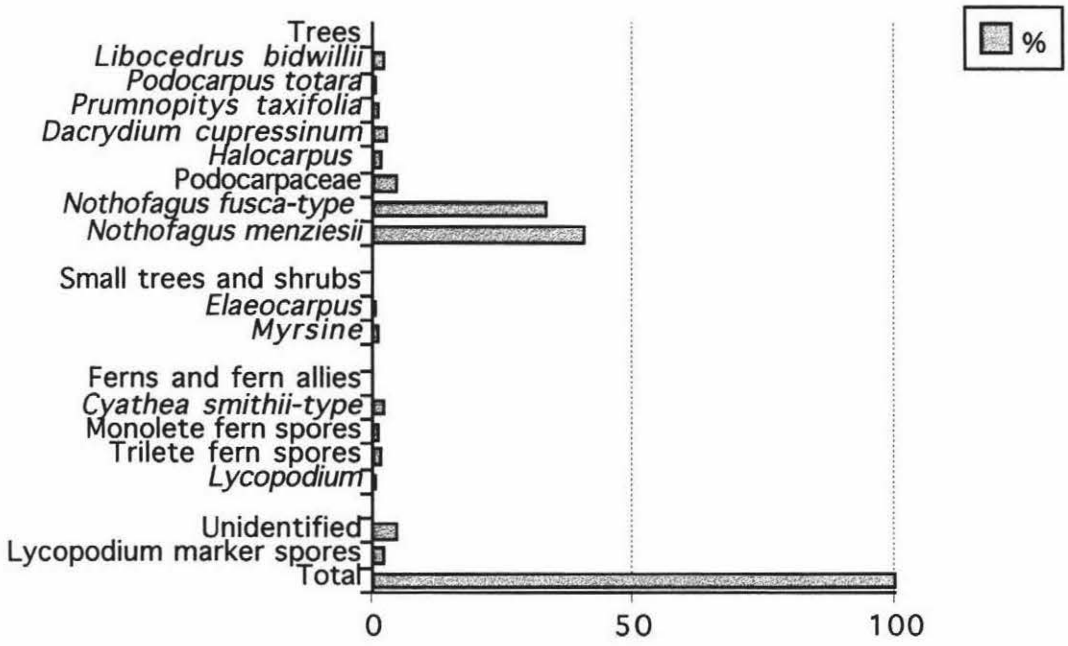
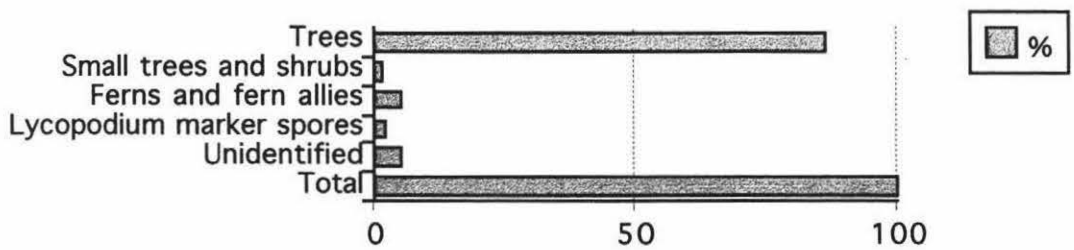


Figure 3.26: Mangatepopo Valley taxa values.



The sample was rich in pollen and spores with only 2% of *Lycopodium* marker spores recorded in the total count of 330. The grains were in a relatively good state of preservation with most being largely unaffected and only 5% remaining unidentified. Sufficient material was available for pH testing with a result of 5.6.

3.3.13 Site 13: Poutu Canal

GR: T19/533294 Altitude: 580 m Date sampled: 11/1/98

This site is located on a forestry track parallel to and southwest of the Poutu Canal south east of the canal bridge on SH 1. The site is on the south side of an overgrown cutting with a major drainage ditch beneath it, about 60 m north west of power lines. The site is very overgrown with tutu, various ferns, and adventive weeds, with surrounding pine forest within 50 m.

Table 3.15: Site 13 - Poutu Canal pollen count.

SITE 13: Poutu Canal		
	Total	%
Tall trees		
Libocedrus	3	1
Podocarpus totara	5	2
Prumnopitys ferruginea	3	1
Dacrydium cupressinum	6	2
Podocarpaceae	18	6
Nothofagus fusca-type	38	12
Nothofagus menziesii	16	5
Metrosideros	22	7
Small trees and shrubs		
Neomyrtus-type	13	4
Myrsine	20	6
Ferns and fern allies		
Cyathea smithii-type	10	3
Monolete fern spores	9	3
Trilete fern spores	70	23
Others	37	12
Unidentified	25	8
Lycopodium marker spores	16	5
Total	311	100
Taxa values		
Trees	111	36
Small trees and shrubs	33	11
Ferns and fern allies	126	41

The appropriate stratigraphy is evident in the profile with the Mangatawai Tephra underlying the palaeosol and the Taupo Tephra above it. The palaeosol is damp and dark in colour and underneath a 1.0 m layer of pumice.

The lower 30 mm of pumice is coarse and iron stained with a sharp and horizontal contact with the palaeosol. There is some horizontal root penetration of the palaeosol from vegetation on the face of the channel (avoided in sampling), but no vertical penetration through the pumice. Charcoal was evident in the tephra with some logs up to 70 mm diameter.

Figure 3.27: Site 13 - Poutu Canal total pollen values.

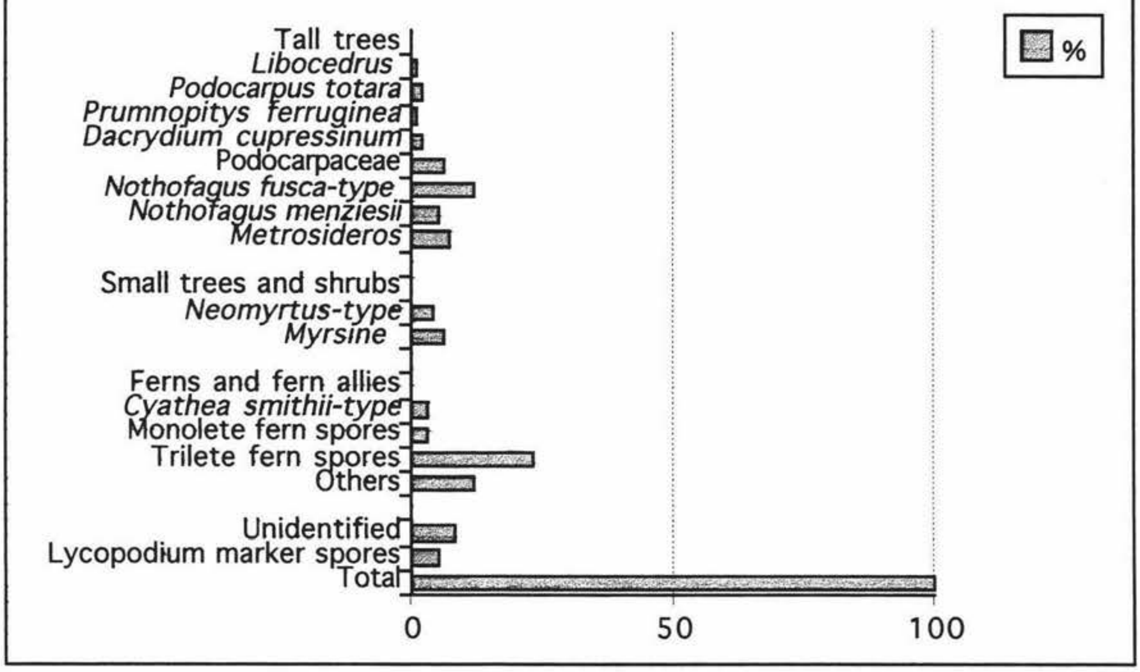
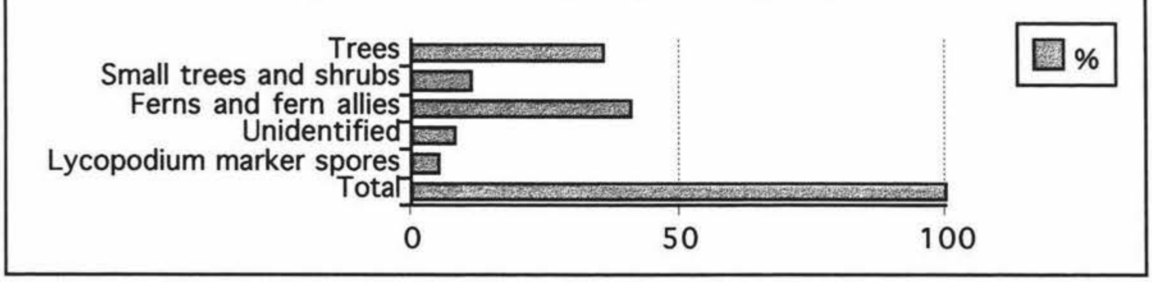


Figure 3.28: Poutu Canal taxa values.



This site lies within the FDI zone and pteridophytes represent the highest single scoring taxon at the site with 41% of the total count. Many grains are fragmented and the site is classed as severely affected, as evidenced in relatively high counts for unidentified pollen (8%) and marker spores (5%) in a total count of 311.

3.3.14 Site 14a: Erua Road (peat)

GR: S20/165171 Altitude: 730 m Date sampled: 6/2/98

This site is located 400 m down Erua Road at a small cutting on the north side of the road, above a drainage ditch running parallel to the road. The surrounding vegetation is low swamp scrub with heather, flax, and toetoe as well as some adventive grasses and weeds. *Halocarpus bidwillii, Gleichenia microphylla* (tangle fern), various *Hebe* spp., and *Empodisma minus* (jointed rush), are also present. There is a pine plantation 200 m to the south of Erua Road at this point.

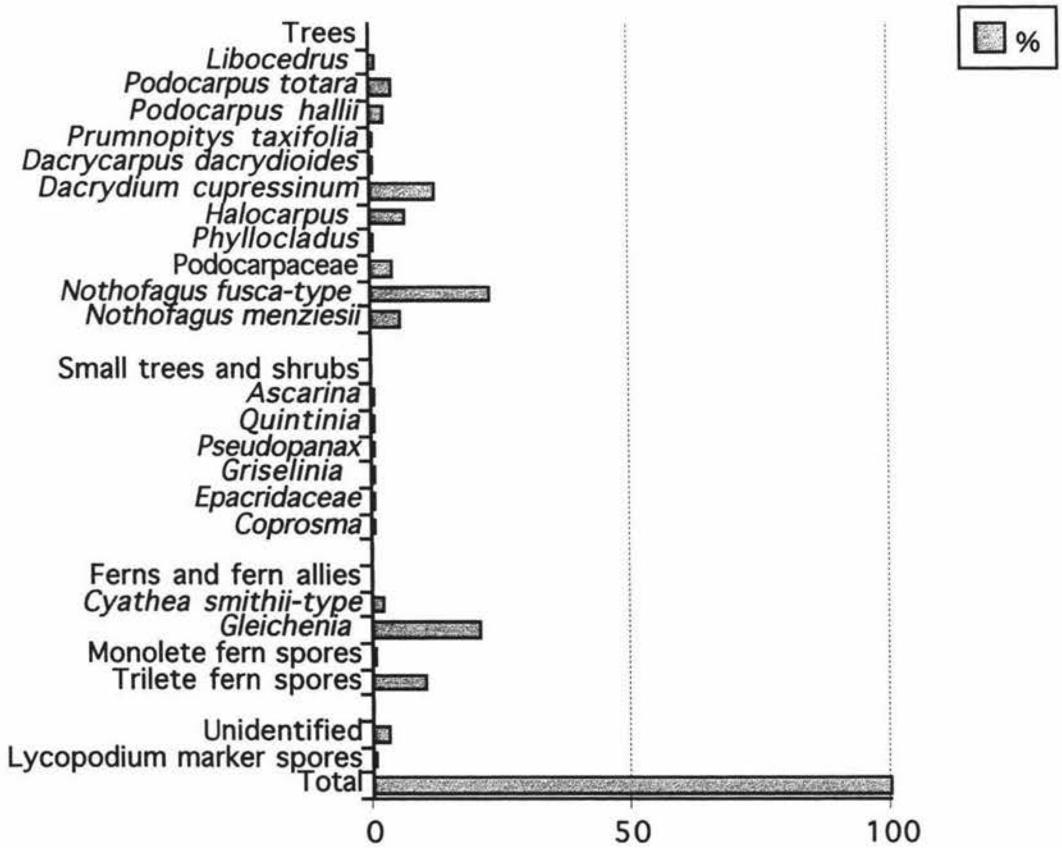
Table 3.16: Site 14 a - Erua Road (peat sample) pollen count (continued on following page).

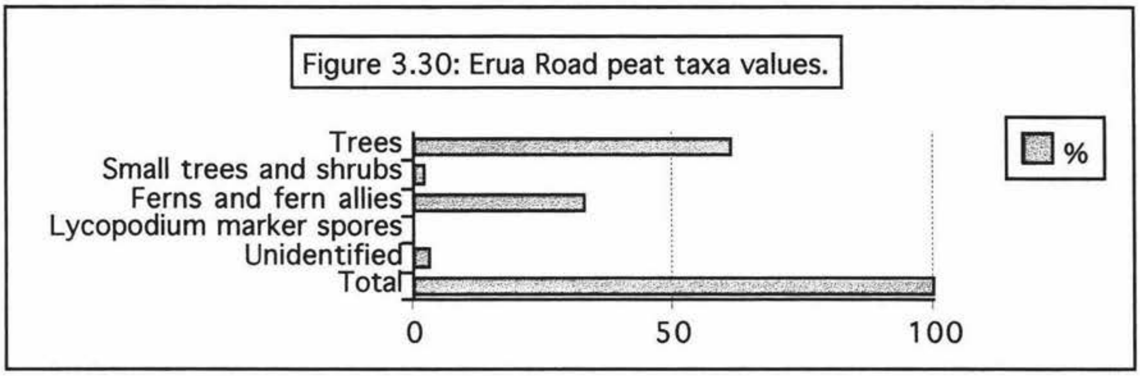
SITE 14a: Erua Road peat sample		
	Total	%
Trees		
Libocedrus	4	1
Podocarpus totara	14	4
Podocarpus hallii	8	2
Prumnopitys taxifolia	1	0
Dacrycarpus dacrydioides	1	0
Dacrydium cupressinum	41	13
Halocarpus	22	7
Phyllocladus	1	0
Podocarpaceae	14	4
Nothofagus fusca-type	74	23
Nothofagus menziesii	18	6
Small trees and shrubs		
Ascarina	1	0
Quintinia	1	0
Pseudopanax	1	0
Griselinia	1	0
Epacridaceae	1	0
Coprosma	1	0
Ferns and fern allies		
Cyathea smithii-type	6	2
Gleichenia	68	21
Monolete fern spores	1	0
Trilete fern spores	33	10
Unidentified	10	3
Lycopodium marker spores	1	0
Total	323	100

(Table 3.16 continued)		
Taxa values		
Trees	198	61
Small trees and shrubs	6	2
Ferns and fern allies	108	33

There is a clear contact between the Taupo Tephra and the underlying peat, and the tephra itself is 0.32 m thick at this location. The basal particles are relatively coarse, up to 25 mm in diameter, and are acting as an aquifer from the swamp. The lower 0.10 m is very heavily iron stained, with iron ochre washing out into the ditch, and the lower 20 mm containing charcoal. Some root penetration of the upper section of the pumice is evident with translocated organic matter in the root channels, but this does not appear to cross the the coarser lower material, or the boundary into the peat. Twigs and woody material *in situ* are evident in the peat, with some larger limbs up to 40 mm diameter. The debris in the drainage channel is thickly coated with iron ochre (probably ferrihydrite).

Figure 3.29: Site 14a - Erua Road peat sample total pollen values.





This is a peat sample and appears to represent a good preservation environment where pollen and spores are largely unaffected with only 3% in the unidentified category. It is also a very rich sample as in a total count of 323 grains only 1 marker spore was encountered.

3.3.15 Site 14b: Erua Road (palaeosol)

GR: S20/160170 Altitude: 730 m Date sampled: 29/8/98

The Erua swamp was revisited, and a second sample (Erua b) was taken at another site, in a small cutting on the southern side of the road at a distance of 900 m from the main highway, and approximately 500 m from the previous site. The site is a small lens of the Taupo ignimbrite, containing charcoal fragments, probably filling a hollow in the original landscape.

Table 3.17: Erua Road (palaeosol sample) total pollen count.

SITE 14 b: Erua Road (palaeosol)		
	Total	%
Tall trees		
Libocedrus bidwillii	7	2
Podocarpus hallii	1	0
Dacrydium cupressinum	16	5
Halocarpus sp	32	10
Podocarpaceae	8	3
Nothofagus fusca-type	111	36
Nothofagus menziesii	70	22
Small trees and shrubs		
Myrsine	4	1
Ferns and fern allies		
Cyathea smithii-type	4	1
Monolete fern spores	2	1
Trilete fern spores	36	12
Unidentified	15	5
Lycopodium marker spores	6	2
Total	312	100
Taxa values		
Trees	245	79
Small trees and shrubs	4	1
Ferns and fern allies	42	13

The top 0.30 m visible in the road cut is anthropogenic overburden which supports an association of heather and *Gleichenia microphylla*. The black, fibrous, peat rich topsoil representing the original uppermost horizon, forms a 0.25 m layer directly below the overburden. Beneath the original topsoil is 0.12 m of brown mottled/variable mixed Taupo pumice and organic matter.

Below these layers the unmixed Taupo ignimbrite is 0.43 m thick and forms several quite distinct units. Uppermost is a 0.28 m unit of pale orange-brown fine ash which grades sharply into a 0.15 m unit of dominantly fine grey ash with coarse fragments of pumice up to 30 mm scattered throughout. Pieces of charcoal up to 20 mm in diameter are also scattered through this layer. The 0.12 m basal unit contains localised patches (up to 40 mm in diameter) of the crystal plus lithic sands typical of material described from basal zones at other sites e.g. Site 26. This basal 0.12 m wedges out across the lens.

Beneath the Taupo pumice there is a 20 - 50 mm thick brown palaeosol above orange-brown allophanic, probably medial, weathered andesitic ash. Some horizontal root penetration of the charcoal and sandy areas was noted but was avoided in sampling. The upper fine ash layer had weathered into joints along which roots had also penetrated, but not passed into the lower unit.

Figure 3.31: Site 14b - Erua Road palaeosol total pollen values.

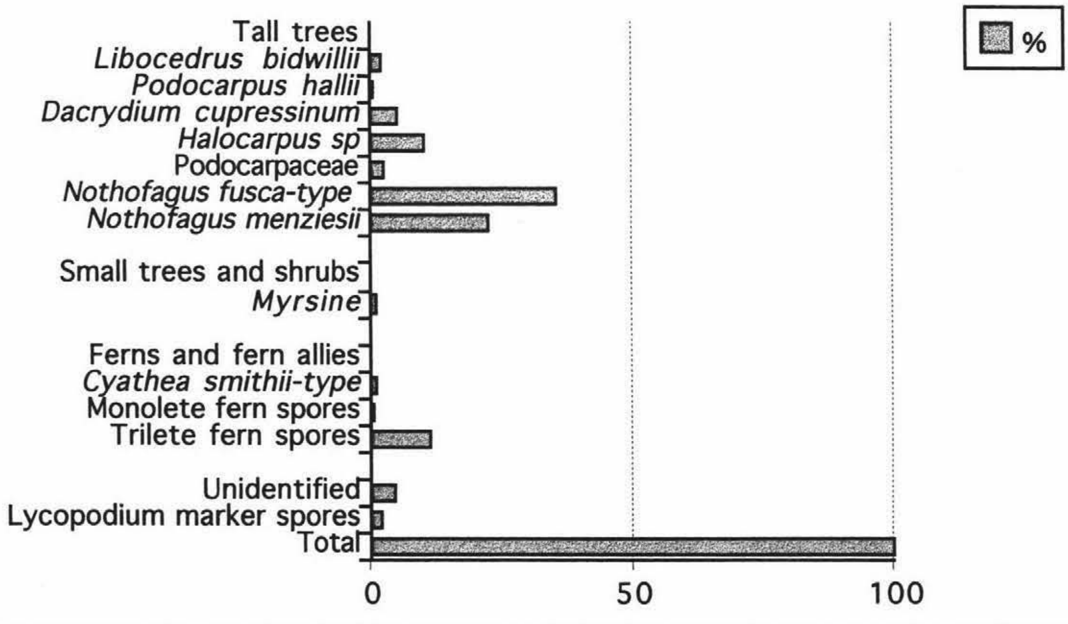
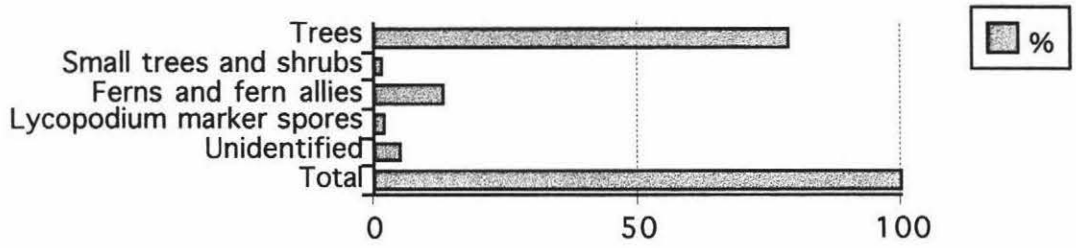


Figure 3.32: Erua Road palaeosol taxa values.



There is a good preservation environment at this site with most pollen and spores largely unaffected and only 5% unidentified in a total count of 312 grains. It is also a relatively rich site with only 2% of *Lycopodium* marker spores recorded.

3.3.16 Site 15: Whakapapaiti Bridge

GR: S19/236225 Altitude: 860 m Date sampled: 6/2/98

The site is on SH 47, 100 metres east of the Whakapapaiti Stream bridge in a road cutting on the northern side of the road. The surrounding vegetation is beech forest, with roadside scrub including native species, notably manuka.

Table 3.18: Site 15 - Whakapapaiti Stream bridge total pollen count.

SITE 15: Whakapapaiti Bridge		
	Total	%
Trees		
Libocedrus bidwillii	11	3
Dacrycarpus dacrydioides	1	0
Dacrydium cupressinum	14	4
Halocarpus	4	1
Nothofagus fusca-type	212	63
Nothofagus menziesii	55	16
Small trees and shrubs		
Neomyrtus	4	1
Weinmannia	1	0
Quintinia	1	0
Myrsine	4	1
Coprosma	1	0
Ferns and fern allies		
Blechnaceae	9	3
Monolete fern spores	1	0
Trilete fern spores	4	1
Unidentified	11	3
Lycopodium marker spores	2	1
Total	335	100
Taxa values		
Trees	297	89
Small trees and shrubs	11	3
Ferns and fern allies	14	4

The contact between the ignimbrite and underlying palaeosol is undulating, but sharp and clearly defined. Charcoal is present in the tephra, with logs up to 0.12 m in diameter. Stratification of the 0.87 m thick overlying Taupo sequence is evident, with the top 0.41 m composed of fine sand sized particles;

from 0.41- 0.44 m being of a more coarse sand sized, mafic rich unit; and from 0.44 - 0.87 m being of a coarse iron-stained unit with pumice clasts up to 50 mm in a sandy matrix. The underlying palaeosol is darker in the upper 70 mm and grades into dark grey sandy material immediately above an old lahar. Some root penetration of the upper pumice was observed, but not as far down as the contact zone.

Figure 3.33: Site 15 - Whakapapiti Stream bridge total pollen values.

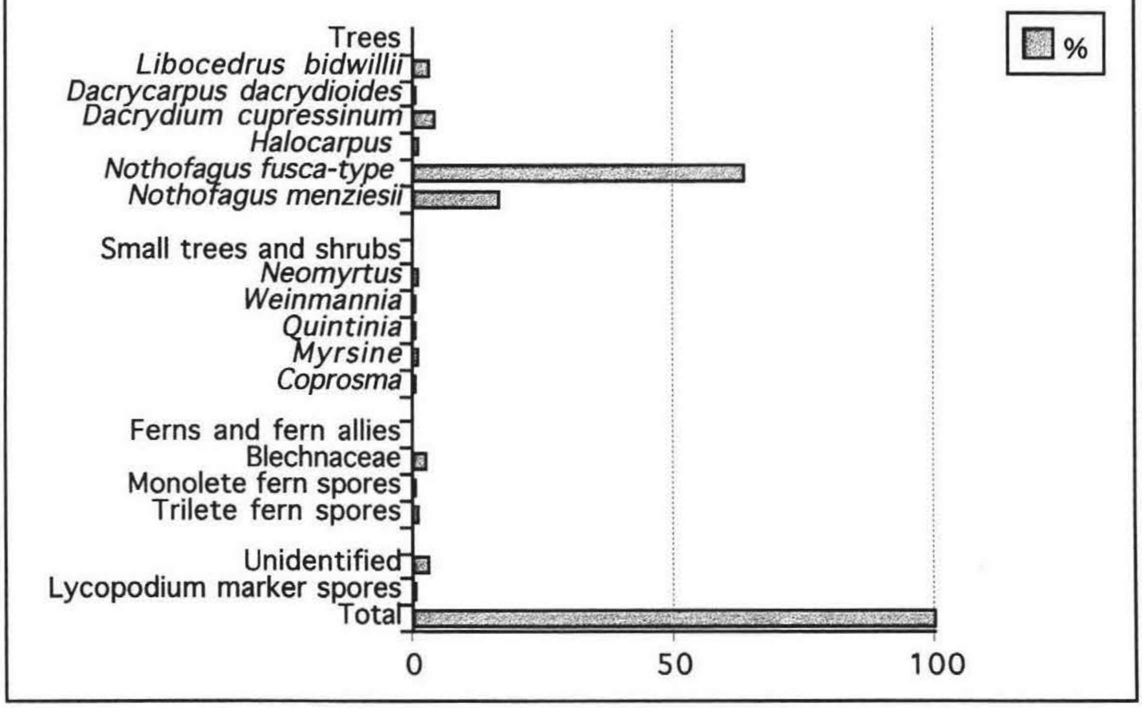
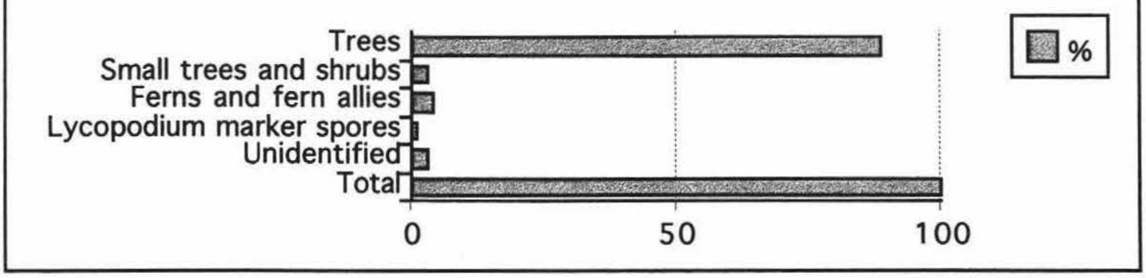


Figure 3.34: Whakapapaiti Stream bridge taxa values.



This sample represents a particularly well preserved site with pollen and spores largely unaffected. In a total count of 335 grains only 3% were unidentified. The relative abundance of pollen and spores is also reflected in the low count (1%) of *Lycopodium* marker spores.

3.3.17 Site 16: Lahar Mounds

GR: S19/265230 Altitude: 960 m Date sampled: 6/2/98

This site is located on the north eastern side of the Whakapapa Village road (SH 48), on Mt. Ruapehu, 200 metres uphill from the Lahar Mounds Walk, where the road cutting has exposed a lahar mound. The surrounding vegetation is predominantly heather and tussock, with flax, *Pseudopanax* spp. (five-finger), manuka, tanekaha, and roadside adventive weeds.

Table 3.19: Site 16 - Lahar Mounds total pollen count.

SITE 16: Lahar Mounds		
	Total	%
Tall trees		
Libocedrus	9	3
Podocarpus totara	3	1
Podocarpus hallii	2	1
Dacrydium cupressinum	24	7
Halocarpus	1	0
Podocarpaceae	5	2
Nothofagus fusca-type	160	49
Nothofagus menziesii	86	26
Small trees and shrubs		
Leptospermum	1	0
Neomyrtus-type	1	0
Myrsine	1	0
Nestegis	1	0
Coprosma	2	1
Ferns and fern allies		
Blechnaceae	1	0
Monolete fern spores	6	2
Trilete fern spores	6	2
Unidentified	14	4
Lycopodium marker spores	3	1
Total	326	100
Taxa values		
Trees	290	89
Small trees and shrubs	6	2
Ferns and fern allies	17	5

The boundary between the Taupo tephra and the underlying palaeosol is sharp but rather scalloped with about 1.0 m of apparent relief. The sample was taken from below a localised lens of the tephra, which at this site was composed of 0.70 m of coarse ash with coarser pumice fragments comprising the lower 50 mm. Charcoal fragments up to 30 mm diameter were apparent. Both the pumice and underlying palaeosol were damp.

Figure 3.35: Site 16 - Lahar Mounds total pollen values.

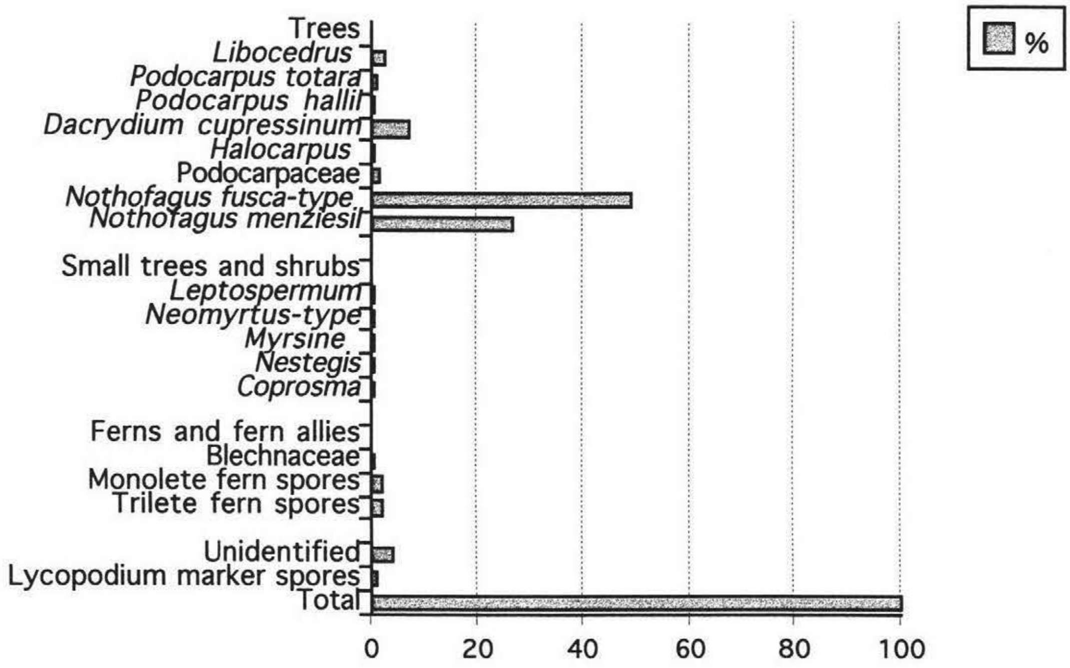
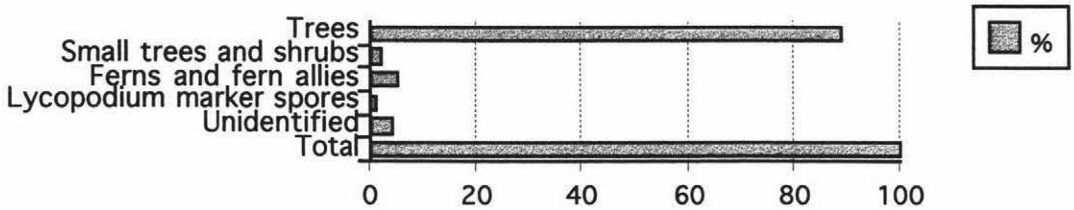


Figure 3.36: Lahar Mounds taxa values.



Pollen and spores were particularly abundant at this site with *Lycopodium* marker spores representing only 1% of the total count of 326 grains. The grains were also well preserved and largely unaffected with only 4% unidentified. This is also indicated by the good state of preservation of the Podocarpaceae pollens which were generally identifiable to species level.

3.3.18 Site 17: Whakapapa Road

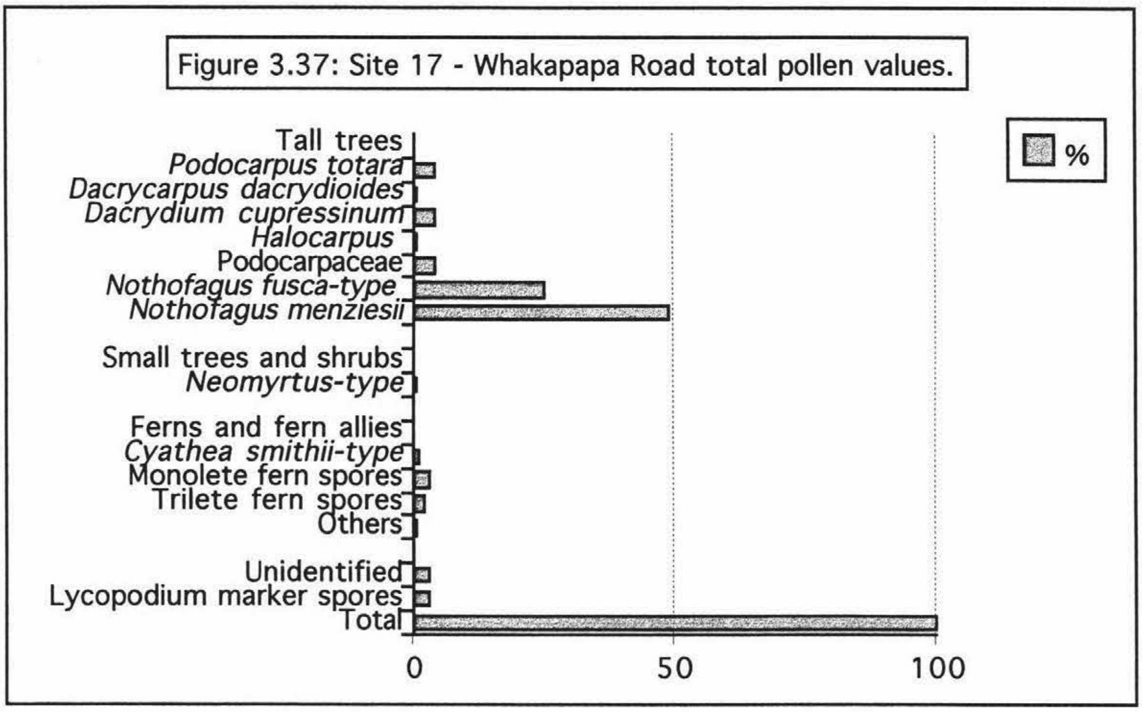
GR: S19/283215 Altitude: 1015 m Date sampled: 6/2/98

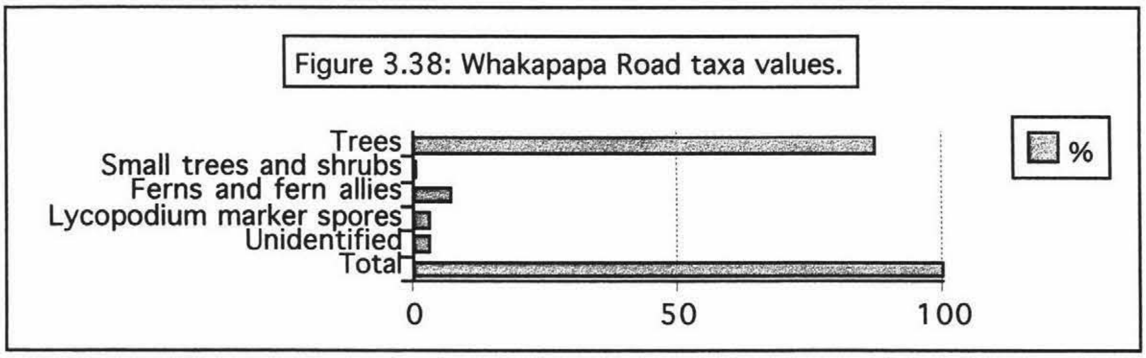
The site is located at a small terrace on the western side of SH 48 (the Whakapapa Road), 200 m above the Whakapapanui Stream bridge on Mt. Ruapehu. The surrounding vegetation is heather and tussock, with flax, five-finger, manuka, and roadside adventive weeds.

Table 3.20: Site 17 - Whakapapa Road total pollen count.

SITE 17: Whakapapa Road		
	Total	%
Tall trees		
Podocarpus totara	13	4
Dacrycarpus dacrydioides	1	0
Dacrydium cupressinum	13	4
Halocarpus	1	0
Podocarpaceae	13	4
Nothofagus fusca-type	80	25
Nothofagus menziesii	157	49
Small trees and shrubs		
Neomyrtus-type	1	0
Ferns and fern allies		
Cyathea smithii-type	4	1
Monolete fern spores	10	3
Trilete fern spores	7	2
Others	1	0
Unidentified	8	3
Lycopodium marker spores	10	3
Total	319	100
Taxa values		
Trees	278	87
Small trees and shrubs	1	0
Ferns and fern allies	22	7

The contact zone between the tephra and the underlying palaeosol is undulating, but clear and sharp. The ash layer is 1.4 m thick and contains a great deal of charcoal, including logs up to 2.2 m in length and 0.27 m in diameter. The lower part of the layer is more coarse grained, iron stained and still damp even in summer.





Most pollen and spores in this sample were largely unaffected being reasonably well preserved and readily identified, with the exception of some of the Podocarpaceae which were not identifiable to genus or species level. In a total count of 319 grains only 3% remained unidentified. Pollen and spores were also reasonably abundant at the site with a *Lycopodium* marker spore count of 3% of the total pollen sum.

3.3.19 Site 18: Skotel, Whakapapa Village

GR: S20/297197 Altitude: 1140 m Date sampled: 6/2/98

The site is located at the edge of a drainage ditch alongside the car park south east of the Skotel building at the Whakapapa Village, Mt. Ruapehu. The vegetation in the surrounding area is sub-alpine scrub including *Gleichenia microphylla, Dracophyllum spp., Empodisma minus*, and manuka.

Table 3.21: Site 18 - Skotel, Whakapapa Village pollen count.

SITE 18: Skotel, Whakapapa Village		
	Total	%
Trees		
Libocedrus	3	1
Podocarpus totara	4	1
Podocarpus hallii	2	1
Prumnopitys taxifolia	3	1
Dacrydium cupressinum	27	9
Halocarpus	2	1
Phyllocladus	2	1
Podocarpaceae	3	1
Nothofagus fusca-type	176	57
Nothofagus menziesii	67	22
Small trees and shrubs		
Ascarina	1	0
Myrsine	1	0
Ferns and fern allies		
Cyathea smithii-type	5	2
Monolete fern spores	4	1
Trilete fern spores	4	1
Pteridium	1	0
Others	5	2
Unidentified	9	3
Lycopodium marker spores	3	1
Total	310	100
Taxa values		
Trees	289	93
Small trees and shrubs	2	1
Ferns and fern allies	19	6

At this site the Taupo Tephra is a discontinuous layer which pinches and swells in the profile. The sample was taken from below 0.48 m of tephra where there was a sharp but undulating contact. Charcoal fragments up to 0.20 m long were present as well as elongate pumice clasts up to 0.10 m in length. The site was very wet as it drains a small upland swampy area and iron staining was evident in the lower pumice. The palaeosol below was darker for 20 mm directly below the actual contact, and a clear Mangatawai Tephra sequence was also evident.

Figure 3.39: Site 18 - Skotel total pollen values.

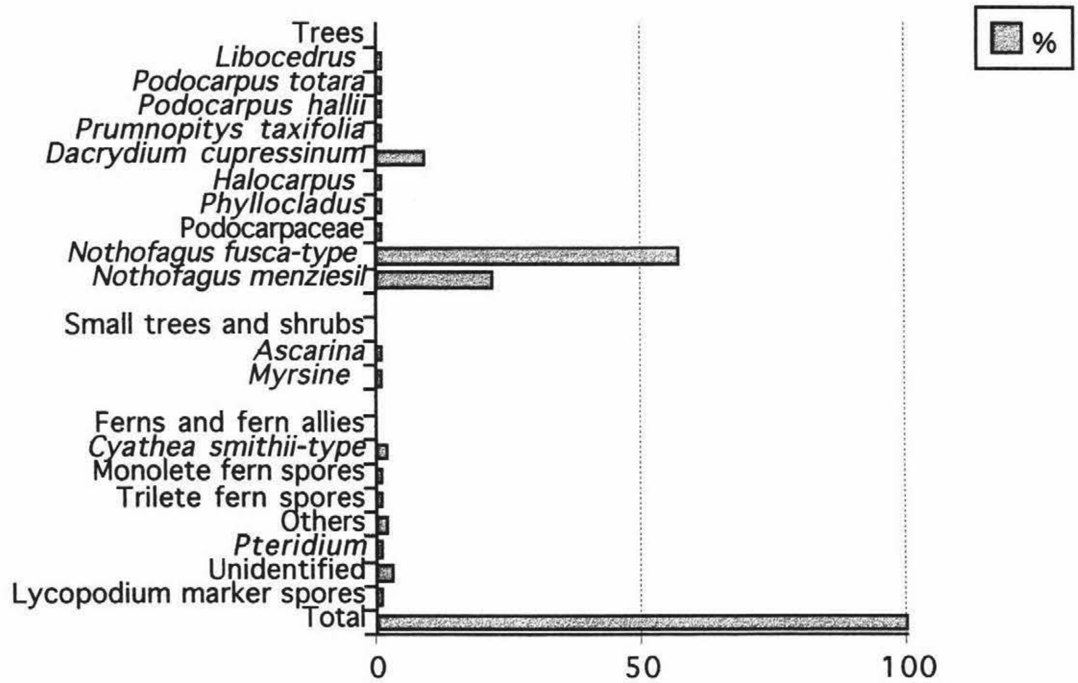
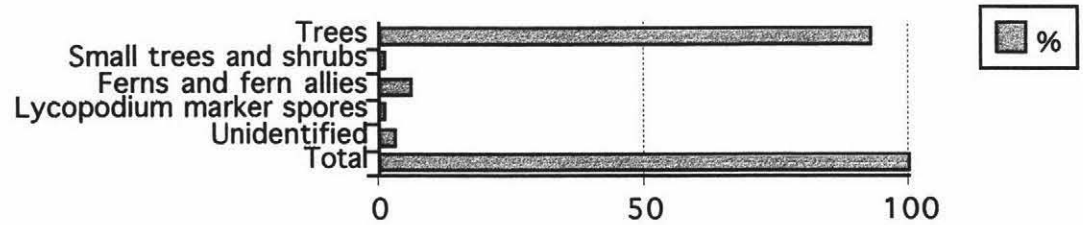


Figure 3.40: Skotel taxa values.



The sample contained abundant well preserved, largely unaffected pollen and spores with only 3% unidentified, and only 1% of *Lycopodium* marker spores in a total count of 301 grains.

3.3.20 Site 19: West Waiouru

GR: T21/394893 Altitude: 800 m Date sampled: 11/4/98 and 9/5/89

This site is located about 1 km from Waiouru in a small cutting on the western side of the Waiouru to Ohakune road (SH 49), approximately 300 m from the 75 km left bend of the railway line. The surrounding vegetation is predominantly pasture with roadside grasses and weeds, with macrocarpa and pine shelter belts nearby.

Table 3.22: Site 19 - West Waiouru pollen count.

SITE 19: West Waiouru		
	Total	%
Trees		
Prumnopitys taxifolia	1	0
Dacrydium cupressinum	2	1
Podocarpaceae	22	7
Nothofagus fusca-type	17	5
Nothofagus menziesii	5	1
Small trees and shrubs		
Myrsine	2	1
Asteraceae	7	2
Ferns and fern allies		
Cyathea smithii-type	4	1
Monolete fern spores	6	2
Trilete fern spores	39	12
Other	23	7
Unidentified	180	54
Lycopodium marker spores	27	8
Total	335	100
Taxa values		
Trees	47	14
Small trees and shrubs	9	3
Ferns and fern allies	72	21
Asteraceae grains are probably		
Olearia		

The sample was taken from a point in the profile where a small hollow had been filled by the Taupo Tephra. The ignimbrite layer at the point of sampling is 1.47 m thick, with the upper 0.64 m being a fine pink ash containing small amounts of charcoal with some penetration of roots down joints in the ash. This layer has a gradual boundary over 0.10 m into a grey ash which goes to the base of the ignimbrite. Charcoal fragments are plentiful with 2 mm sized fragments spread throughout this layer and larger fragments up to 80 mm diameter towards the base. There is no root penetration of this zone. The boundary of the Taupo Tephra with the underlying palaeosol is sharp and sloping downwards to the east. The palaeosol is allophanic rather than organic in appearance.

The initial qualitative analysis at this site showed a rather impoverished sample with a great many damaged and fragmented grains. A second sample (19a) was taken at this site during a later visit on 9/5/89 from the cutting on the eastern side of the road approximately 20 m away from the first sample site. Although the stratigraphy was the same the palaeosol was noticeably darker and more organic in appearance. Some lateral penetration of roots in the area was noticed, but these were avoided in taking the sample. Qualitative analysis of this sample was seen to be similar in quality to that of the first, and the results shown here (Table 3.22) come from the quantitative analysis of the original sample.

Figure 3.41: Site 19 - West Waiouru total pollen values.

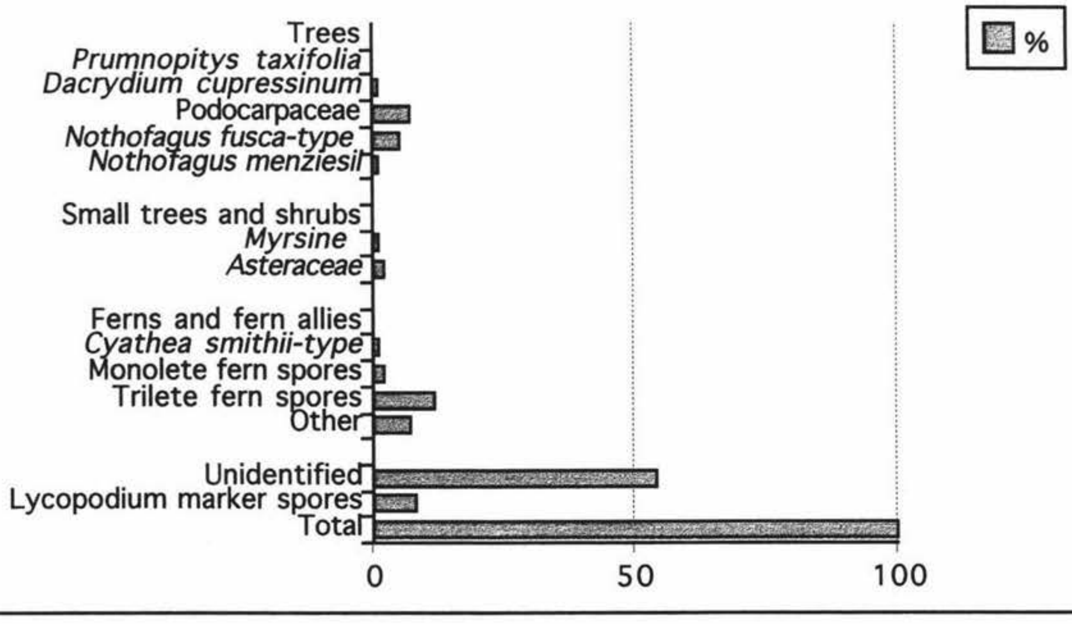
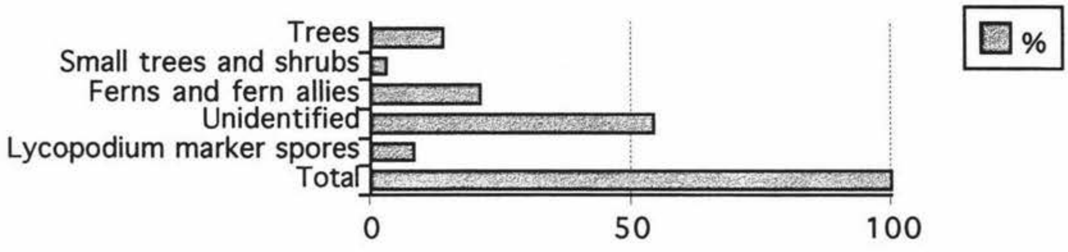


Figure 3.42: West Waiouru taxa values.



The preservation of pollen and spores at this site is very poor, with almost all grains severely affected, as shown by a 54% count of unidentified grains in a total count of 335. The count of 8% of *Lycopodium* marker spores is also high and suggests that the site is not a rich one. The pteridophyte count at 21% is higher than that of any other identified taxon. Sufficient material was available for pH testing and the sample was found to be rather high at 6.3.

3.3.21 Site 20: Waitangi Stream Bridge

GR: T21/357894 Altitude: 720 m Date sampled: 11/4/98

The site is located in a small cutting on the southern side of SH 49 between Waiouru and Tangiwai, about 100 m east of the Waitangi Stream bridge. The surrounding vegetation is pasture, with pines, manuka scrub, roadside grasses and weeds.

Table 3.23: Site 20 - Waitangi Stream Bridge pollen count.

SITE 20: Waitangi Stream Bridge		
	Total	%
Trees		
Podocarpaceae	4	1
Metrosideros	26	8
Nothofagus fusca-type	7	2
Nothofagus menziesii	4	1
Small trees and shrubs		
Leptospermum-type	16	5
Neomyrtus-type	8	3
Myrsine	5	2
Ferns and fern allies		
Cyathea smithii-type	1	0
Monolete fern spores	10	3
Trilete fern spores	28	9
Others	18	6
Unidentified	181	57
Lycopodium marker spores	10	3
Total	318	100
Taxa values		
Trees	41	13
Small trees and shrubs	29	9
Ferns and fern allies	57	18

The Taupo Tephra is 1.70 m thick at this site and contains plentiful fragments of charcoal with some larger pieces being up to 0.17 m in diameter. The upper part of the tephra is composed of fine pinkish ash which becomes paler with depth. Below 1.37 m the ignimbrite is marked by fine (1 mm size) charcoal distributed throughout. Between 1.43 and 1.46 m there is a transition into a grey zone of fine ash which extends to a basal crystal rich layer. Below this grey zone there is a basal layer which is composed of coarse charcoal fragments (up to 20 mm in size) in a crystal rich pumice matrix. A poorly developed iron pan has formed within the base of the Taupo Tephra and this varies from being 10 or 20 mm to about 0.20 m above the lower boundary of the zone.

There is no obvious underlying palaeosol in the allophanic layer below the ignimbrite, and the contact between the zones is broadly undulating with small (up to 5 mm) peaks of allophanic material protruding up into the ignimbrite. As at the previous site, the underlying palaeosol is highly allophanic and this high clay content may mean it is quite impervious to water. The grey colouring of the lower layer of the covering ignimbrite at these two sites may therefore be the result of gleying.

Figure 3.43: Site 20 - Waitangi Stream Bridge total pollen values.

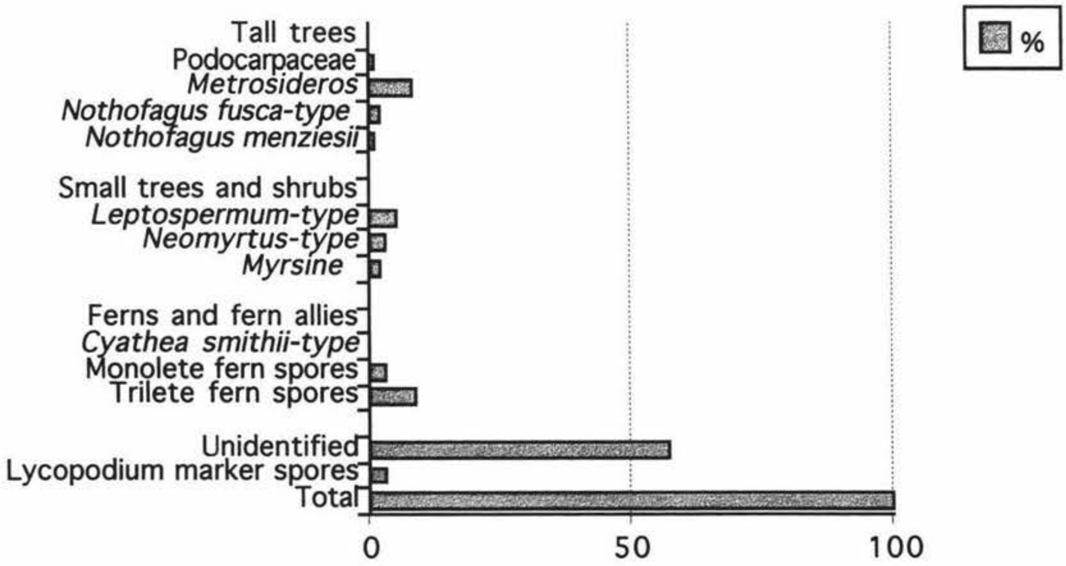
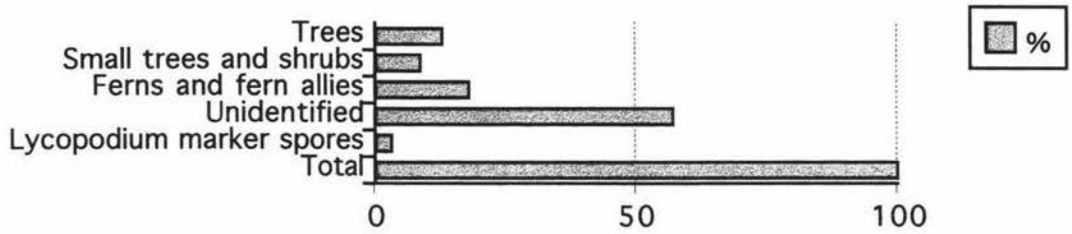


Figure 3.44: Waitangi Stream Bridge taxa values.



Although this sample was reasonably rich in pollen and spores with 3% of *Lycopodium* marker spores in a total count of 318, the overall state of preservation was very poor. Most grains were severely affected, as they were torn, degraded, or fragmented with 57% remaining unidentified. Pteridophyte spores were the highest scoring identified taxon. The pH of the sample was 6.3.

3.3.22 Site 21: Waihohonu Stream

GR: T20/480185 Altitude: 900 m Date sampled: 11/4/98

This site is located in a cutting north of the Waihohonu Stream on the eastern side of the Desert Road about 50 m north of a small stream and 100 m south of the point where the pylon-supported power lines cross the road. The surrounding vegetation is tussock grassland with manuka and heather scrub, and beech forest nearby.

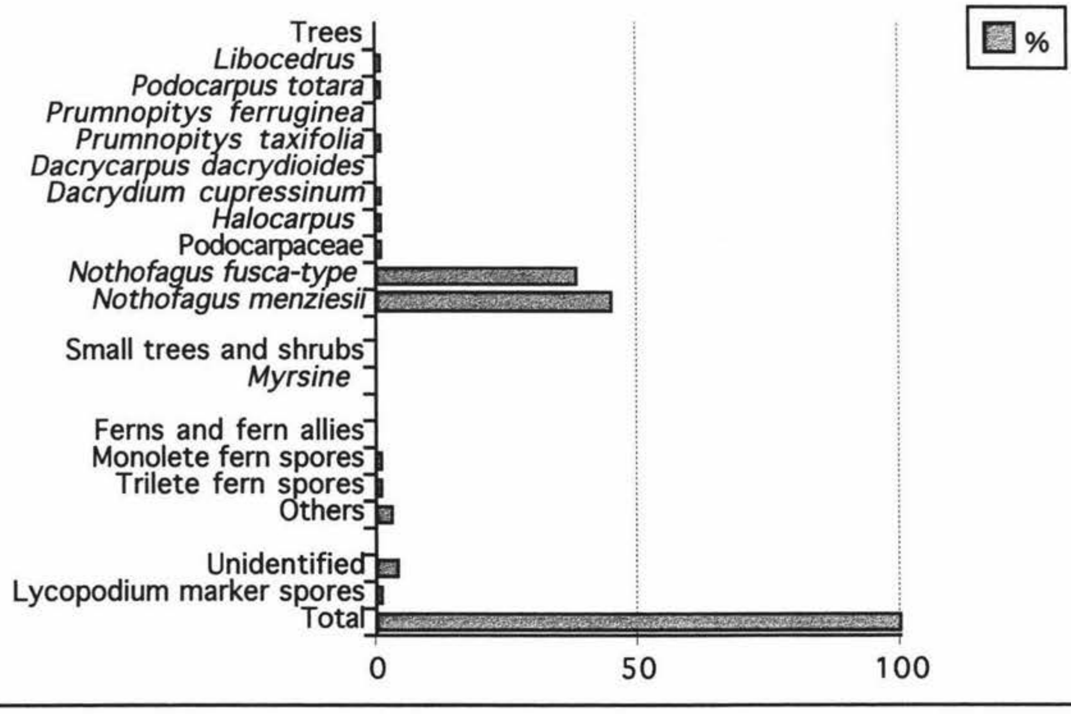
Table 3.24: Site 21 - Waihohonu Stream pollen count.

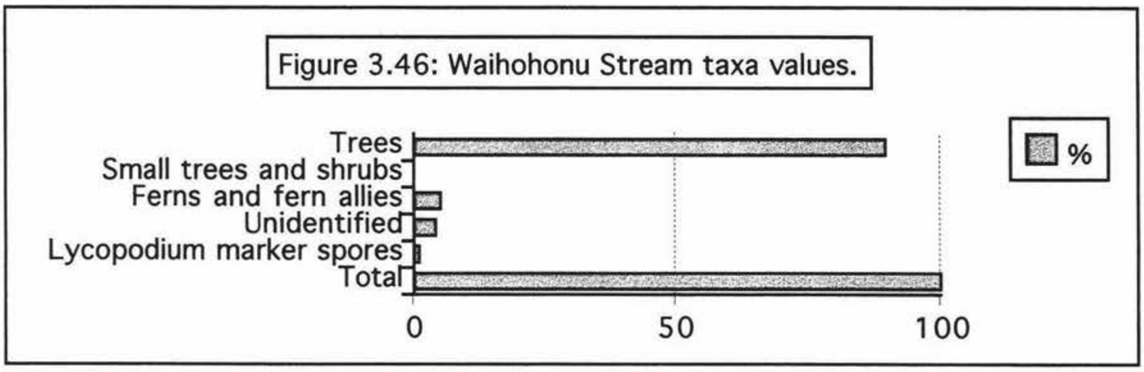
SITE 21: Waihohonu Stream		
	Total	%
Trees		
Libocedrus	3	1
Podocarpus totara	3	1
Prumnopitys ferruginea	1	0
Prumnopitys taxifolia	3	1
Dacrycarpus dacrydioides	1	0
Dacrydium cupressinum	3	1
Halocarpus	5	1
Podocarpaceae	3	1
Nothofagus fusca-type	132	38
Nothofagus menziesii	156	45
Small trees and shrubs		
Myrsine	1	0
Ferns and fern allies		
Monolete fern spores	2	1
Trilete fern spores	3	1
Others	11	3
Unidentified	13	4
Lycopodium marker spores	3	1
Total	343	100
Taxa values		
Trees	310	90
Small trees and shrubs	1	0
Ferns and fern allies	16	5

The Mangatawai Tephra is present at this site and contains fossilised beech leaves. Charcoal is present in the Taupo Tephra as well as pumice clasts up to 60 mm in diameter. The overlying ignimbrite is 0.63 m thick and somewhat stratified. The upper 40 mm is composed of coarse pumice, over a fine ash layer between 40 and 120 mm. Beneath this is a coarse pumice layer containing charcoal from 120 to 160 mm, above a fine ash with scattered 10 mm pumice clasts from 0.16 to 0.45 m, and a lower fine ash with increasing amounts of coarse pumice and charcoal fragments from 0.45 to 0.63 m. The boundary with the underlying Mangatawai Tephra is slightly disturbed over a vertical distance of about 10 mm. The zone between 0.63 and 0.69 m is composed of a fine brown allophanic "palaeosol" which has vertical cracks (about 3 mm wide) through it.

The underlying layer is represented by a continuous Mangatawai sequence with black ash from 0.69 to 0.70 m, brown medial ash from 0.70 to 0.95 m, and discontinuous black ash from 0.95 to 0.99 m. From between 0.99 and 1.20 m there is a fine brown allophanic medial ash and from 1.20 to 1.38 m there is a stratified, beech leaf bearing member of the Mangatawai Tephra.

Figure 3.45: Site 21 - Waihohonu Stream total pollen values.





Pollen and spores at this site are well preserved and largely unaffected with very few degraded or damaged grains as indicated by a low unidentified count of 4% in a full count of 343. The low count of *Lycopodium* marker spores (1%) also indicates a good preserving environment with abundant spores and pollens.

3.3.23 Site 22: South Waiouru

GR: T21/400852 Altitude: 800 m Date sampled: 11/5/98

The site is located in a cutting on the side of a farm access track approximately 2.7 km south of Waiouru Army Museum on SH 1 750 m south west of the railway crossing fly-over. The surrounding area is in pasture with some tussock clumps present.

Table 3.25: Site 22 - South Waiouru pollen count.

SITE 22: South Waiouru		
	Total	%
Trees		
Podocarpus totara	1	0
Nothofagus fusca-type	12	4
Nothofagus menziesii	1	0
Metrosideros	1	0
Small trees and shrubs		
Leptospermum-type	1	0
Myrsine	1	0
Ferns and fern allies		
Monolete fern spores	54	16
Trilete fern spores	90	27
Others	13	4
Unidentified	129	39
Lycopodium marker spores	28	8
Total	331	100
Taxa values		
Trees	15	5
Small trees and shrubs	2	1
Ferns and fern allies	157	47

At this site the palaeosol is overlain by 1.12 m of ignimbrite which in nearby outcrops 100 m to the south and 10 m to the north is strongly salmon pink in colour. The upper 25 cm of the ignimbrite is an open and porous mixture of coarse (up to 40 mm) pumice (c.30%) and charcoal (40-50%) fragments and fine ash. Below this zone is a fine ash which grades in colour from pinkish to creamy in the lower 0.25 m of the profile. This lowest 0.25 m is a pale grey, fine ash with occasional charcoal fragments (4 mm sized) and with a wide horizontal banding that is manifest as a slight change in the intensity of the grey colour. The grey colouration appears to be the result of gleying. (The fine pale grey ash appears to be a later phase which has eroded a more charcoal rich, coarser, pinker phase as evidenced in the right hand side of the profile. The fine darker ash deposited in an apparent joint opening to the right presumably originates from swirls and eddies in the outer edges of the turbulent flow.)

Occasional vertical joints are present in the face of the cutting and were avoided when sampling. To the right of the sampling location c. 8 mm of coarser ash immediately overlies the allophanic material. This coarser ash is in turn overlain by the base of the grey unit which contains occasional charcoal fragments up to 15 mm. A 1 mm thick oxidation band is present between the coarse basal layer and the overlying fine grey ash. The contact zone with the palaeosol is sharp with 20 - 30 mm high undulations along the band.

Figure 3.47: Site 22 - South Waiouru total pollen values.

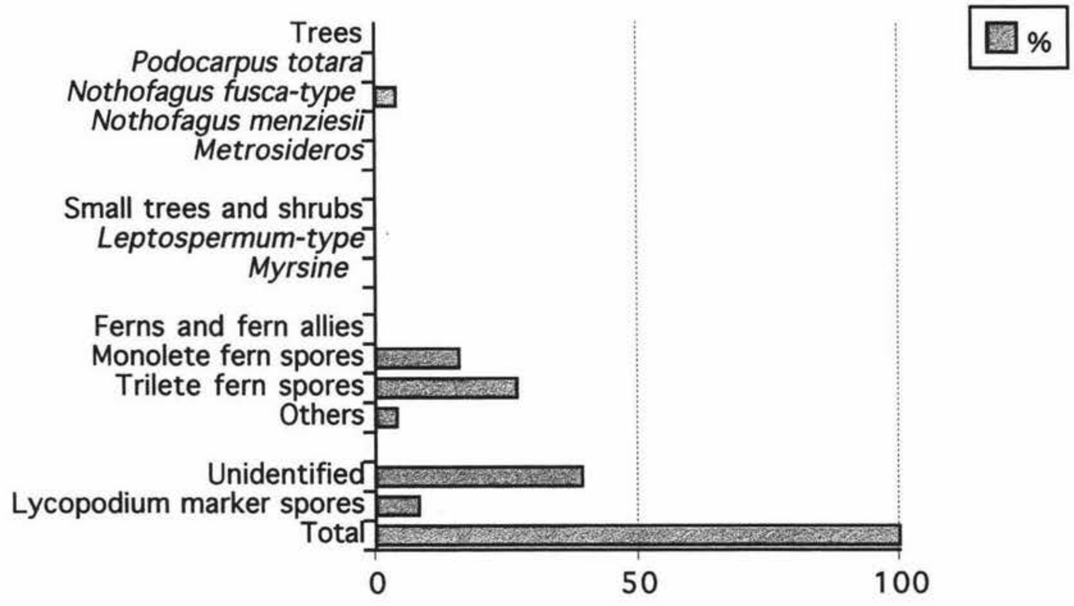
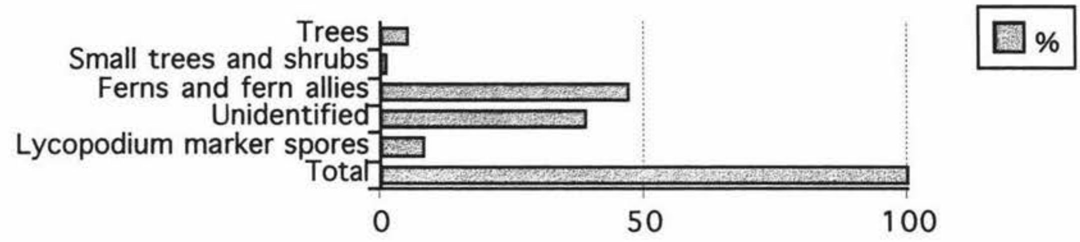


Figure 3.48: South Waiouru taxa values.



Pollen and spores at this site were severely affected in that they were extremely degraded and often very fragmented. There is a high count of 39% unidentified grains with 8% of *Lycopodium* marker spores in a total count of 331 grains. Pteridophyte spores are the highest percentage of the total at 47%. The sample has a pH of 6.4.

3.3.24 Site 23: Bates' Farm

GR: T21/377893 Altitude: 730 m Date sampled: 11/5/98

This site is located in an excavation pit on a terrace on the true left side of a small stream in hill country *c.* 100 m south of the Waiouru to Ohakune Road (SH 49), approximately 3.0 km from Waiouru. The ignimbrite flow from the eruption has filled the valley up to the terrace but limestone outcrops can be seen on the upper slopes of the valley. The area is in pasture with occasional manuka scrub.

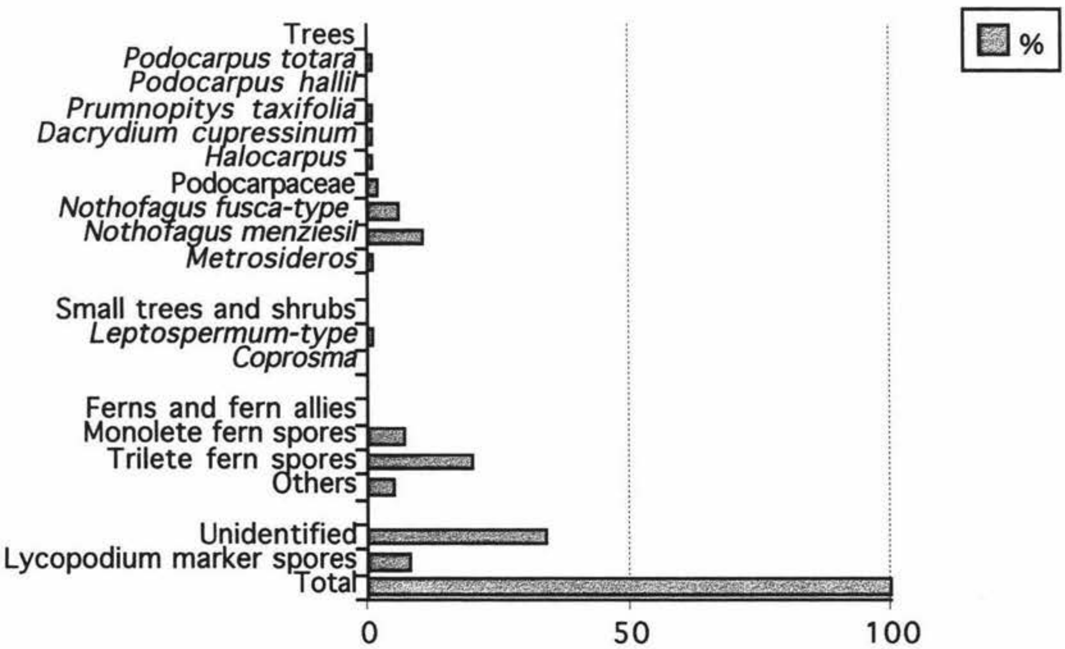
Table 3.26: Site 23 - Bates' Farm pollen count.

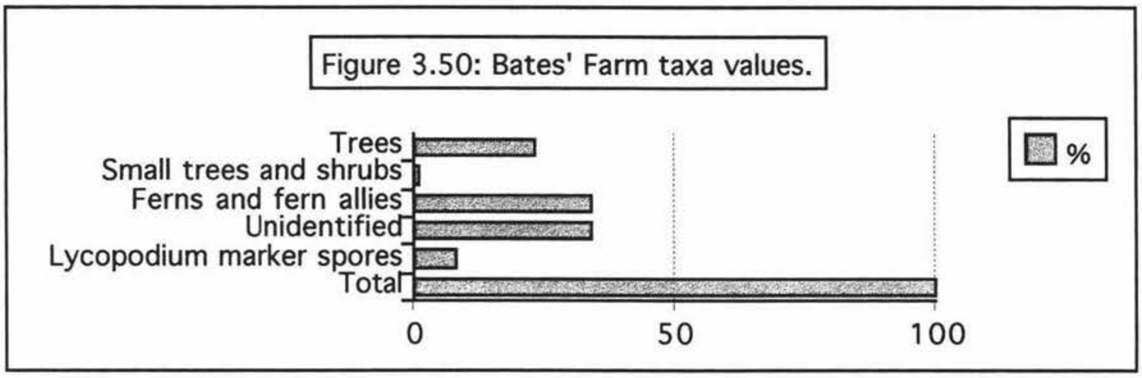
SITE 23: Bates' Farm		
	Total	%
Trees		
Podocarpus totara	2	1
Podocarpus hallii	1	0
Prumnopitys taxifolia	3	1
Dacrydium cupressinum	3	1
Halocarpus	5	1
Podocarpaceae	6	2
Nothofagus fusca-type	21	6
Nothofagus menziesii	37	11
Metrosideros	2	1
Small trees and shrubs		
Leptospermum-type	4	1
Coprosma	1	0
Ferns and fern allies		
Cyathea smithii-type	7	2
Monolete fern spores	23	7
Trilete fern spores	68	20
Others	18	5
Unidentified	115	34
Lycopodium marker spores	26	8
Total	340	100
Taxa values		
Trees	78	23
Small trees and shrubs	5	1
Ferns and fern allies	116	34

There are several points of interest at this site as not only has the pit been excavated previously, but there is also a hollow tube or hole penetrating the Taupo Tephra. This hole appears to have been a tree which was inundated by the pyroclastic flow but which remained standing as it burnt. The outline of trunk and roots (with some charcoal present) can still be seen in the ignimbrite. A railway pin and limestone blocks were found among the debris of the excavation pit into the terrace.

The pit excavated into the scarp of the terrace exposed a face where the ignimbrite is 2.23 m thick. Neighbouring outcrops reveal that the upper 0.70 m of the ignimbrite is composed of a fine pink pumice while the lower part of the unit consists of a fine grey ash. The boundary between these two zones is covered by vegetation. The lower 60 mm contains abundant fine filaments of charcoal up to 60 mm long. Some jointing is apparent in the ignimbrite and this was avoided during sampling. The palaeosol is darker at the boundary which is sharp and relatively level. Below the contact zone is 50 mm of a blotchy mixture of apparently organic rich material with paler aggregates which appear to be more similar to the underlying B horizon than to the overlying fine grey ash.

Figure 3.49: Site 23 - Bates' Farm total pollen values.





This site was another where preservation was very poor with many pollen and spores being severely affected as they were very degraded and fragmented. The sample had a high count of unidentified grains at 34% of the total count of 340. The 8% count of *Lycopodium* marker spores indicates it was also not a particularly rich one. Pteridophyte spores again scored highly at 34% of the total count. The soil pH was also high at 6.4.

3.3.25 Site 24: Upper Karioi Forest

GR: T20/379046 Altitude: 1180 m Date sampled: 11/5/98

The site is located on the true right of the Makahikatoa Stream above the Karioi Forest on the northern side of a small beech outpost on the south eastern flank of Mt. Ruapehu. The surrounding vegetation is beech forest and fellfield in the immediate vicinity, with pine forests *c.* 400 m distant.

Table 3.27 : Site 24 - Upper Karioi Forest pollen count.

SITE 24: Upper Karioi Forest		
	Total	%
Trees		
Libocedrus	1	0
Podocarpus totara	4	1
Podocarpus hallii	1	0
Prumnopitys taxifolia	2	1
Dacrydium cupressinum	2	1
Halocarpus	1	0
Phyllocladus	1	0
Podocarpaceae	5	1
Nothofagus fusca-type	150	45
Nothofagus menziesii	120	36
Small trees and shrubs		
Myrsine	1	0
Ferns and fern allies		
Cyathea smithii-type	5	1
Monolete fern spores	4	1
Trilete fern spores	4	1
Others	4	1
Unidentified	16	5
Lycopodium marker spores	13	4
Total	334	100
Taxa values		
Trees	287	86
Small trees and shrubs	1	0
Ferns and fern allies	17	5

The stratigraphy at this site reveals the Taupo and Waimihia Tephras sub horizontal beneath members of the Tufa Trig Formation (Donoghue *et al*

1995) which appear to be mantling a dune form younger than the Taupo and Waimihia Tephras. The Mangatawai Tephra is also evident. The Taupo Tephra is 0.35 m thick, with individual pumice clasts up to 60 mm long, and contains frequent fragments of charcoal up to 120 mm long. The ignimbrite pinches and swells for about 40 m across the outcrop and is creamy in colour with some iron staining evident. Some fractures were evident but were avoided in sampling. The contact zone is sharply defined and undulating over 60 mm at the sampled site.

Figure 3.51: Site 24 - Upper Karioi Forest total pollen values.

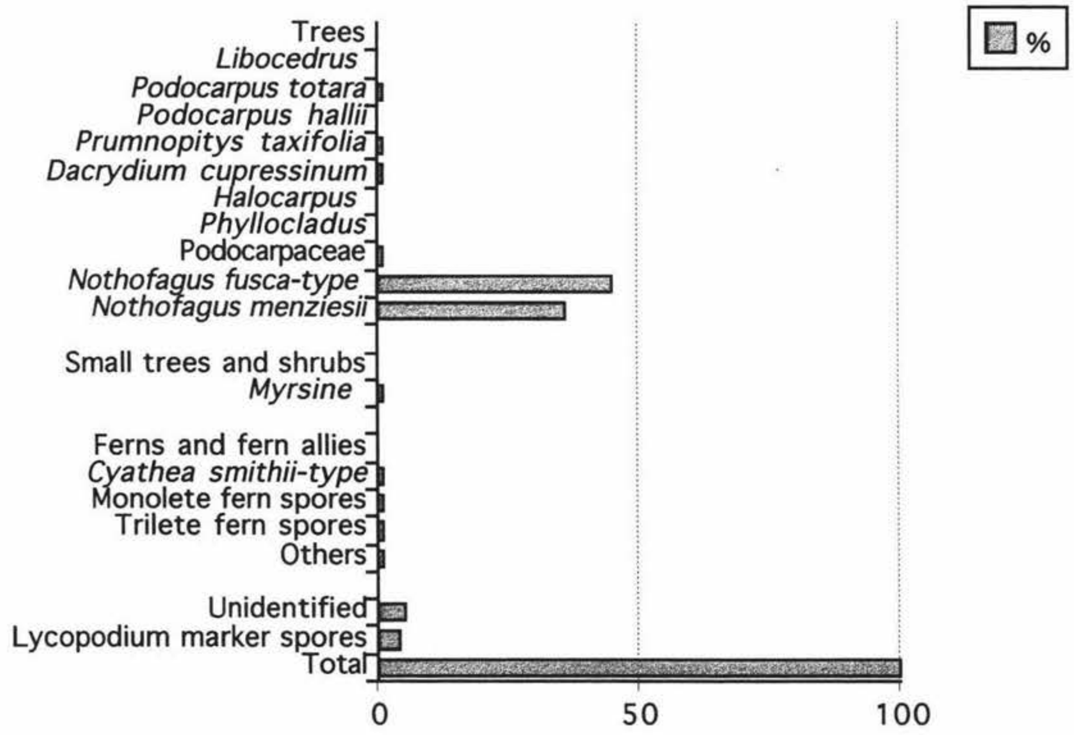
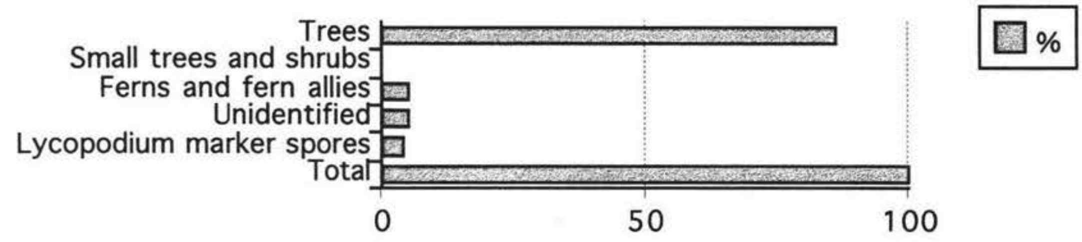


Figure 3.52: Upper Karioi Forest taxa values.



The preservation of the sample appears to be intermediately affected due to the presence of a number of fragmented or damaged grains, with 5% unidentified in a total count of 334 of pollen and spores. The sample also appears to be reasonably rich as the frequency of *Lycopodium* marker spores was only 4%. The pH of the sample was 6.2.

3.3.26 Site 25: Lower Karioi Forest

GR: T20/391986 Altitude: 920 m Date sampled: 11/5/98

This site is located in a cutting on the west side of the road 100 m south from the 4-way intersection with the Waihianoa Aqueduct road in the Karioi Forest. The surrounding vegetation is young second generation pine forest with toetoe, tussocks and grasses.

Table 3.28: Site 25 - Lower Karioi Forest pollen count.

SITE 25: Lower Karioi Forest		
	Total	%
Trees		
Halocarpus	3	1
Phyllocladus	1	0
Podocarpaceae	2	1
Metrosideros	58	18
Nothofagus fusca-type	23	7
Nothofagus menziesii	72	22
Small trees and shrubs		
Ascarina	2	1
Kunzea	1	0
Neomyrtus-type	7	2
Myrsine	28	9
Ferns and fern allies		
Cyathea smithii-type	7	2
Monolete fern spores	2	1
Trilete fern spores	43	13
Others	18	5
Unidentified	31	9
Lycopodium marker spores	30	9
Total	328	100
Taxa values		
Trees	159	48
Small trees and shrubs	38	12
Ferns and fern allies	70	21

A 0.46 m layer of coarse pumiceous ignimbrite overlies a sharp, relatively straight contact with the underlying palaeosol. There is abundant charcoal throughout with fragments up to 100 by 40 mm. The ignimbrite is almost fines depleted with coarse lapilli in the lower region, but there is a finer band towards the top. There is some root penetration, but this was avoided during sampling.

Figure 3.53: Site 25 - Lower Karioi Forest total pollen values.

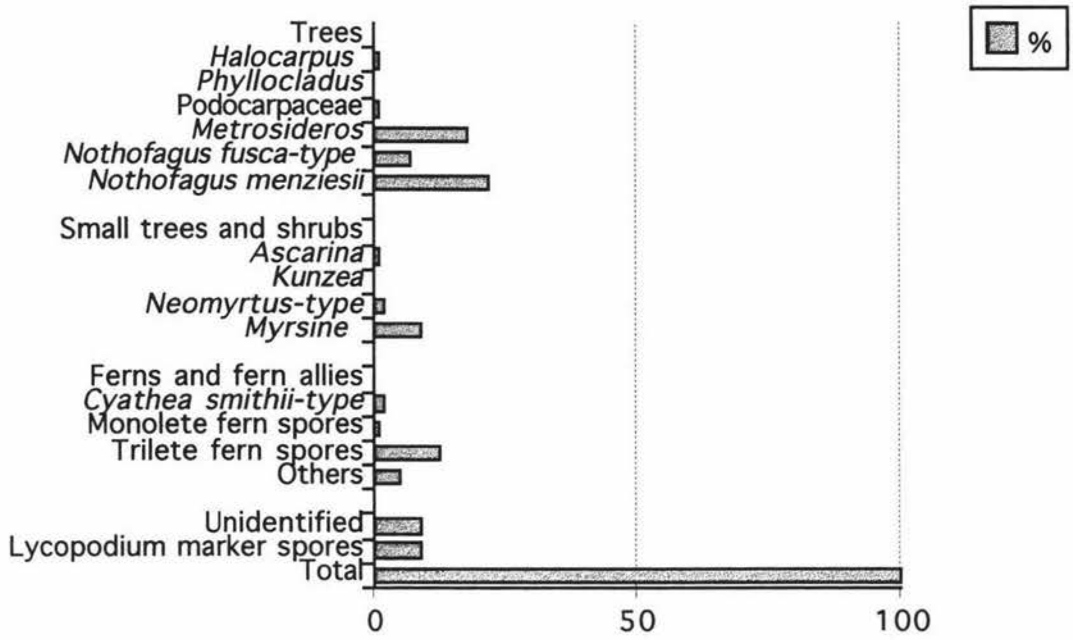
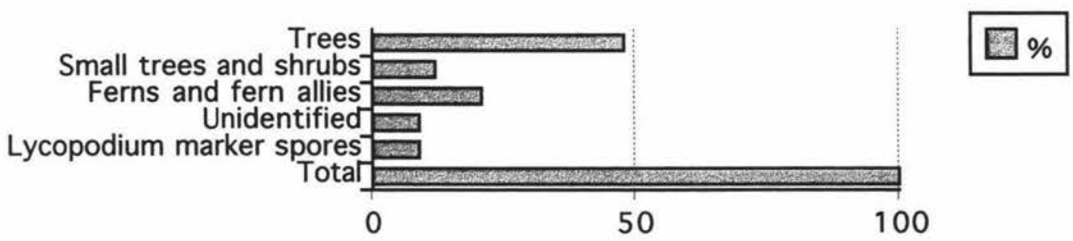


Figure 3.54: Lower Karioi Forest taxa values.



The standard of preservation at this site is classed as intermediately affected as many grains are distorted and degraded, even though most were still recognisable. In consequence, the count of unidentified pollen and spores is relatively high at 9%. The frequency of *Lycopodium* marker spores is also high at 9% in a total pollen count of 328. The pH of the sample is 5.9.

3.3.27 Site 26: Burma Road, Rangipo Prison Farm

GR: T19/569388 Altitude: 440 m Date sampled: 5/6/98

The site is located in a road cutting on the north side of Burma Road in the Rangipo Prison Farm. The area is in pasture with some nearby pine shelter belts.

Table 3.29: Site 26 - Burma Road, Rangipo Prison Farm pollen count.

SITE 26: Burma Road		
	Total	%
Trees		
Podocarpus totara	1	0
Dacrydium cupressinum	1	0
Podocarpaceae	1	0
Nothofagus fusca-type	18	5
Nothofagus menziesii	8	2
Small trees and shrubs		
Myrsine	2	1
Ferns and fern allies		
Cyathea smithii-type	42	13
Monolete fern spores	4	1
Trilete fern spores	205	61
Others	27	8
Unidentified	13	4
Lycopodium marker spores	13	4
Total	335	100
Taxa values		
Trees	29	9
Small trees and shrubs	2	1
Ferns and fern allies	278	83

The Taupo Tephra is overlain by 0.20 m of black fibrous organic matter with remnants of bracken rhizomes which penetrate the upper section of the tephra. The ignimbrite itself is 0.45 m thick, with the upper 0.15 m a darker brown due to the admixture of organic matter from above. Below this layer is 0.17 m of sandy ash with pumice fragments up to 10 mm diameter, and 0.11 m of coarse (10-20 mm) fines depleted lapilli. The basal layer is 20-30 mm of mafic rich, crystal/pumice sand sized particles. The pumice is very wet with no charcoal evident at the site. There is an incipient iron pan 1 mm thick above the basal layer. The contact with the underlying palaeosol is sharp and undulating, and the palaeosol is brown and allophanic. The Mangatawai Tephra is present.

Figure 3.55: Site 26 - Burma Road total pollen values.

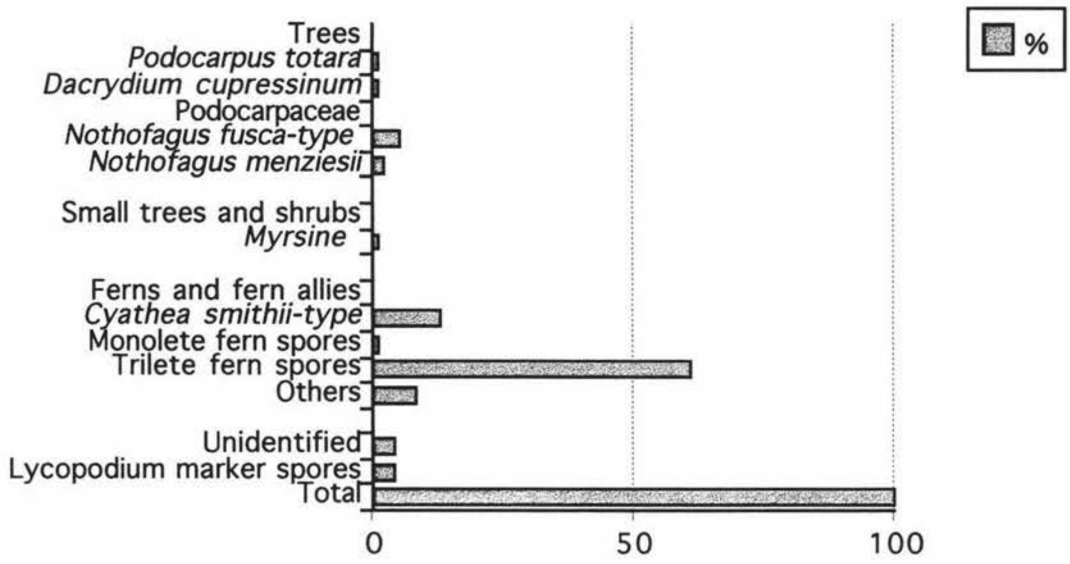
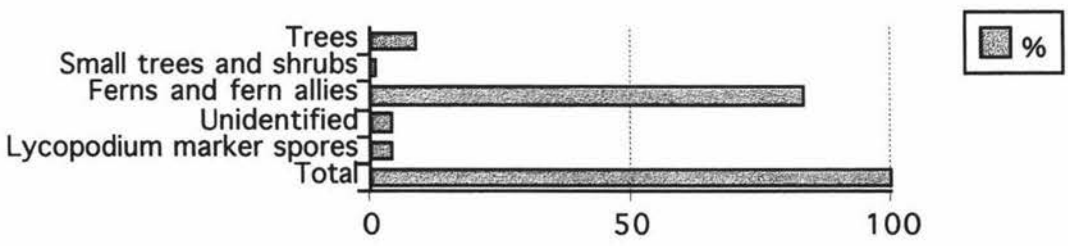


Figure 3.56: Burma Road taxa values.



Preservation of pollen and spores at this site was severely affected with almost all grains degraded, corroded and torn. *Lycopodium* marker spores were 4% of the total count of 335 and 4% remained unidentified. The highest scoring group was fern spores (83%), most of which showed some signs of degradation. The site lies within the FDI zone.

3.3.28 Site 27: Hautu Road, Rangipo Prison Farm

GR: T19/569350 Altitude: 480 m Date sampled: 5/6/98

This site is located in the east bank of a road cutting on Hautu Road in the Rangipo Prison Farm, 50 m south from the Kakiherea Stream. The surrounding vegetation is a pine plantation with roadside heather, bracken and manuka scrub.

Table 3.30: Site 27 - Hautu Road, Rangipo Prison Farm pollen count.

SITE 27: Hautu Road, Rangipo		
	Total	%
Trees		
Dacrydium cupressinum	2	1
Metrosideros	1	0
Nothofagus fusca-type	10	3
Nothofagus menziesii	13	4
Small trees and shrubs	0	
Ferns and fern allies		
Cyathea smithii-type	23	7
Trilete fern spores	147	47
Others	25	8
Unidentified	36	12
Lycopodium marker spores	55	18
Total	312	100
Taxa values		
Trees	26	8
Small trees and shrubs	0	0
Ferns and fern allies	195	62

The Taupo Tephra varies in thickness along the road cut as the ignimbrite flow appears to have filled in hollows in a slightly hummocked and terraced landscape. The minimum thickness at the site was 0.84 m, and the pumice is composed of a wide variety of clasts ranging in size from 60 mm in diameter to sand sized particles. Larger clasts of 200 by 100 mm were also seen in vicinity. The tephra was damp with some apparent iron staining, and apparently without charcoal.

The underlying palaeosol is sub horizontal at the sampling location with a sharp, slightly undulating boundary, and the Mangatawai Tephra is evident in the stratigraphy below the contact. There is some horizontal root penetration of the palaeosol which was avoided in taking the sample.

Figure 3.57: Site 27 - Hautu Road total pollen values.

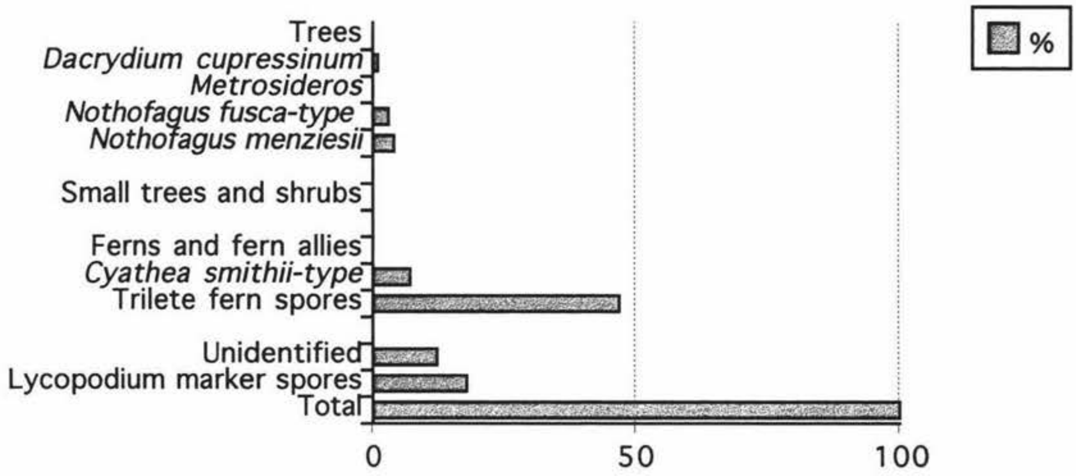
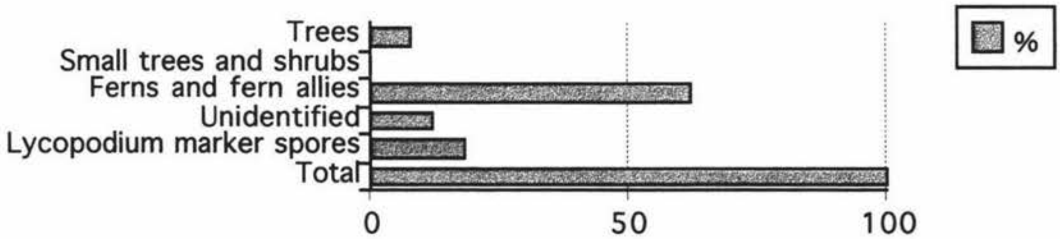


Figure 3.58: Hautu Road taxa values.



Sufficient material was available from this sample for pH testing with a result of 6.1. The site is also within the FDI zone. Preservation was poor with many severely affected, degraded and fragmented grains contributing to an unidentified count of 12% in a total of 312 pollen and spores. The sample was also impoverished with a high count (18%) of *Lycopodium* marker spores.

3.3.29 Site 28: Te Ponanga Saddle Road

GR: T19/438391 Altitude: 580 m Date sampled: 5/6/98

This site is located in the northern side of a road cutting north of Lake Rotoaira on the Te Ponanga Saddle Road. The surrounding vegetation is podocarp forest with roadside regenerating manuka and kanuka scrub, toetoe, grasses, pines and gorse (*Ulex europaeus*).

Table 3.31: Site 28 - Te Ponanga Saddle Road pollen count.

SITE 28: Te Ponanga Saddle Road		
	Total	%
Trees		
Podocarpus totara	2	1
Dacrydium cupressinum	1	0
Podocarpaceae	1	0
Nothofagus fusca-type	3	1
Nothofagus menziesii	8	2
Small trees and shrubs		
Ferns and fern allies		
Monolete fern spores	2	1
Trilete fern spores	323	95
Unidentified	0	0
Lycopodium marker spores	0	0
Total	340	100
Taxa values		
Trees	15	4
Small trees and shrubs	0	0
Ferns and fern allies	325	96

The overlying Taupo ignimbrite is 1.5 m thick at this site. It contains some large clasts up to 0.21 m in diameter mixed with sand sized particles, and charcoal fragments up to 10 by 70 mm are plentiful. Towards the base there appears to be an increase in a grey lithic sand component equivalent to that previously described as the base unit at other sites. The contact zone with the underlying palaeosol is sharp, almost horizontal, and relatively flat. The upper section of the underlying palaeosol (towards the contact) is darker and less allophanic in appearance.

Figure 3.59 : Site 28 - Te Ponanga Saddle Road total pollen values.

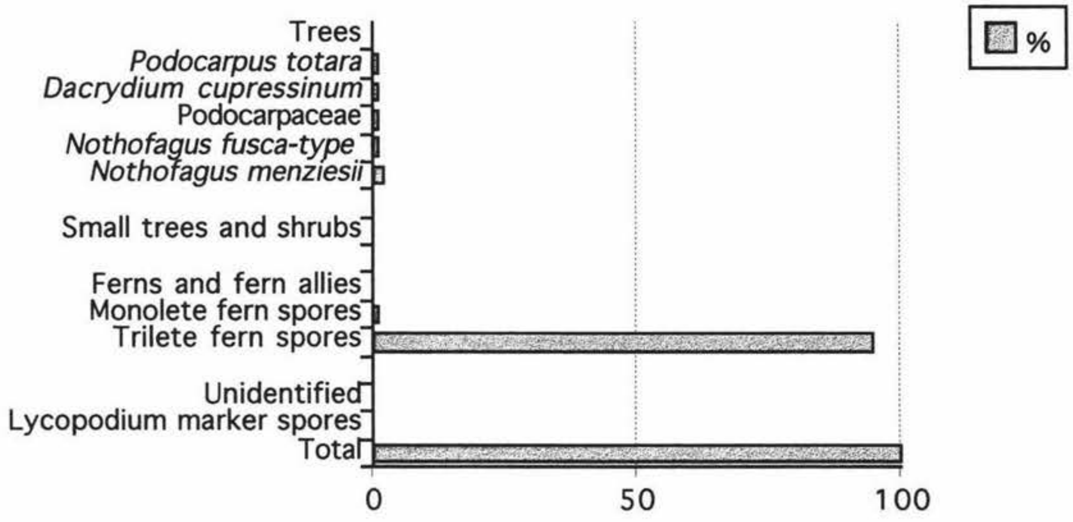
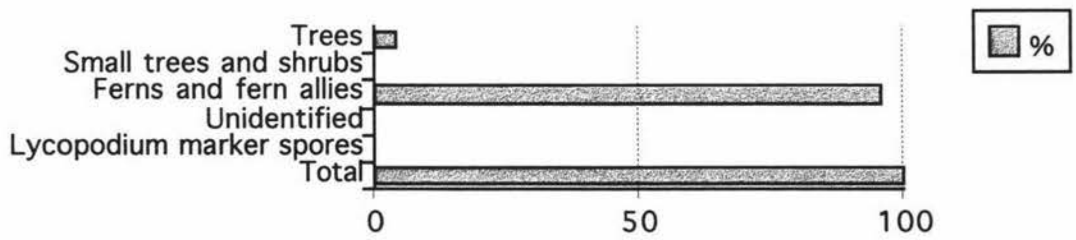


Figure 3.60: Te Ponanga Saddle Road taxa values.



Of the total sum of 340 pollen grains and spores counted in this sample, 96% were of pteridophyte spores. The site was very rich in that no *Lycopodium* marker spores were encountered. It was also in a reasonably good state of preservation, intermediately affected with no unidentified grains, although most of the trilete fern spores had some superficial granulated sculpturing, and there were some degraded and fragmented grains. The site lies within the FDI zone.

3.3.30 Site 29: Otukou Quarry

GR: T19/396386 Altitude: 610 m Date sampled: 5/6/98

The site is located on the southern side of a road cut alongside the fault outcrop on the left access road at the northwestern end of the northern Otukou pumice quarry. The surrounding vegetation is pine forest with broom, grasses, and blackberry.

Table 3.32: Site 29 - Otukou Quarry pollen count.

SITE 29: Otukou Quarry		
	Total	%
Trees		
Libocedrus	2	1
Podocarpus totara	2	1
Dacrydium cupressinum	29	9
Halocarpus	1	0
Podocarpaceae	10	3
Metrosideros	1	0
Nothofagus fusca-type	22	7
Nothofagus menziesii	47	14
Small trees and shrubs		
Kunzea	1	0
Neomyrtus-type	2	1
Elaeocarpus	2	1
Quintinia	1	0
Pseudopanax	4	1
Myrsine	29	9
Ferns and fern allies		
Monolete fern spores	15	4
Trilete fern spores	80	24
Unidentified	42	13
Lycopodium marker spores	44	13
Total	334	100
Taxa values		
Trees	114	34
Small trees and shrubs	39	12
Ferns and fern allies	95	28

A 0.70 m layer of anthropogenic overburden at this site overlies 0.48 m of Taupo ignimbrite which is stained with iron. The upper 0.28 m of the tephra is sand sized pumice, while the lower 0.20 m is more coarsely grained with pumice fragments up to 80 mm long scattered through out. Charcoal fragments up to 50 mm long are also present. The ignimbrite layer is quite compacted and contains scattered 40 by 20 mm angular lithic fragments.

Figure 3.61: Site 29 - Otukou Quarry total pollen values.

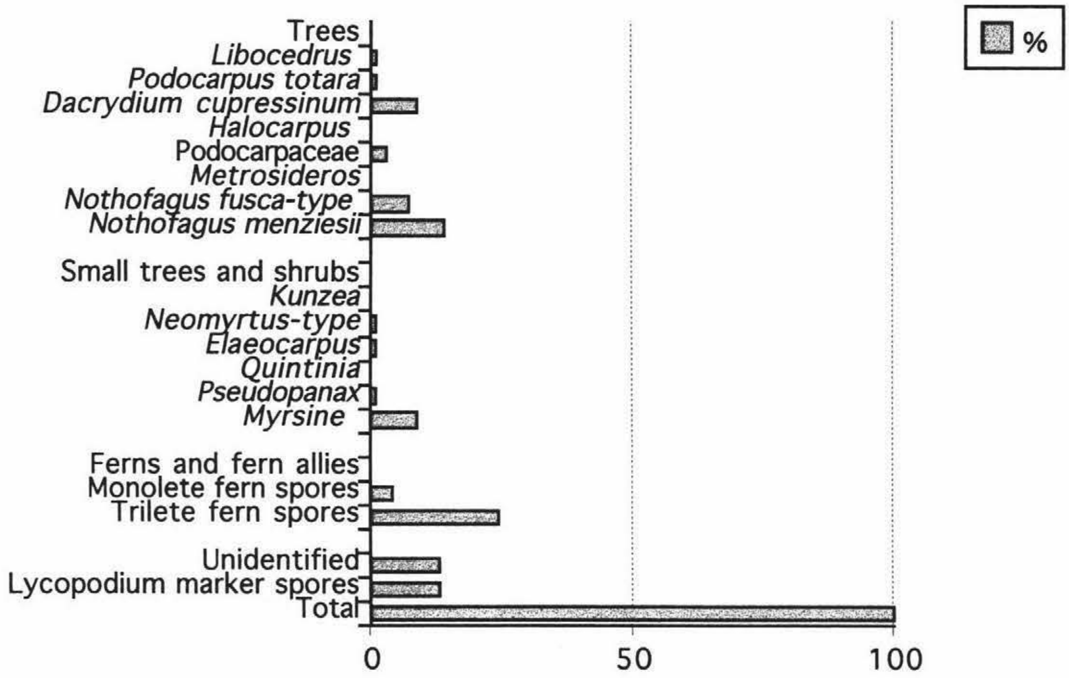
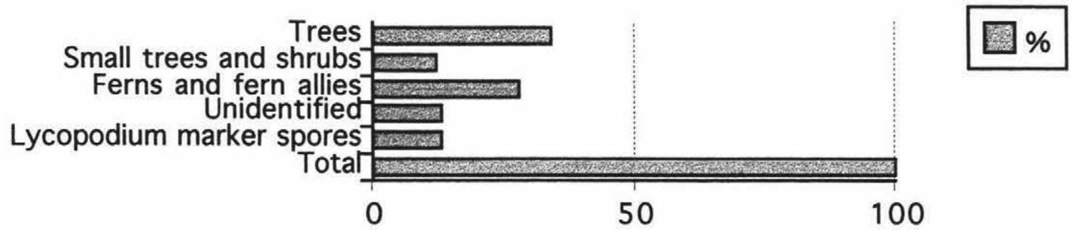


Figure 3.62: Otukou Quarry taxa values.



Pollen and spores in this sample were generally degraded and often torn or fragmented. The degree of preservation appears to be severely affected with 13% unidentified and 13% of *Lycopodium* marker spores in a total pollen sum of 334 grains. The site lies within the FDI zone and has a pH value of 6.2.

3.3.31 Site 30: Mangaparuparu Stream

GR: T19/343438 Altitude: 660 m Date sampled: 5/6/98

The site is located on the south western side of the southern end of a forestry road cutting at the Mangaparuparu stream crossing on Ruamata Road, approximately 3 kilometres north west of Lake Otamangakau. The area is in pine forest with some roadside grasses.

Table 3.33: Site 30 - Mangaparuparu Stream pollen count.

SITE 30: Mangaparuparu Stream		
	Total	%
Trees		
Libocedrus	2	1
Podocarpus totara	4	1
Dacrycarpus dacrydioides	2	1
Dacrydium cupressinum	41	13
Halocarpus	5	2
Podocarpaceae	21	7
Nothofagus fusca-type	10	3
Nothofagus menziesii	4	1
Small trees and shrubs		
Ascarina	1	0
Kunzea	1	0
Griselinia	1	0
Pseudopanax	1	0
Grasses		
Poaceae	1	0
Ferns and fern allies		
Cyathea smithii-type	11	3
Monolete fern spores	33	10
Trilete fern spores	120	38
Others	5	2
Unidentified	39	12
Lycopodium marker spores	15	5
Total	317	100
Taxa values		
Trees	89	28
Small trees and shrubs	4	1
Grasses	1	0
Ferns and fern allies	169	53

The road cutting has 0.18 m of anthropogenic overburden above 90 mm of buried A horizon. The underlying Taupo ignimbrite is 0.43 m thick, with the upper half containing pumice clasts generally 40 mm in diameter but with some up to 150 mm in diameter. Charcoal fragments up to 35 mm in diameter are mixed throughout this upper half, but tend to be concentrated at the boundary with the lower half which is composed of the grey lithic-rich sand sized unit described as the basal unit at other sites.

Figure 3.63: Site 30 - Mangaparuparu Stream total pollen values.

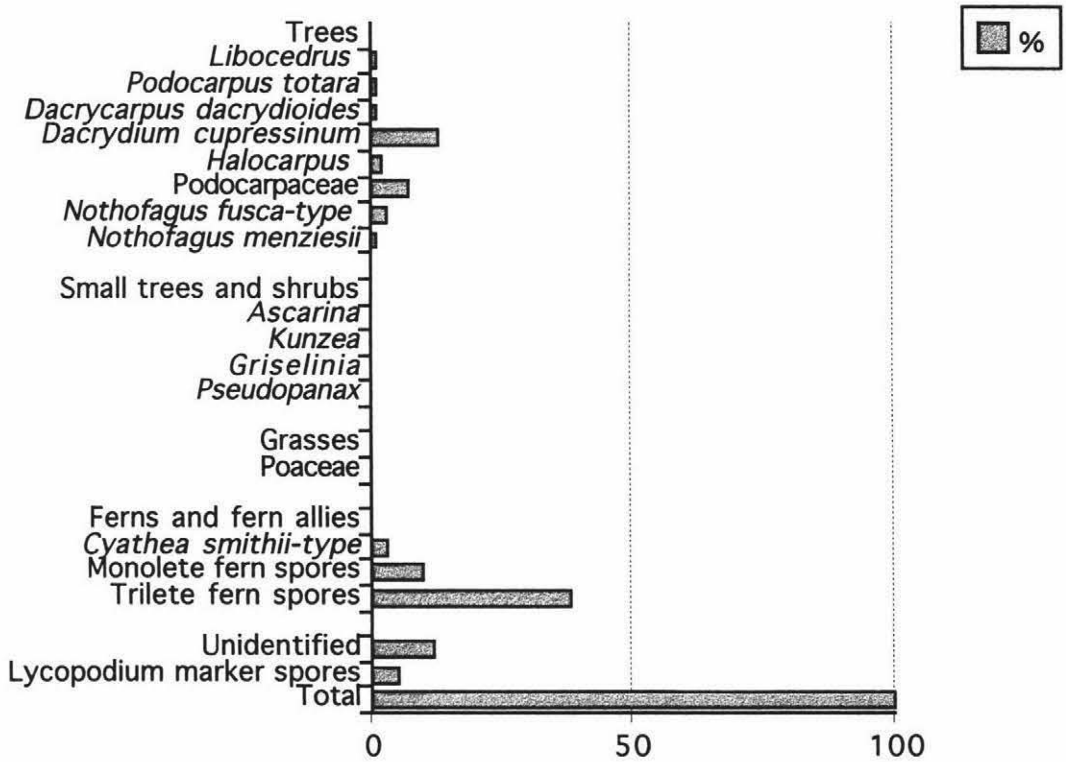
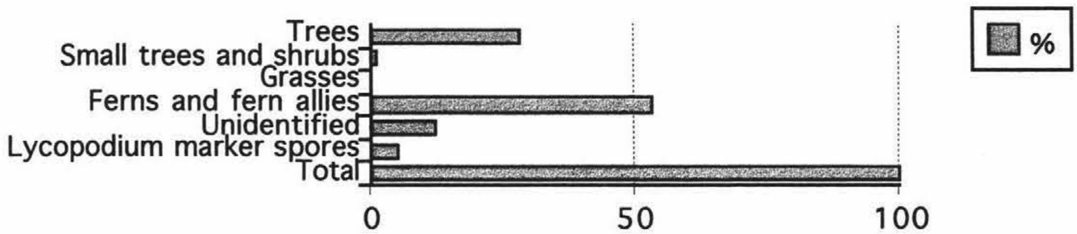


Figure 3.64: Mangaparuparu Stream taxa values.



This site lies within the FDI zone and has a pH value of 6.1. The preservation of pollen and spores within the sample is severely affected and most have superficial granulated sculpturing, or are generally degraded. The unidentified count is high at 12%, although the frequency of *Lycopodium* marker spores is not unacceptably high at 5% in a total count of 317.

3.3.32 Site 31: Mangahouhounui Stream

GR: T19/516319 Altitude: 580 m Date sampled: 6/6/98

This site is located in the northern side of a road cut at the Rangipo West end of the Lake Rotoaira Road (SH 46), 100 m east of the Mangahouhounui Stream. The area is in pasture with scattered pines.

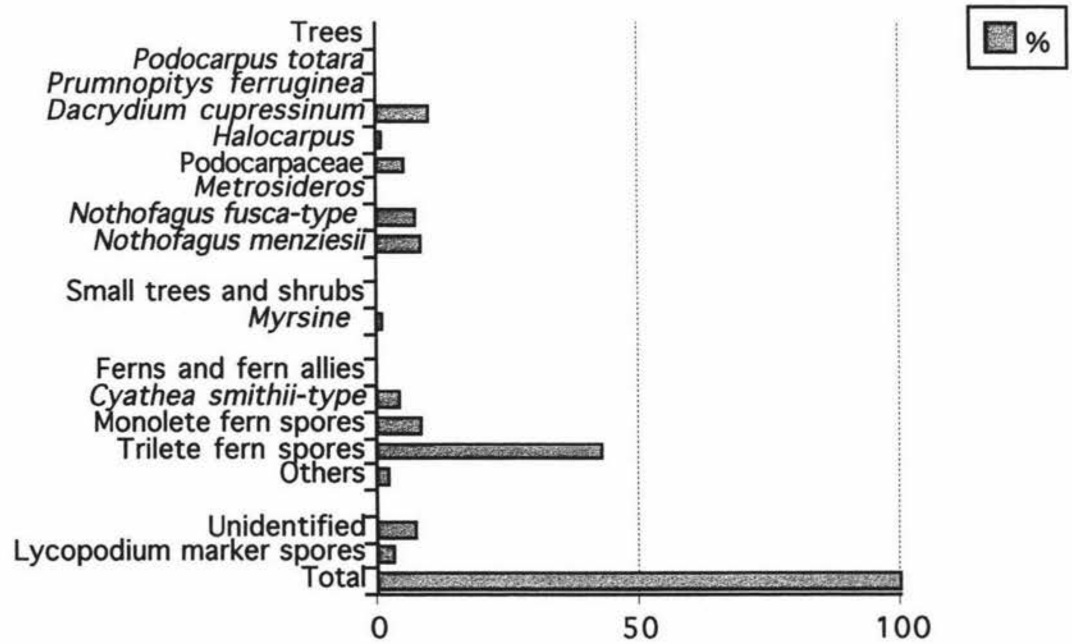
Table 3.34: Site 31 - Mangahouhounui Stream pollen count.

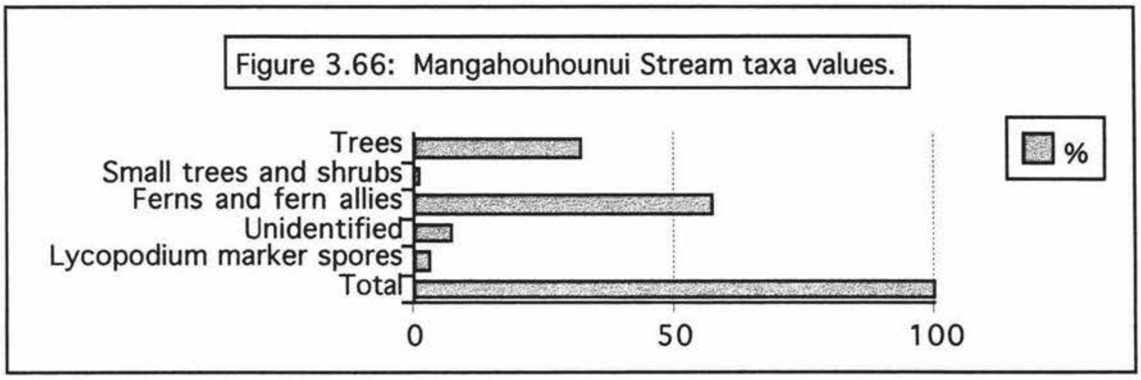
SITE 31: Mangahouhounui Stream		
	Total	%
Trees		
Podocarpus totara	1	0
Prumnopitys ferruginea	1	0
Dacrydium cupressinum	30	10
Halocarpus	2	1
Podocarpaceae	16	5
Metrosideros	1	0
Nothofagus fusca-type	21	7
Nothofagus menziesii	25	8
Small trees and shrubs		
Myrsine	4	1
Ferns and fern allies		
Cyathea smithii-type	11	4
Monolete fern spores	26	8
Trilete fern spores	131	43
Others	7	2
Unidentified	21	7
Lycopodium marker spores	10	3
Total	307	100
Taxa values		
Trees	97	32
Small trees and shrubs	4	1
Ferns and fern allies	175	57

Several layers can be seen in the 2.87 m of unwelded Taupo ignimbrite at this site. The upper layer is the present land surface and so does not have its upper boundary recorded although it is over 1.60 m thick. It is composed of compacted ignimbrite with clasts up to 0.20 m in diameter. Below this layer is an 80 mm layer of the grey, sandy, crystal and lithic unit similar to those previously described as the basal unit at other sites. The next unit is 0.42 m of a loose and coarse fines-depleted ignimbrite which tends to have been eroded back in the outcrop. Below this (and with abundant charcoal) is a 0.13 m repeat of the grey, sandy, lithic rich unit. The lowest unit is 0.55 m thick and composed of coarse and unwelded clasts ranging up to 80 mm in diameter with occasional fragments of charcoal. At the contact zone between this unit and the underlying palaeosol is a fine grey ash layer.

The contact zone of the palaeosol with the underlying Mangatawai sequence is sharp and undulating. Below the boundary, at about 0.21 m into the Mangatawai Tephra there is a discreet, dark grey zone about 40 mm thick of disrupted sandy tephra which appears to parallel the contact zone above. The upper 0.12 m is mottled in appearance and has sub vertical joints along which roots have penetrated. The source of these roots was unable to be determined, but since the lower metre of the overlying Taupo Tephra shows no signs of any root penetration it is assumed that they either have grown in horizontally from vegetation on the cutting face, or that they pre-date the eruption. Those areas where the roots were found were avoided in sampling.

Figure 3.65: Site 31 - Manghouhounui Stream total pollen values.





Pollen and spores in this sample are severely affected with many spores degraded or fragmented. Podocarpaceae pollen, in particular, are often torn, corroded and difficult to identify to species level. In a total count of 307 grains 7% remained unidentified. The sample was reasonably rich in pollen with a count of only 3% of *Lycopodium* marker spores. Pteridophyte spores were the highest scoring taxon with 57% of the pollen sum. The site is within the FDI zone.

3.3.33 Site 32: Papakai

GR: T19/350363 Altitude: 680 m Date sampled: 6/6/98

This site is located below the Papakai Trig on the south eastern side of a road cutting on SH47 between Eivin's Motor Lodge (300 m to the east) and Te Porere Redoubt. The area is in pasture and pine forest.

Table 3.35: Site 32 - Papakai pollen count.

SITE 32: Papakai		
	Total	%
Trees		
Podocarpus totara	1	0
Dacrydium cupressinum	10	3
Halocarpus	3	1
Podocarpaceae	5	2
Nothofagus fusca-type	135	42
Nothofagus menziesii	93	29
Small trees and shrubs		
Ferns and fern allies		
Cyathea smithii-type	2	1
Monolete fern spores	35	11
Trilete fern spores	28	9
Unidentified	12	4
Lycopodium marker spores	0	0
Total	324	100
Taxa values		
Trees	247	76
Small trees and shrubs	0	0
Ferns and fern allies	65	20

The 90 mm of topsoil which overlies the Taupo Tephra contains occasional large pumice clasts. The ignimbrite layer is 0.48 m thick with an upper 0.18 m which is slightly oxidised, and a lower 0.30 m which is unoxidised. The ignimbrite layer overall is composed of loose pumice fragments up to 40 mm in diameter and with occasional charcoal. Towards the base there is a slight increase in the grey crystal and lithic component previously described. The contact with the underlying Mangatawai sequence is sharp and undulating with a dark layer 2-3 mm thick which is either rich in charcoal or in organic matter at the actual contact.

Within the cutting are areas where pumice has moved up to 0.14 m down root channels into the Mangatawai sequence and these areas were avoided in sampling. The upper 0.05 m of this sequence appears to be darker in colour, apparently due the presence of organic matter. Below this, at a depth of 0.20 m there is a distinct tephra of grey sands dispersed over about 30 mm. This grey ash sequence approximately parallels the base of the Taupo Tephra throughout the road cutting.

Figure 3.67: Site 32 - Papakai total pollen values.

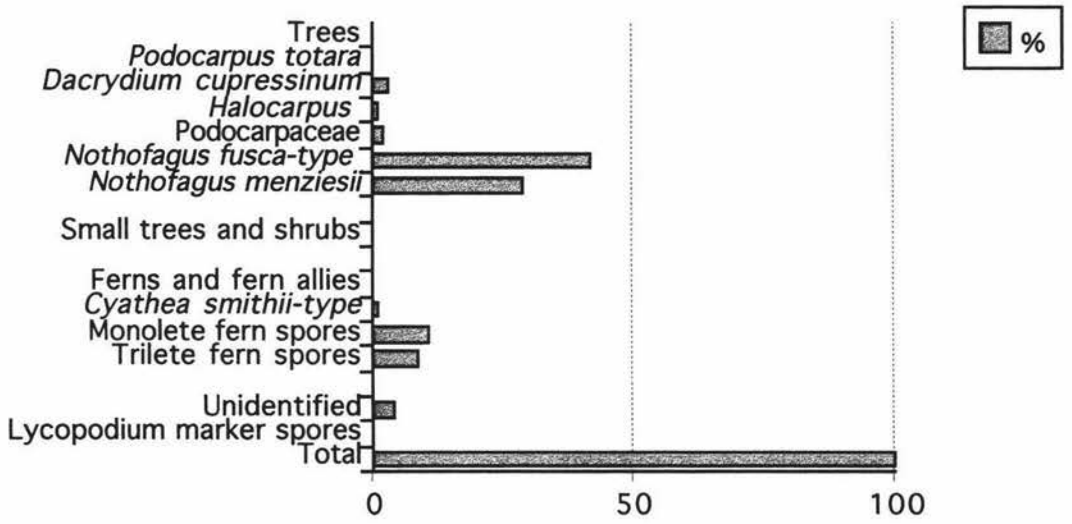
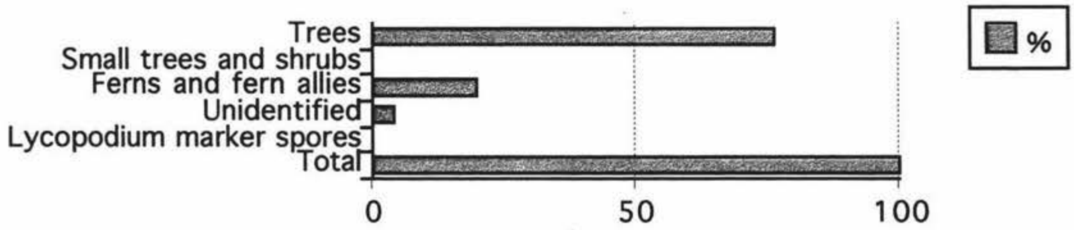


Figure 3.68: Papakai taxa values.



Pollen and spores in this sample appear to be both plentiful and largely unaltered with no *Lycopodium* marker spores recorded, and only 4% unidentified in a total count of 324 grains.

3.3.34 Site 33: North National Park

GR: S19/172253 Altitude: 780 m Date sampled: 6/6/98

The site is located in a roadside bank beside a drainage ditch on the eastern side of SH 4 opposite the northern end of a rest area, north of National Park. The vegetation of the surrounding area is regenerating native forest, with toetoe, bracken, broad leaved shrubs, grasses and flax along the roadside.

Table 3.36: Site 33 - North National Park pollen count.

SITE 33: North National Park		
	Total	%
Trees		
Libocedrus	4	1
Podocarpus totara	8	2
Prumnopitys ferruginea	11	3
Prumnopitys taxifolia	8	2
Dacrydium cupressinum	75	22
Phyllocladus	2	1
Podocarpaceae	6	2
Nothofagus fusca-type	9	3
Nothofagus menziesii	7	2
Small trees and shrubs		
Epacridaceae-type tetrad	2	1
Myrsine	19	5
Ferns and fern allies		
Cyathea smithii-type	18	5
Monolete fern spores	23	7
Trilete fern spores	70	20
Hymenophyllaceae	59	17
Unidentified	24	7
Lycopodium marker spores	3	1
Total	348	100
Taxa values		
Trees	130	37
Small trees and shrubs	21	6
Ferns and fern allies	170	49

A 0.18 m layer of anthropogenic overburden at the top of the profile covers an A horizon 210 mm thick which has fine pumice distributed throughout, and an incipient basal iron pan approximately 3 mm thick. There is abundant charcoal present in the Taupo ignimbrite with one large fragment to the right of the site measuring 300 by 40 mm. The ignimbrite layer is 0.32 m thick and composed of predominantly sand sized pumice with the upper 0.12 m slightly more coarse grained with pumice clasts up to 30 mm in diameter. The basal 0.06 m also contains similar slightly coarser clasts than the middle section of the unit and has noticeable fine charcoal throughout. The contact zone with the underlying palaeosol is sharp and straight. Some horizontal roots (avoided in sampling) were present in this layer but there was no apparent vertical penetration through the contact zone into the palaeosol.

At this distance of *c.* 50 km from the eruptive source the flow is unevenly spread across the landscape. The thickest ash band seen in this road cutting was 0.50 m and contained a basal member rich in fine charcoal and an upper member rich in coarse charcoal similar to that seen at the sampling site.

Figure 3.69: Site 33 - North National Park total pollen values.

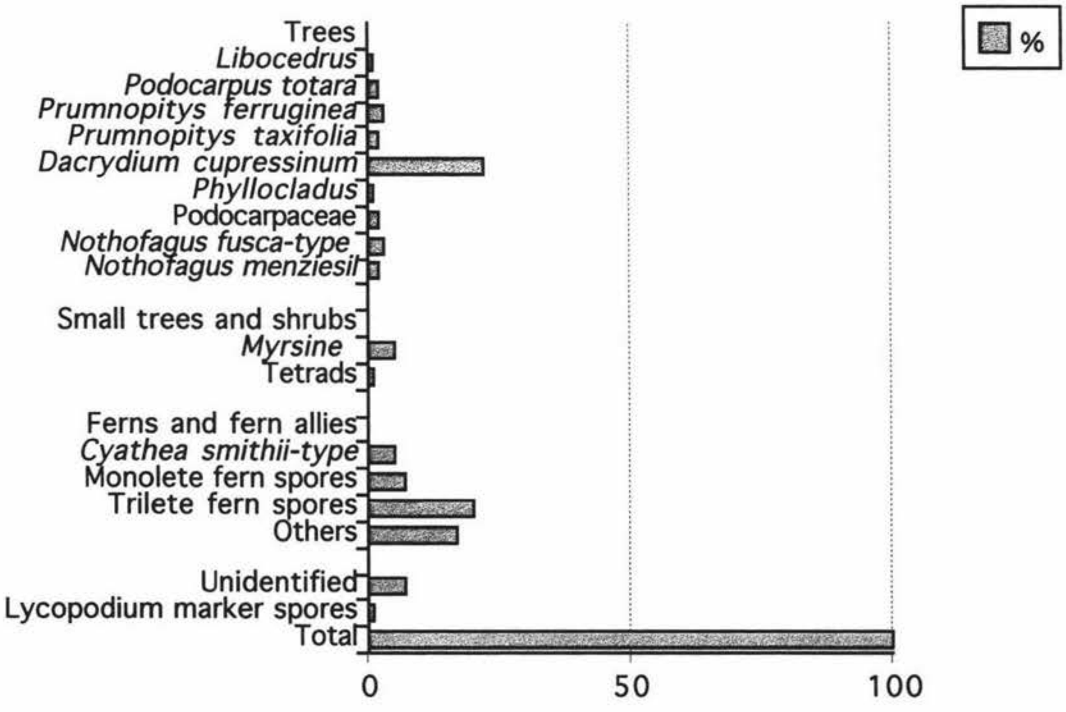
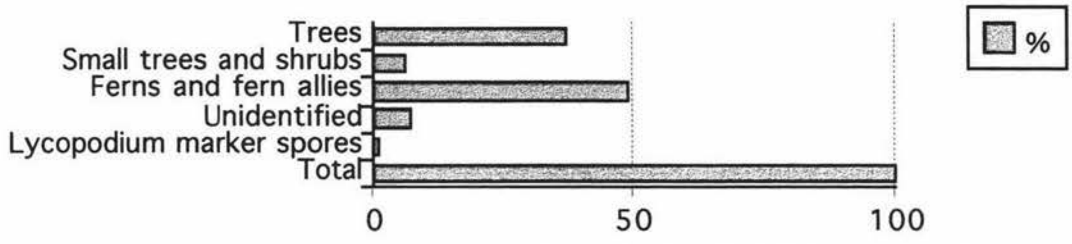


Figure 3.70: North National Park taxa values.



Grains within the sample were intermediately affected with frequent torn and degraded pollen and spores. Identification was therefore difficult in some cases, and 7% of the total 348 pollen sum remained unidentified. However, the count of only 1% *Lycopodium* marker spores indicates that the site has abundant pollen and spores. Pteridophytes are the highest scoring taxon at 49% of the count, which includes 17% Hymenophyllaceae.

3.3.35 Site 34: North Waiouru

GR: T20/414955 Altitude: 880 m Date sampled: 6/6/98

The site is located north of Waiouru in a drainage ditch on the western side of the Desert Road (SH 1), 200 m north of the point where the pylon line crosses the road. The area is in tussock grassland and heather with scattered pines.

Table 3.37: Site 34 - North Waiouru pollen count.

SITE 34: North Waiouru		
	Total	%
Trees		
Podocarpus totara	4	1
Prumnopitys ferruginea	2	1
Prumnopitys taxifolia	8	3
Dacrydium cupressinum	21	7
Halocarpus	30	10
Phyllocladus	4	1
Podocarpaceae	28	9
Nothofagus fusca-type	37	12
Nothofagus menziesii	47	15
Small trees and shrubs		
Melicytus	1	0
Griselinia	2	1
Pseudopanax	3	1
Epacridaceae-type tetrad	1	0
Myrsine	10	3
Coprosma	2	1
Ferns and fern allies		
Cyathea smithii-type	8	3
Monolete fern spores	7	2
Trilete fern spores	60	19
Unidentified	27	9
Lycopodium marker spores	9	3
Total	311	100
Taxa values		
Trees	181	58
Small trees and shrubs	19	6
Ferns and fern allies	75	24

The section exposed in the ditch shows as a lens of Taupo ignimbrite which has presumably filled a small hollow in the landscape. Neighbouring outcrops also indicate an uneven deposition possibly due to thinning of the flow at this distance from the source.

The natural profile is covered by 0.14 m of anthropogenic overburden. Below this is 0.24 m of dark organic rich fine sandy dark andesitic tephra. At a depth of 0.40 m there is a noticeable coarse sandy andesitic tephra above a 0.14 m mixed layer of brown soil and Taupo-derived material. The Taupo ignimbrite forms a layer 0.51 m thick and is composed of fine ash with rare clasts up to 30 mm in diameter. The ignimbrite contains abundant charcoal (logs up to 0.20 m in diameter and at least 0.50 m long) and some non charcoalized wood. The basal 0.08 m of this layer is composed of the grey crystal and lithic rich unit as previously described, with scattered charcoal fragments up to 10 mm in diameter. Some vertical root penetration along the logs was observed, but was avoided during sampling.

Figure 3.71: Site 34 - North Waiouru total pollen values.

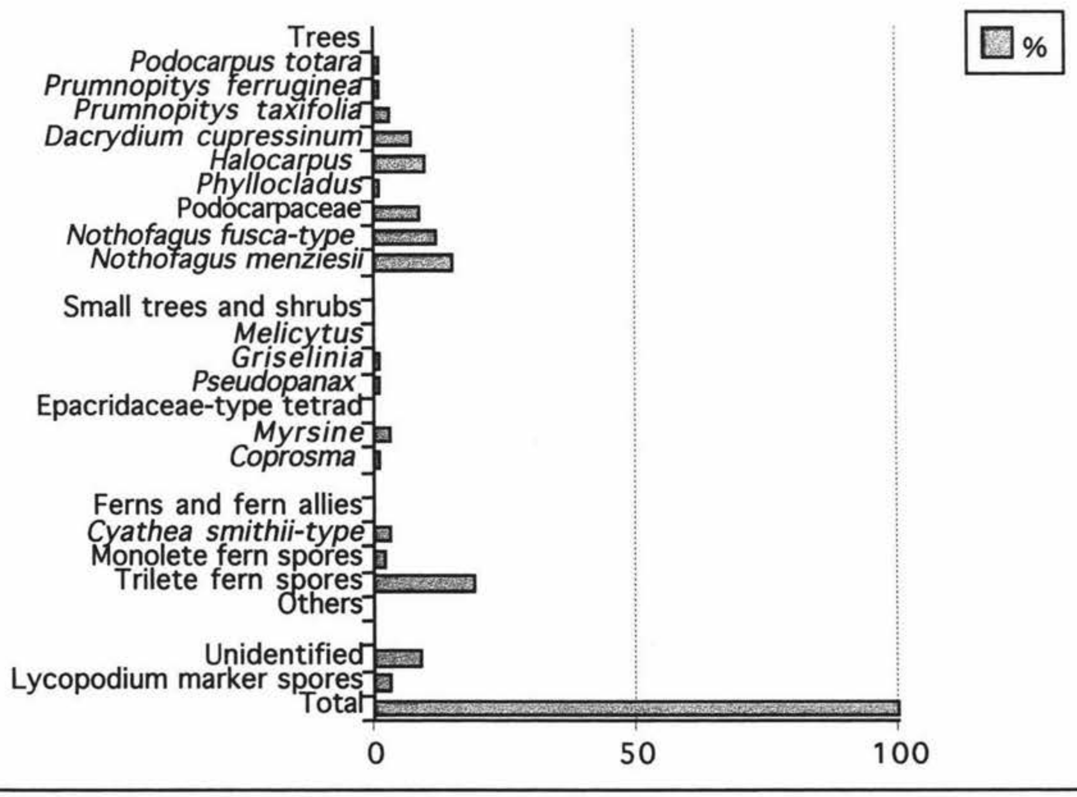
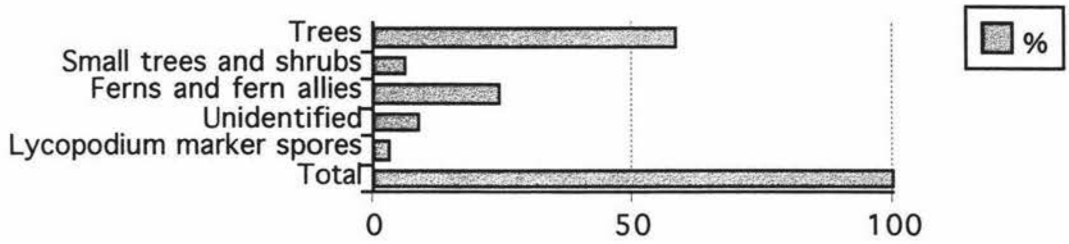


Figure 3.72: North Waiouru taxa values.



Most pollen and spores in this sample were severely affected and showed some signs of corrosion. Many were also collapsed, torn or fragmented. Split and torn podocarp grains were frequent, and many whole grains were too degraded for species identification. In a pollen sum of 311, the count of unidentified grains was relatively high at 9% of the total. The sample does, however, appear to have an abundance of pollen and spores as the *Lycopodium* marker spore count was only 3%.

3.3.36 Site 35: Silica Springs Track

GR: S20/194181 Altitude: 1240 m Date sampled: 29/8/98

The site is located on the east side of an exposed gully north of a point about 100 m from the start of the Silica Springs track on Mt. Ruapehu. The surrounding vegetation is predominantly native herbfield with tussock and heather, and with scattered pockets of beech forest within 500 m.

Table 3.38: Site 35 - Silica Springs Track pollen count.

SITE 35: Silica Springs Track		
	Total	%
Trees		
Libocedrus	1	0
Podocarpus totara	1	0
Podocarpus hallii	21	6
Prumnopitys ferruginea	5	1
Prumnopitys taxifolia	6	2
Dacrydium cupressinum	42	12
Halocarpus	13	4
Phyllocladus	66	20
Podocarpaceae	5	1
Nothofagus fusca-type	100	30
Nothofagus menziesii	40	12
Small trees and shrubs		
Myrsine	2	1
Coprosma	3	1
Ferns and fern allies		
Cyathea smithii-type	7	2
Monolete fern spores	7	2
Trilete fern spores	8	2
Unidentified	8	2
Lycopodium marker spores	1	0
Total	336	100
Taxa values		
Trees	300	89
Small trees and shrubs	5	1
Ferns and fern allies	22	7

Outcrops in the vicinity of this site represent the highest altitude outcropping of the thick Taupo Tephra in the area. There is a 0.60 m layer of young ash from Ruapehu and Ngauruhoe immediately above the Taupo Tephra which is 0.52 m thick. The upper 0.30 m of the ignimbrite is a fine-grained ash with occasional large pumice clasts up to 30 mm long. Below this is a 40 mm band of coarse sandy ignimbrite above a large charcoalized log which is 40 mm wide and at least 0.53 m long. Similar charcoalized remnants can be seen in nearby exposures. Below the log is a zone of mixed sized pumice grains, with coarse pumice up to 40 mm, as well as sand and very fine sandy pumice. Immediately below the log the ignimbrite is dark grey in colour. As this colour appears to be restricted to areas beneath charcoal it may represent downward translocation of charcoal in the profile. Fine charcoal fragments are distributed throughout this zone below the log.

There is marked iron staining throughout the Taupo ignimbrite above the log and along the contact with the underlying Mangatawai Tephra. The contact is distinct, with the underlying material a grey allophanic ash. Within the ash there has been allophane replacement of roots typical of the Mangatawai Tephra. Discrete sandy members of the Mangatawai Tephra are also present at various levels.

Figure 3.73: Site 35 - Silica Springs Track total pollen values.

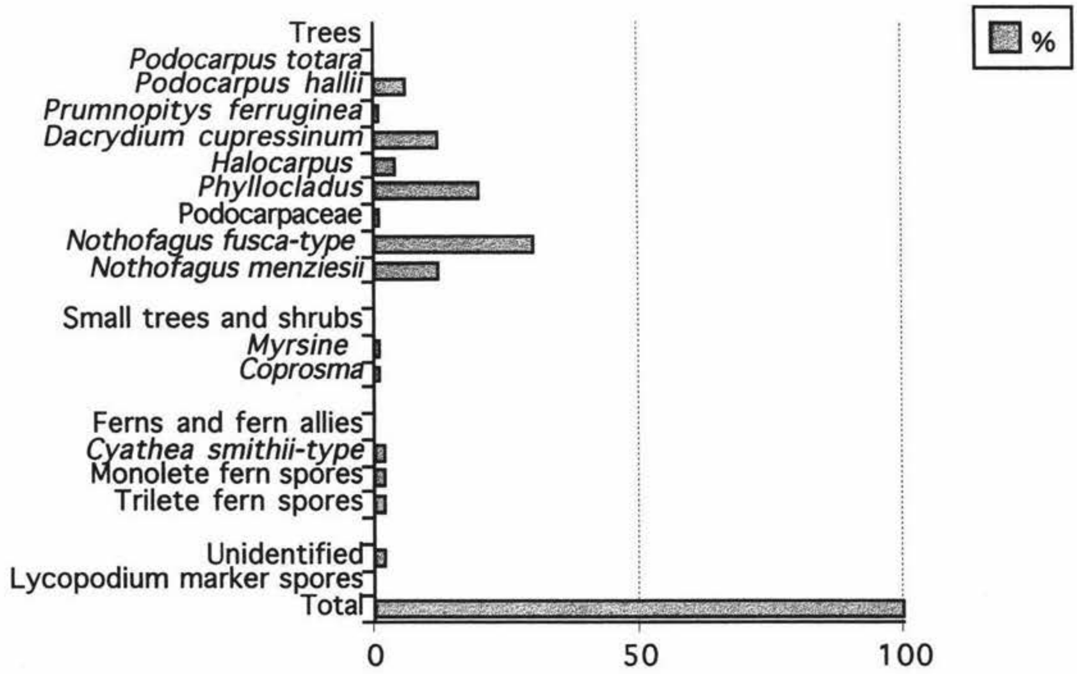
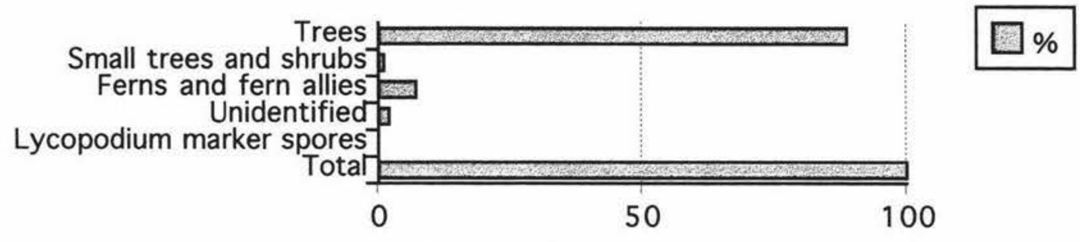


Figure 3.74: Silica Springs Track taxa values.



There was a very good degree of preservation in this sample with most pollen and spores largely unaffected and only 2% unidentified in a total pollen count of 336. The relative abundance was also high with only one *Lycopodium* marker spore (less than 1%) counted.

3.3.37 Site 36: Umukarikari Track (Kaimanawa Road)

GR: T19/546257 Altitude: 640 m Date sampled: 30/8/98

The site is located on Kaimanawa Road in a deep road cutting which is opposite the branch road and bridge leading to the start of the Umukarikari Track. The roadside vegetation is adventive weeds and grasses with some manuka and toetoe, surrounded by the beech forest of the Kaimanawa Forest Park.

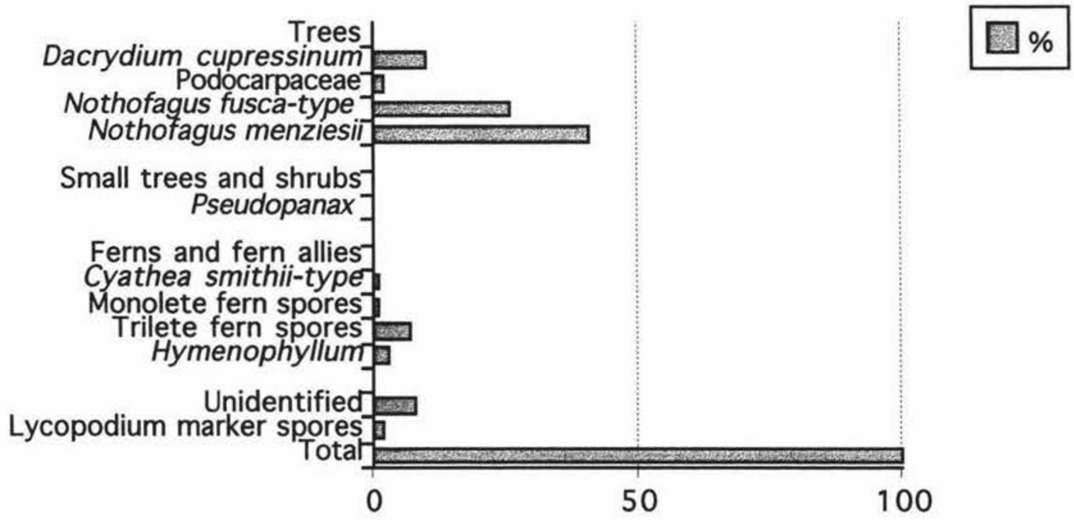
Table 3.39: Site 36 - Umukarikari Track pollen count.

SITE 36: Umukarikari Track		
	Total	%
Trees		
Dacrydium cupressinum	31	10
Podocarpaceae	7	2
Nothofagus fusca-type	82	26
Nothofagus menziesii	129	41
Small trees and shrubs		
Pseudopanax	1	0
Ferns and fern allies		
Cyathea smithii-type	2	1
Monolete fern spores	3	1
Trilete fern spores	22	7
Hymenophyllum	8	3
Unidentified	25	8
Lycopodium marker spores	5	2
Total	315	100
Taxa values		
Trees	249	79
Small trees and shrubs	1	0
Ferns and fern allies	35	11

The site lies in a road cutting under about 25 m of massive, welded Taupo ignimbrite, which had originally filled in the valley of a small tributary of the Tongariro River above the Waikato Falls. Immediately above the contact with the underlying palaeosol is 0.20 m of the grey, lithic plus crystal, sandy unit typical of the Taupo ignimbrite basal layer at other sites. An iron pan 1 - 2 mm thick lies at the base of this unit, immediately above the underlying palaeosol. This basal unit is immediately overlain by a lens-shaped unit, 0.10 m deep at its maximum thickness, of coarse pumice with clasts up to 60 mm in diameter. Above this is a zone of approximately 25 m of fine sandy pumice ash with occasional charcoal, as well as frequent large clasts of pumice with maximum dimensions up to 0.18 m, scattered throughout. The contact is undulating over an apparent palaeoswale which is influencing ground water flow. Water drained from the palaeoswale immediately after the face had been exposed.

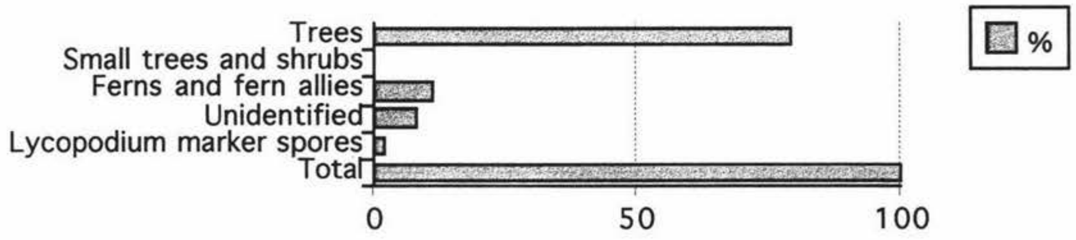
The Mangatawai sequence directly below the contact zone is dark due to organic matter, and is composed of allophanic, andesitic sands in which thicker individual Mangatawai Tephra members are obvious. The palaeosol at the interface with the Taupo ignimbrite is a 40 mm thick, dark brown, weakly cemented unit. The dark colour may, therefore, be due in part to iron precipitation from within the palaeoswale, or to organic matter from a dark organic rich unit below the iron pan. The dark, organic-rich allophanic material is thicker at the axis, rather than the sides of the palaeoswale, so it appears to have been accumulating organic material prior to the eruption.

Figure 3.75: Site 36 - Umukarikari Track total pollen values.



There are two points immediately beneath the contact with the Taupo ignimbrite where hollows have filled with decayed organic matter. One of these is 70 mm in diameter and extends back into the face for 0.90 m. These hollows probably represent branches or limbs lying on, or in, the original surface litter or soil, which appear to have rotted *in situ*, rather than having been burnt during the eruption.

Figure 3.76: Umukarikari Track taxa values.



Most of the pollen and spores at this site have been intermediately affected as they are not in a particularly good state of preservation. Many grains are collapsed, folded and corroded. In a total pollen count of 315 grains the unidentified score is 8%, which probably reflects the poor standard of preservation. However, the sample appears to be reasonably abundant in pollen and spores as the *Lycopodium* marker spore count is only 2% of the total.

3.3.38 Site 37: Kaimanawa Road

GR: T19/524282 Altitude: 640 m Date sampled: 17/11/98

This site is located in a road cutting on the northern side of Kaimanawa Road, 30 m from where Kaimanawa Road turns off from the Desert Road (SH 1). The surrounding vegetation includes nearby stands of gum and pine trees with roadside vegetation of adventive broom (*Cytisus*), various weeds and grasses.

Table 3.40: Site 37 - Kaimanawa Road pollen count.

SITE 37: Kaimanawa Road		
	Total	%
Trees		
Podocarpus totara	3	1
Prumnopitys ferruginea	4	1
Prumnopitys taxifolia	3	1
Dacrydium cupressinum	10	3
Podocarpaceae	11	4
Nothofagus fusca-type	11	4
Nothofagus menziesii	8	3
Small trees and shrubs		
Pseudowintera	2	1
Nestegis	4	1
Ferns and fern allies		
Cyathea smithii-type	42	14
Monolete fern spores	26	8
Trilete fern spores	173	56
Unidentified	13	4
Lycopodium marker spores	1	0
Total	311	100
Taxa values		
Trees	50	16
Small trees and shrubs	6	2
Ferns and fern allies	241	77

The top of the cutting has been removed during road making, and a 0.29 m layer of anthropogenic overburden lies directly upon a 0.34 m layer of Taupo Tephra. This overburden consists of an upper 0.25 m of brown topsoil, and a lower 40 - 60 mm of pumiceous fragments (up to 30 mm long) and andesitic pebbles (up to 70 mm long) in a fine sand matrix. Fragments of charcoal up to 10 mm long are common within this pumiceous base.

The Taupo Tephra occurs in three main zones. The upper 0.18 m is medium sand-sized pumice with occasional clasts up to 50 mm in length. From 0.18 - 0.25 m is a coarse sand pumice with occasional fragments up to 10 mm and charcoal up to 15 mm. The lower 0.25 - 0.34 m contains coarse pumice fragments (up to 70 mm in length) in a coarse sand matrix with scattered 10 mm fragments of charcoal. No root penetration was seen within this zone.

The Taupo Tephra overlies a 0.10 m layer of allophanic sands which are above a 0.32 m Mangatawai sequence consisting of 20 mm of Mangatawai cream cakes, 60 mm of allophanic sand, 50 mm of allophanic sand with Mangatawai ash, and 220 mm of a mixture of Mangatawai and allophanic ash. Below this mixture, at 0.45 - 0.48 m in the profile is a major Mangatawai ash member.

Figure 3.77: Site 37 - Kaimanawa Road total pollen values.

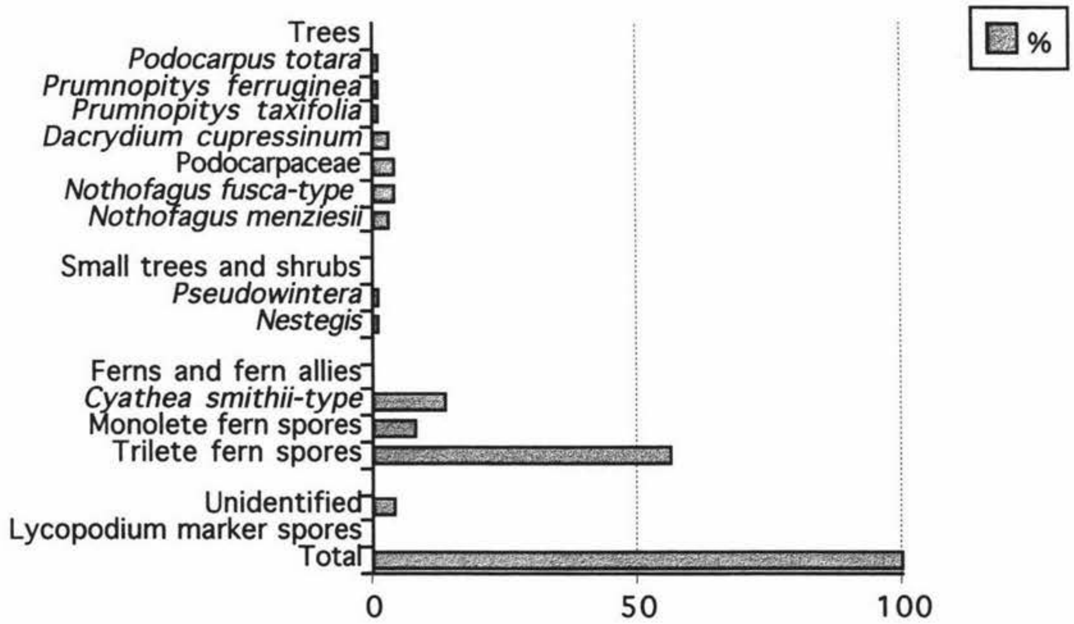
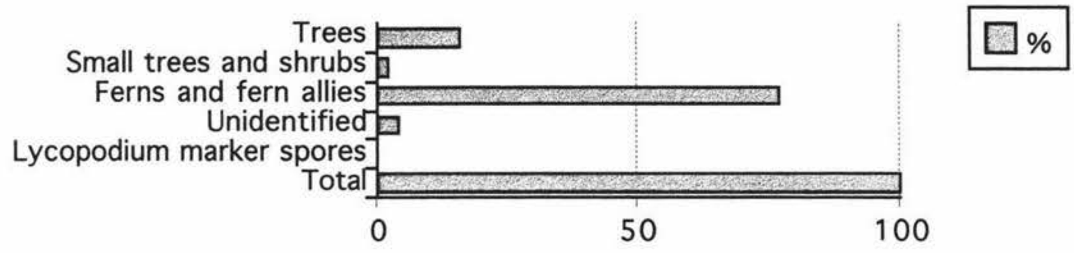


Figure 3.78: Kaimanawa Road taxa values.



Preservation within this sample is varied as the fern spores are largely unaffected, while the podocarp pollen is much less well preserved. The site is therefore classed as intermediately affected. Pteridophyte spores dominate with 77% of the pollen sum of 311, which has resulted in a depressed count of 4% unidentified pollen and spores. The count of *Lycopodium* marker spores is less than 1% which indicates quite an abundance of pollen and spores within the sample. The site lies within the FDI zone.

3.3.39 Site 38: Mangatawai Stream

GR: T19/493236 Altitude: 860 m Date sampled: 17/11/98

The site is located in a road cutting south of the Mangatawai Valley on the western side of the Desert Road (SH 1), and *c.* 150 m north of the point where the transmission lines cross the road. The surrounding vegetation is regenerating manuka scrub.

Table 3.41: Site 38 - Mangatawai Stream pollen count.

SITE 38: Mangatawai Stream		
	Total	%
Trees		
Libocedrus	1	0
Podocarpus totara	3	1
Prumnopitys ferruginea	3	1
Prumnopitys taxifolia	5	1
Dacrydium cupressinum	8	2
Phyllocladus	1	0
Podocarpaceae	7	2
Nothofagus fusca-type	215	62
Nothofagus menziesii	67	19
Small trees and shrubs		
Myrsine	5	1
Ferns and fern allies		
Cyathea smithii-type	1	0
Monolete fern spores	2	1
Trilete fern spores	7	2
Hymenophyllum	1	0
Unidentified	17	5
Lycopodium marker spores	3	1
Total	346	100
Taxa values		
Trees	310	90
Small trees and shrubs	5	1
Ferns and fern allies	11	3

A layer of dark grey Ngauruhoe ash 0.27 m thick overlies 0.18 m of mixed Taupo Tephra and Ngauruhoe ash. This layer is mainly grey sand, but with some pumice fragments up to 30 mm.

The Taupo Tephra is 0.45 m thick and consists mainly of coarse ash with pumice fragments up to 50 mm and charcoal pieces of at least 100 mm long scattered throughout. The base of this layer contains more lithic material and appears to be more fines depleted than the upper region. There was some root penetration into the FDI, but the sample was taken from a region where roots were absent and which appeared to be darker and more organic rich than the rest of the exposure at this site.

Figure 3.79: Site 38 - Mangatawai Stream total pollen values.

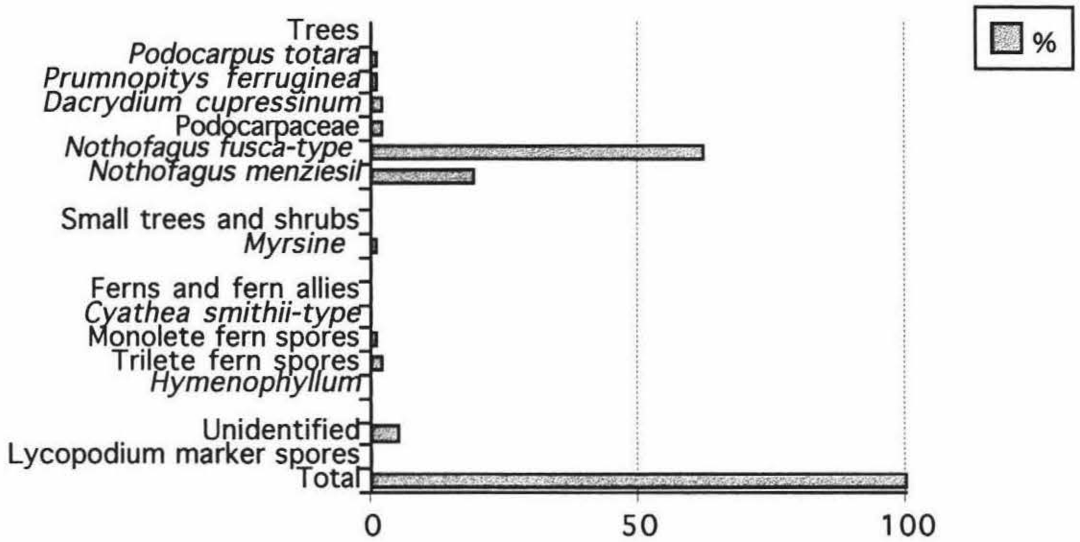
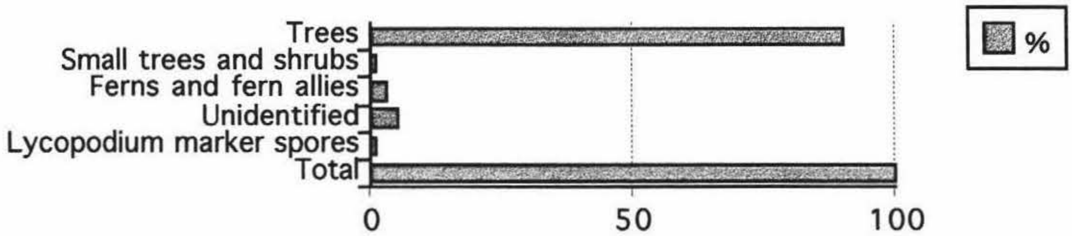


Figure 3.80: Mangatawai Stream taxa values.



The sample contains abundant, largely unaffected pollens and spores in a good state of preservation, with only 5% unidentified and 1% *Lycopodium* marker spores counted in a pollen sum of 346 grains. Sufficient material was available for pH testing and the sample has a pH value of 6.0.

3.3.40 Site 39: East National Park

GR: S19/189221 Altitude: 845 m Date sampled: 9/7/00

The site is the exposed face of a roadside drainage ditch on the northern side of SH47, approximately 1 km from National Park and 150 m west of a pine shelter belt. The surrounding vegetation is heather and tussock grassland with manuka scrub.

Table 3.42: Site 39 - East National Park pollen count.

SITE 39: East National Park		
	Total	%
Trees		
Prumnopitys ferruginea	3	1
Dacrydium cupressinum	16	5
Halocarpus	2	1
Podocarpaceae	4	1
Nothofagus fusca-type	166	50
Nothofagus menziesii	93	28
Small trees and shrubs		0
Ferns and fern allies		
Cyathea smithii-type	7	2
Monolete fern spores	3	1
Trilete fern spores	24	7
Lycopodium sp.	1	0
Unidentified	10	3
Lycopodium marker spores	1	0
Total	330	100
Taxa values		
Trees	284	86
Small trees and shrubs	0	0
Ferns and fern allies	35	11

An undulating layer of anthropogenic roading overburden comprising a mixture of pumice and topsoil overlies 200 mm of black, very organic rich, almost peat, topsoil. This layer grades through 130 mm of coarse pumice with clasts up to 60 mm in diameter. Many of the clasts appear to be slightly rounded. This coarse pumice grades into a 290 mm layer of fine ash, the top half of which is slightly orange in colour, while the lower half of the unit is grey. Below this is a sudden boundary into 230 mm of coarse pumice containing fragments of charcoal up to 50 mm in diameter.

There is a sharp contact of the Taupo Tephra with the underlying palaeosol, and the tephra in the contact zone is very oxidised. The palaeosol is dominated by brown weathered andesitic ash, and is underlain by a very mottled orange, yellow and brown weathered andesitic ash.

Figure 3.81: Site 39 - East National Park total pollen values.

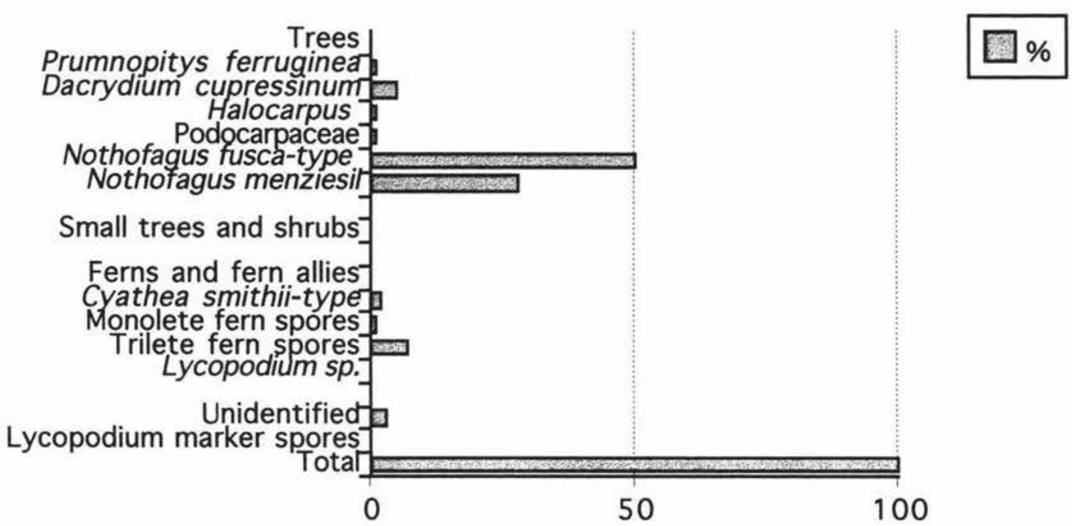
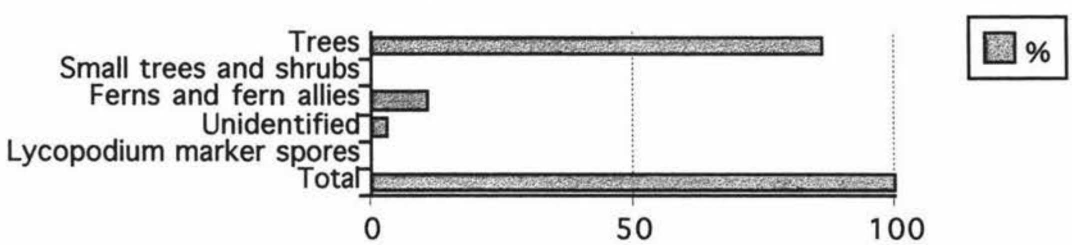


Figure 3.82: East National Park taxa values.



Although the pH value of this sample is relatively high at 6.1 the preservation still appears to have been good, as grains in the sample appear to be largely unaffected. From a total pollen sum of 330 pollen and spores the relative frequency of *Lycopodium* marker spores is less than 1%, while only 3% remained unidentified.

3.3.41 Site 40: Wairehu Canal

GR: T19/401398 Altitude: 610 m Date sampled: 9/7/00

The site is located at the intersection of the Wairehu Canal access road with the Te Ponanga Saddle Road in a road cutting on the north eastern corner of the intersection. The surrounding vegetation is pine plantation and grassland.

Table 3.43: Site 40 - Wairehu Canal pollen count.

SITE 40: Wairehu Canal		
	Total	%
Trees		
Dacrydium cupressinum	10	3
Halocarpus	1	0
Podocarpaceae	22	7
Nothofagus fusca-type	26	8
Nothofagus menziesii	25	8
Small trees and shrubs		
Pseudopanax	1	0
Coprosma	2	1
Ferns and fern allies		
Cyathea smithii-type	22	7
Monolete fern spores	25	8
Trilete fern spores	139	42
Lycopodium	9	3
Unidentified	31	9
Lycopodium marker spores	19	6
Total	332	100
Taxa values		
Trees	84	25
Small trees and shrubs	3	1
Ferns and fern allies	195	59

There is a 120 mm layer of topsoil on the top of the road cut which overlies a 970 mm deposit of the Taupo Tephra. The tephra has three distinct layers: an upper 320 mm of coarse pumice fragments up to 60 mm in length, a 100 mm middle layer of fine pumice fragments up to 10 mm in length, and a lower 550 mm layer of coarse pumice with some fragments up to 150 mm long but mainly about 40 mm in length. Grey andesitic lithics up to 50 mm in length are noticeable throughout all three layers. These lithics form about 5% of the total sample and are up to 50 mm in length. There are also rare, small fragments of charcoal up to 10 mm present. The contact between the Taupo Tephra and the underlying palaeosol is sharp and gently undulating along the profile.

Figure 3.83: Site 40 - Wairehu Canal total pollen values.

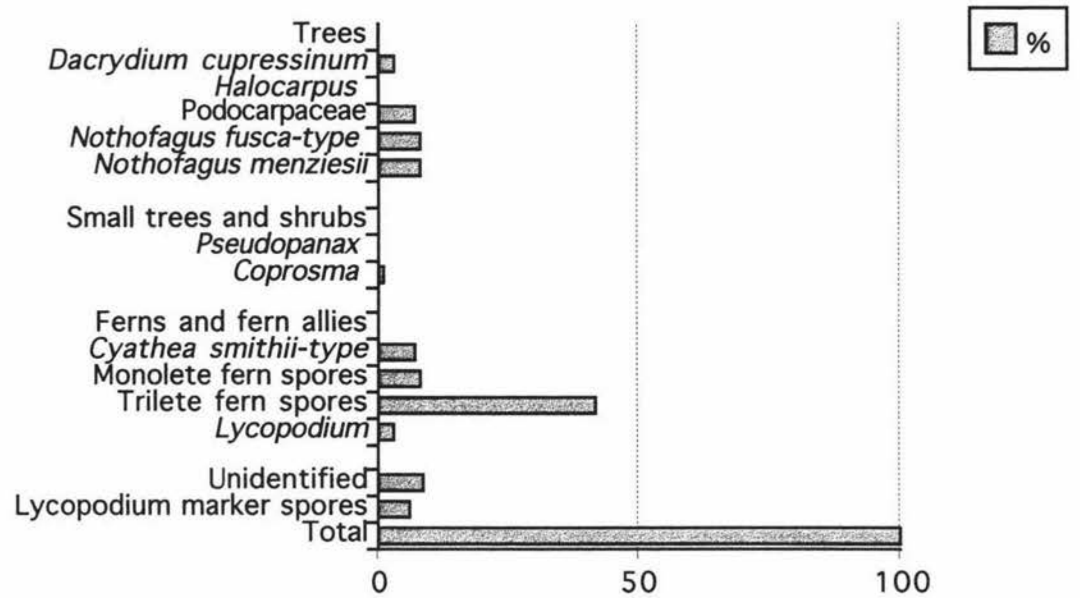
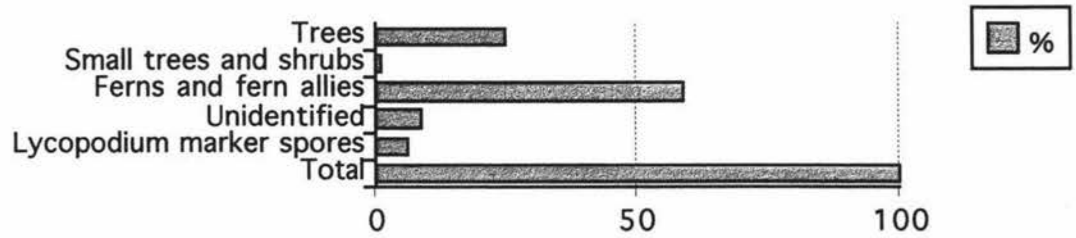


Figure 3.84: Wairehu Canal taxa values.



Most pollen and spores in this sample are severely affected as they are battered and degenerate in appearance. The preservation environment does not appear to have been particularly good as the count of unidentified spores is 9%, while the relative frequency of *Lycopodium* marker spores is 6% in a pollen sum of 332 grains. The pteridophyte spore count is 59% and represents the single highest scoring taxon. The site lies within the FDI zone, and has a pH value of 6.3.

3.3.42 Site 41: Makiokio Stream

GR: T20/407918 Altitude: 810 m Date sampled: 9/7/00

The site is located on the exposed, north facing edge of what appears to be an old, disused quarry, 50 m east of the Desert Road (SH 1) above the true left bank of the Makiokio Stream just north of Waiouru. The area is in tussock grassland with some pines in the distance.

Table 3.44: Site 41 - Makiokio Stream pollen count.

SITE 41: Makiokio Stream		
	Total	%
Trees		
Dacrydium cupressinum	3	1
Halocarpus	1	0
Phyllocladus	1	0
Podocarpaceae	10	3
Metrosideros	3	1
Nothofagus fusca-type	43	13
Nothofagus menziesii	31	9
Small trees and shrubs		
Myrtaceae-type	6	2
Neomyrtus-type	5	2
Elaeocarpus	2	1
Pseudopanax	1	0
Myrsine	8	2
Asteraceae-type	2	1
Ferns and fern allies		
Cyathea smithii-type	3	1
Monolete fern spores	15	5
Trilete fern spores	77	23
Unidentified	83	25
Lycopodium marker spores	38	11
Total	332	100
Taxa values		
Trees	92	28
Small trees and shrubs	24	7
Ferns and fern allies	95	29

Above the Taupo Tephra a 300 mm layer of topsoil overlies another 300 mm layer of mixed andesitic ash and dark brown soil with ash percolating down through worm holes. This layer has a sharp boundary with the tephra. The tephra itself has an upper 200 mm zone of pale to yellow fine ash, and a lower 280 mm zone of dark grey fine ash with 5 mm spots of charcoal scattered throughout. The lower 5 mm of the tephra is characterized by the previously described coarse ash and lithic rich deposit seen at other sites. Both layers have occasional 10 mm long pumice lapilli scattered throughout, as well as charcoalized logs up to 70 mm in diameter and 350 mm in length. The boundary with the underlying palaeosol is sharp and undulating along the profile.

This site is located towards the distal edges of the ignimbrite flow and is also near the perimeter of the Volcanic Plateau. At this distance from the source of the Taupo eruption, as well as from the Central North Island volcanoes, outcrops of mudstone can be seen underlying the volcanic coverbeds in many of the roadside cuttings.

Figure 3.85: Site 41 - Makiokio Stream total pollen values.

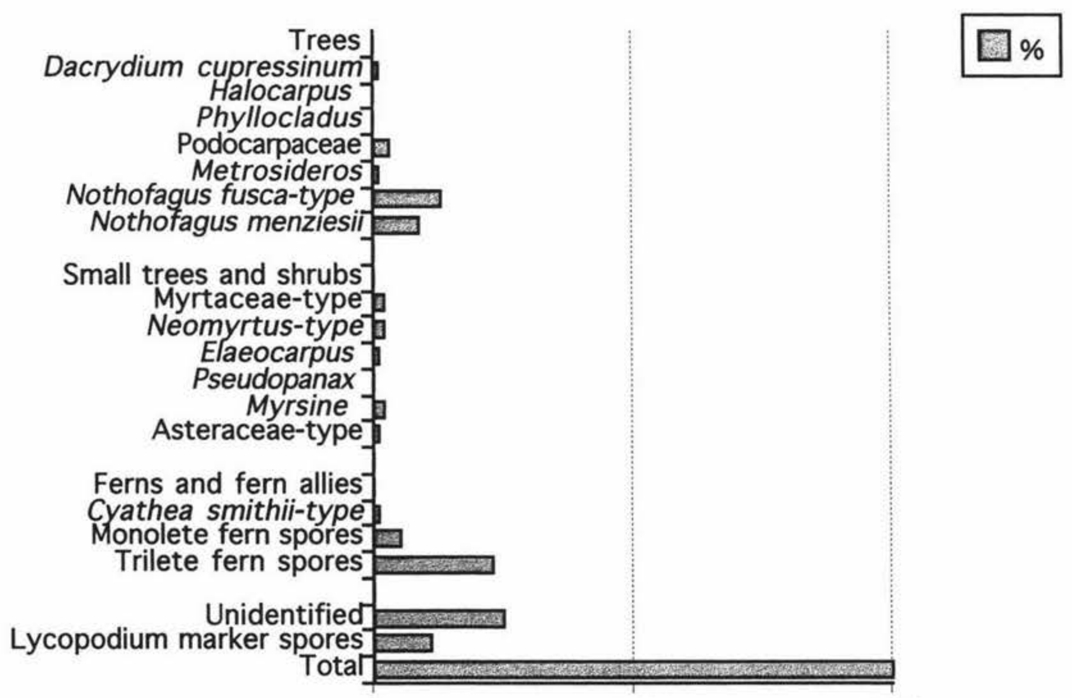
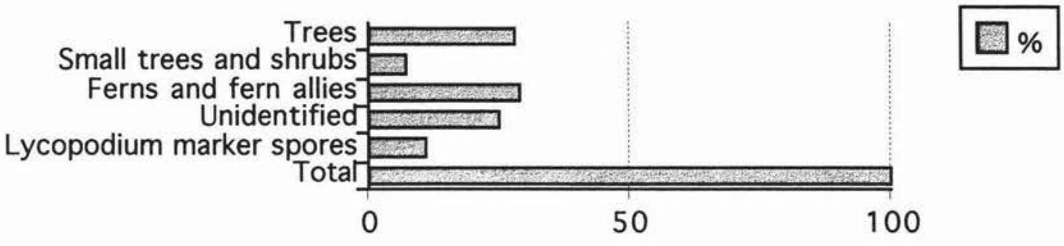


Figure 3.86: Makiokio Stream taxa values.



Pollen and spores within this sample were severely affected with many grains showing evidence of degradation and tearing. In a total count of 332 grains 25% remained unidentified. The relative frequency of pollens and spores within the sample was also low with 11% of *Lycopodium* marker spores counted. Pteridophyte spores were the single highest scoring taxon with 29% of the total. The sample has a pH value of 6.5.

3.4 Pollen values - trends and analysis

"There is strong evidence that that the effect of pollen from vegetation outside a given community may be very much less than one might expect, particularly if the site under investigation carries forest." (Dimbleby 1957).

Using the criteria presented in Chapter 4, there are 25 sites from the total 42 where the data are considered to be suitable for analysis (Table 3.45). These sites are arranged here (Table 3.45) according to their geographical distribution and in order of increasing altitude. The climatic zones according to altitude are in terms of Wardle (1964) as described for the North Island at 41°S. No suitable sites were found within the Tongariro Volcanic Centre which represented either the warm temperate or the high alpine zones.

Zone:	High Alpine (HA)	over 1525 m
	Lower Alpine (LA)	1220-1525 m
	Subalpine (SA)	916-210 m
	Montane (M)	416-915 m
	Warm temperate	0-416 m

Table 3.45: Geographical distribution and pollen values (Continued on following page)

Table 3.45: Geographical distribution and pollen values						
		Altitude	Climatic	Tree	Beech	Conifer
Northern group		m a.s.l.	Zone	%	%	%
S32	Papakai	680	M	76	71	6
S1	West Ketetahi	725	M	62	53	11
Eastern group						
S36	Umukarikari Track	640	M	79	67	12
S38	Mangatawai Stream	860	M	90	81	7
S34	North Waiouru	880	M	58	27	32
S21	Waihohonu Stream	900	M	90	83	6
S8	Waipakihi Road	920	SA	93	88	4
S5	Desert Road (tank crossing)	1040	SA	88	58	28
S7	Lower Tukino Road	1180	SA	93	85	8
S24	Upper Karioi Forest	1180	SA	86	81	4
S6	Upper Tukino Road	1280	LA	88	77	11

Table 3.45 continued: Geographical distribution and pollen values						
		Altitude	Climatic	Tree	Beech	Conifer
Western group		m a.s.l.	Zone	%	%	%
S9	Okupata Intake Road	620	M	54	9	44
S10	Okupata Drop Shaft	700	M	60	8	48
S14a	Erua Road	730	M	61	29	31
S14b	Erua Road	730	M	79	58	20
S3	Whakapapanui Bridge	840	M	71	24	45
S39	East National Park	845	M	86	78	8
S15	Whakapapaiti Bridge	860	M	89	79	8
S2	Whakapapa Intake Road	880	M	71	30	42
S16	Lahar Mounds	960	SA	89	75	14
S17	Whakapapa Road	1015	SA	87	74	12
S12	Mangatepopo Valley	1080	SA	87	75	13
S18	Skotel, Whakapapa Village	1140	SA	93	79	16
S11	Pukeonake	1225	SA	89	77	13
S35	Silica Springs Track	1240	LA	89	42	46

All the sites sampled are dominated by tree pollen which never drops to less than 50% of the pollen sum, and reaches 90% or more at five sites (Table 3.45). Beech is represented at all sites, but the highest recorded frequencies (over 80%) are in the east, and the lowest recorded (below 10%) in the west (Fig. 3.87).

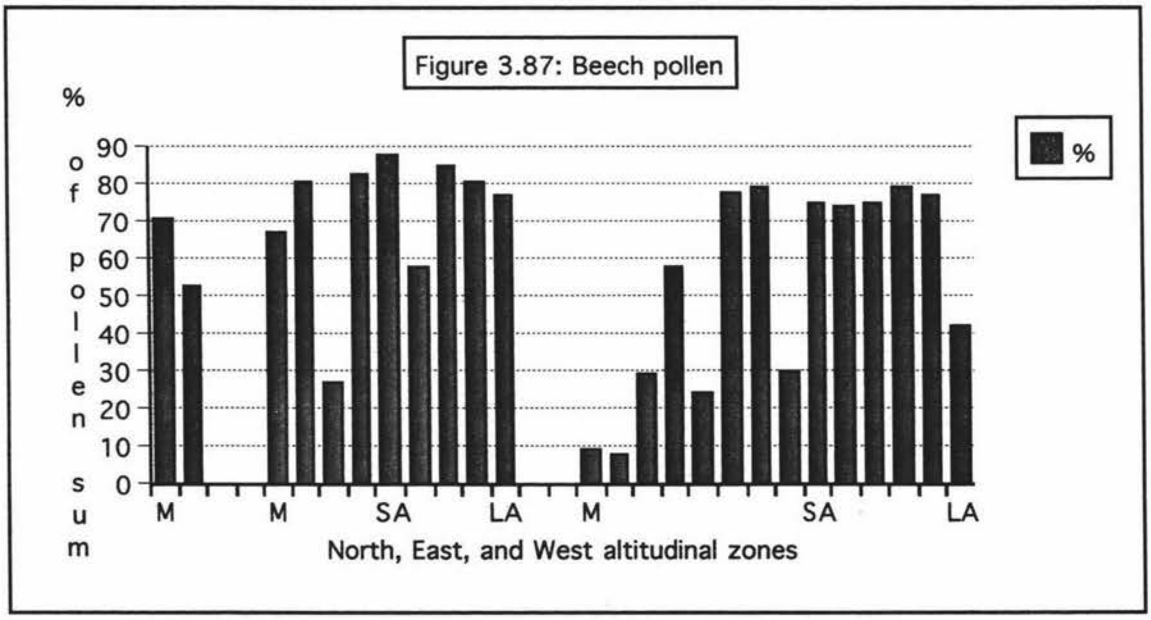
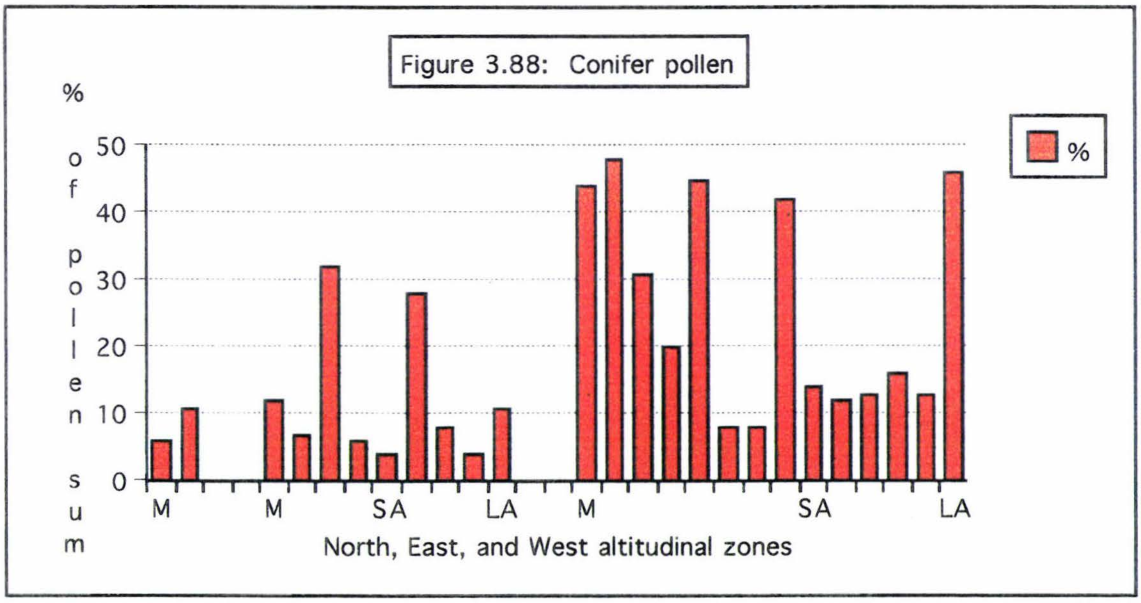
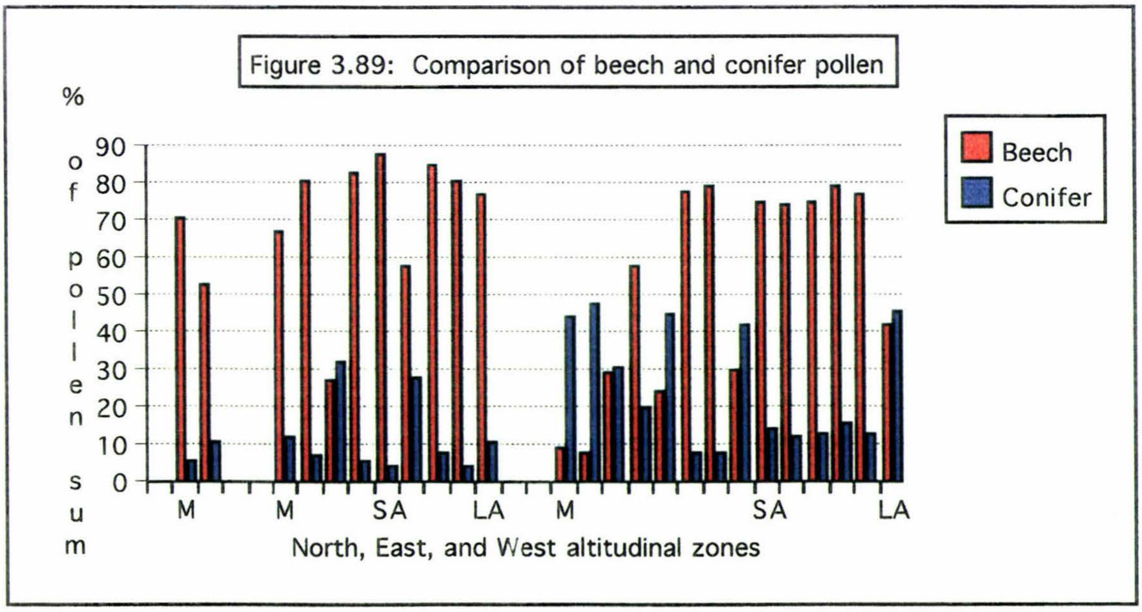


Figure 3.87: Beech pollen

Pollen from the Podocarpaceae (Fig. 3.88) is also represented at every site, although in much smaller relative quantities. The greatest percentages were recorded in the west where five sites had frequencies in excess of 40%, and only two dropped below 10%.



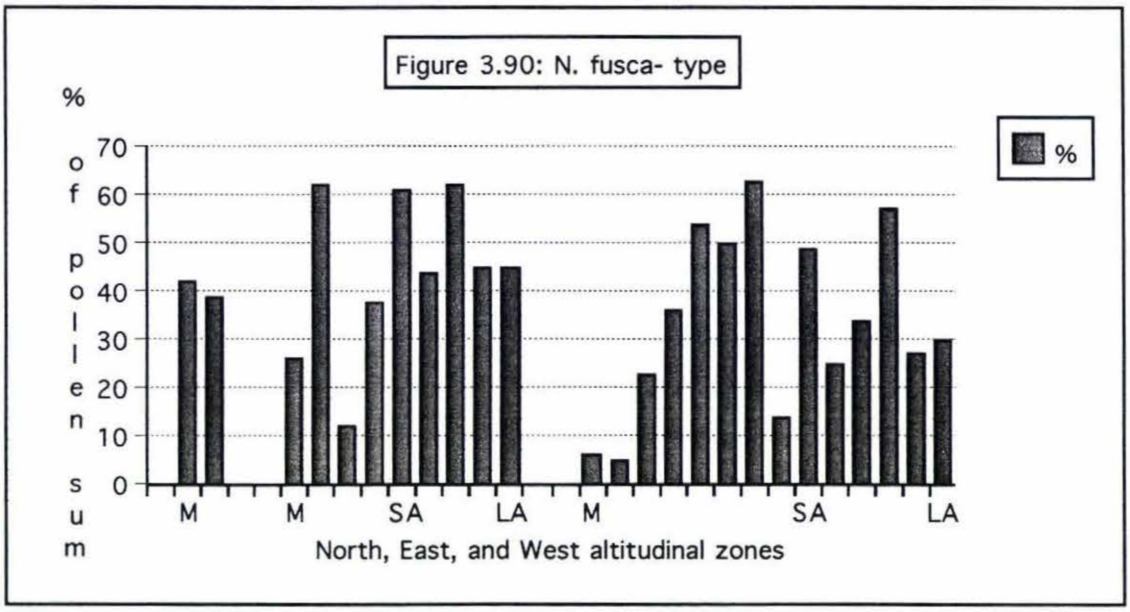
The relative distributions of beech and conifer pollen (Fig. 3.89) indicate less plentiful conifer representation in the east and north where beech appears to be better represented.



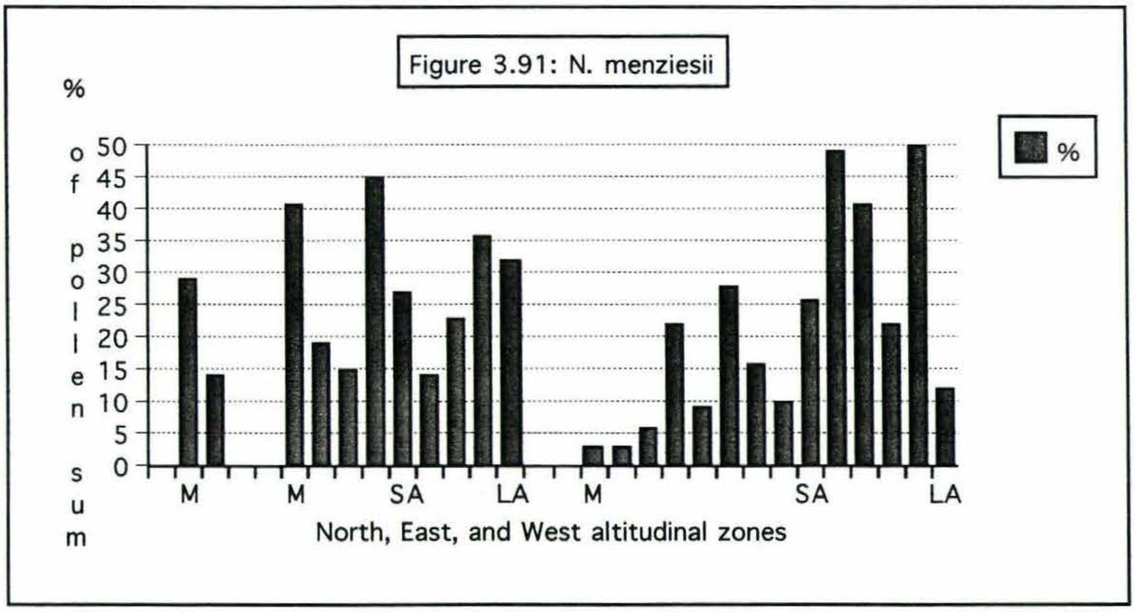
The most frequently occurring species among the tree pollen recorded were *N. fusca*-type, *N. menziesii*, *D. cupressinum*, and *Libocedrus* (Table 3.46).

Table 3.46: Species distribution by group and altitude							
		Altitude	Climatic	*N. fusca*	*N.men-*	*D. cupr-*	*Libo-*
Northern group		m a.s.l.	Zone	-type	*ziesii*	*essinum*	*cedrus*
S32	Papakai	680	M	42	29	3	0
S1	West Ketetahi	725	M	39	14	3	1
Eastern group							
S36	Umukarikari Track	640	M	26	41	10	0
S38	Mangatawai Stream	860	M	62	19	2	0
S34	North Waiouru	880	M	12	15	7	0
S21	Waihohonu Stream	900	M	38	45	1	1
S8	Waipakihi Road	920	SA	61	27	1	0
S5	Desert Road (tank crossing)	1040	SA	44	14	9	0
S7	Lower Tukino Road	1180	SA	62	23	2	0
S24	Upper Karioi Forest	1180	SA	45	36	1	0
S6	Upper Tukino Road	1280	LA	45	32	5	1
Western group							
S9	Okupata Intake Road	620	M	6	3	17	10
S10	Okupata Drop Shaft	700	M	5	3	24	6
S14a	Erua Road	730	M	23	6	13	1
S14b	Erua Road	730	M	36	22	5	2
S3	Whakapapanui Bridge	840	M	54	9	8	1
S39	East National Park	845	M	50	28	5	0
S15	Whakapapaiti Bridge	860	M	63	16	4	3
S2	Whakapapa Intake Road	880	M	14	10	17	16
S16	Lahar Mounds	960	SA	49	26	7	3
S17	Whakapapa Road	1015	SA	25	49	4	0
S12	Mangatepopo Valley	1080	SA	34	41	3	2
S18	Skotel, Whakapapa Village	1140	SA	57	22	9	1
S11	Pukeonake	1225	SA	27	50	3	2
S35	Silica Springs Track	1240	LA	30	12	12	0

N.fusca- type (Fig. 3.90) is found at all sites and is generally well represented in each case, although it occurs at a higher average frequency in the east.

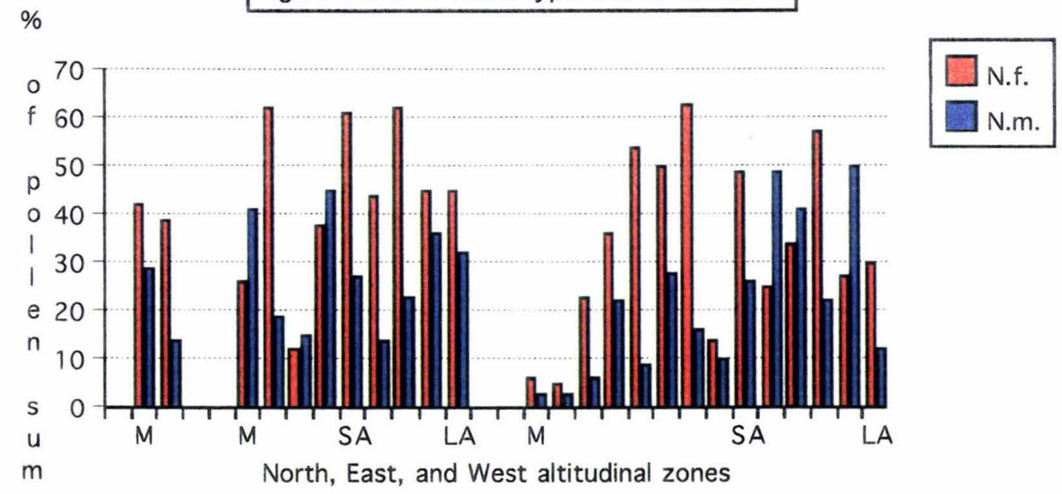


N. menziesii (Fig. 3.91) is also represented at each site but has a tendency to be better represented in the east and north, and at higher altitudes, particularly in the subalpine zone, in the west. The recorded frequency falls below 10% only at the montane sites in the west.



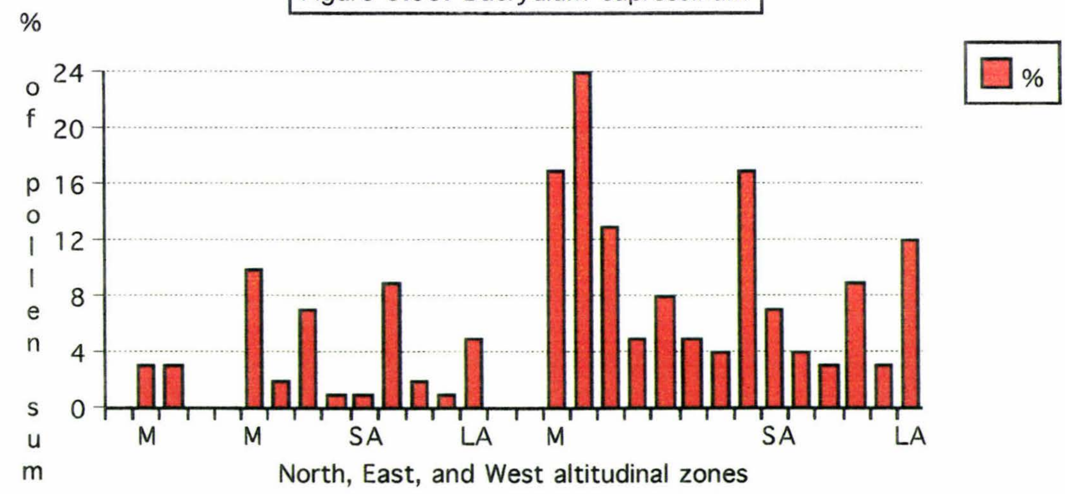
A comparison between both species of *Nothofagus* (Fig. 3.92) indicates that *N. fusca*-type is more widespread throughout the area, and is relatively more abundant than *N. menziesii* at most sites.

Figure 3.92: N. fusca-type and N. menziesii

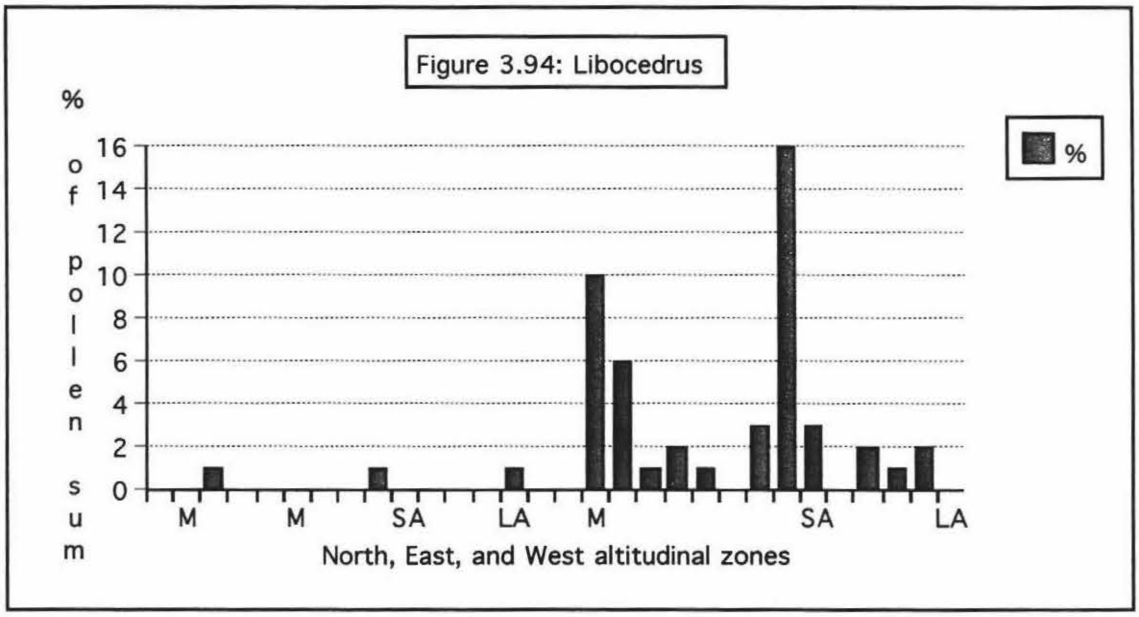


D. cupressinum (Fig. 3.93) occurs at every site, but is very much better represented in the west than in the east or north where only minimal amounts were recorded.

Figure 3.93: Dacrydium cupressinum



The distribution of *Libocedrus* (Fig. 3.94) indicates a greater abundance in the west where it is recorded at most sites, especially in the montane zone.



Small hardwood trees and shrubs are not well represented in this study. At those sites where the bulk of pollen is contributed by *Nothofagus* and which are then interpreted as being relatively uniform beech forests the relative values of small trees and shrubs ranges from 0-3% of the pollen sum at the palaeosol samples, but is 6% of the total at the single peat site (Table 3.47)

Table 3.47: Small tree and shrub values in beech dominated forests

Site	Small trees and shrubs %	Forest type	Peat or palaeosol	Geographical group	Altitude m a.s.l.
32	0	beech	palaeosol	North	680
1	1	beech	palaeosol	North	725
36	0	beech	palaeosol	East	640
38	1	beech	palaeosol	East	860
21	0	beech	palaeosol	East	900
8	0	beech	palaeosol	East	920
24	0	beech	palaeosol	East	1180
7	1	beech	palaeosol	East	1180
6	1	beech	palaeosol	East	1280
3	6	beech	peat	West	840
39	0	beech	palaeosol	West	845
15	3	beech	palaeosol	West	860
16	2	beech	palaeosol	West	960
17	0	beech	palaeosol	West	1015
12	2	beech	palaeosol	West	1080
18	1	beech	palaeosol	West	1140
11	0	beech	palaeosol	West	1200

The remaining sites reflect a more mixed tree pollen assemblage and have been classed as either mixed with dominant beech, mixed with approximately equal amounts of beech and podocarp, or mixed with dominant podocarps (Table 3.48).

Table 3.48: Small tree and shrub values in mixed forest associations					
Site	Small trees and shrubs %	Forest type	Peat or palaeosol	Geographical group	Altitude metres a.s.l.
5	1	mixed beech dominant	palaeosol	East	1040
14b	1	mixed beech dominant	palaeosol	West	730
14a	2	mixed beech dominant	peat	West	730
34	6	mixed beech and podocarp	palaeosol	East	880
2	9	mixed beech and podocarp	peat	West	880
35	1	mixed beech and podocarp	palaeosol	West	1240
9	14	mixed podocarp dominant	palaeosol	West	620
10	17	mixed podocarp dominant	peat	West	700

The results indicate that small trees and shrubs are generally better represented in peat samples than in palaeosols. The group also has higher relative values where there is an increasingly large proportion of podocarps, that is in forests at lower altitudes.

CHAPTER 4: DISCUSSION

4.1 Pollen percolating through pumice profiles

The implication of the results is that the Taupo Tephra seems to act as an effective filter in preventing the post eruption penetration or percolation of pollen and spores into the peats or palaeosols beneath it. This may be due to the highly vesicular nature of rhyolitic pumice, as Wallace (1987) observed pumice lapilli in the Aokautere Ash entrapping minor illuviated silts and clays. Certainly the Taupo Tephra appears to be an effective filter against the downward translocation of pollen and spores as only the *Lycopodium* marker spores were found within it.

Horrocks and Ogden (1998b) did find pollen deposited within the Taupo Tephra in their sites at Erua swamp, but they considered that "redeposition may have occurred." They also found that the Taupo Tephra "is very diffusely scattered through c. 25 cm of sandy silt" and that within this layer pollen "is very corroded", which is certainly consistent with a redeposition interpretation. Where the Taupo Tephra is present as primary deposit ignimbrite it is unlikely to include any other sediments, as well as having been too hot to preserve pollen.

Contamination of the underlying palaeosol through ground water percolation would thus appear to have been unlikely, and the data obtained from peats or palaeosols below the Taupo Tephra are therefore most likely to be of pollen and spores deposited prior to the Taupo eruption. There is further support for this opinion in the absence of exotic taxa at any of the sites sampled, in spite of their present day prevalence within the Tongariro Volcanic Centre.

4.2 pH values

"......pollen which falls on neutral or basic soils is decomposed fairly rapidly. Even under anaerobic, waterlogged conditions pollen grains are sometimes subject to decay if the pH is high." Moore and Webb (1978).

The survival of pollen deposited at any site is dependent upon the preservation environment of the site. Pollen and spores are best preserved by the exclusion of oxygen and in low pH (acidic) deposit conditions where Faegri (1971) observes there is apparently no degradation of pollen grain walls and that these, along with spores, can be recovered from deposits of any age showing that sporopollenin membranes are remarkably resistant to breakdown. However, although the exine is extremely resistant it is not indestructible.

Havinga (1971) concluded from his experiments that decay of pollen and spores depends, among other things, on soil type, soil pH, and climate. He was able to show that the pollen of different species show differing preservation in sediments. Faegri (1971) proposed that this would indicate that either different types of sporopollenin are present in the pollen grain wall or alternatively, that exines consist of sporopollenin plus some other component, and that therefore, the variation of sporopollenin in the wall may explain this difference in preservation.

Within the sites surveyed during this investigation there appear to be a number of common factors which may have contributed to the preservation environment, and one of the primary contributing factors appears to be the pH of the sample. Results from the eighteen sites from which sufficient material was available to test for pH showed that where the pH was above a value of 6.0 the preservation was usually sufficiently poor for the site to be regarded as potentially unreliable (Table 4.1). This is probably the result of increased biological activity in these less acid soils. Dimbleby (1961) concluded that the preservation of pollen in palaeosols was dependent on the biological activity of the soil, which is closely correlated with soil pH values.

There were three sites which were exceptions to this correlation. Site 25 (Lower Karioi Forest) had a pH value of 5.94, but was regarded as potentially unreliable due to a high percentage of *Lycopodium* marker spores. Site 24 (Upper Karioi Forest at pH 6.19) and Site 39 (East National Park at pH 6.08) were not considered to be potentially unreliable as there were no other contraindications (as discussed later in Sections 4.3 and 4.4). The pH values are only marginally in excess of 6.0 and there may be other factors involved in favouring the preservation environment at these sites.

Eleven of the tested sites were found to be above a pH of 6.0. These included the southern group, and all but Site 1 from the northern group. The pH results were generally lower in the eastern and western groups, with only

Site 39 in the west and Site 24 in the east being above pH 6.0.

Table 4.1: Potentially unreliable sites and known pH values.

Table 4.1: Unreliable sites and pH		pH	Potentially
Site			unreliable
Northern group			sites
1	West Ketetahi	5.9	
27	Hautu Road	6.1	X
29	Otukou Quarry	6.2	X
30	Mangaparuparu Stream	6.1	X
40	Wairehu Canal	6.3	X
Eastern group			
24	Upper Karioi Forest	6.2	
25	Lower Karioi Forest	5.9	X
38	Mangatawai Stream	6.0	
Southern group			
19	West Waiouru	6.3	X
20	Waitangi Stream	6.3	X
22	South Waiouru	6.4	X
23	Bates' Farm	6.4	X
41	Makiokio Stream	6.5	X
Western group			
2	Whakapapa Intake Road	5.5	
9	Okupata Intake Road	5.4	
10	Okupata Drop Shaft	5.7	
12	Mangatepopo Valley	5.6	
39	East National Park	6.1	

When these results are examined in combination with other factors which may have affected the preservation of pollen and spores it appears that they support Dimbleby's conclusion (1957) that soils with a pH in excess of 6 are virtually worthless for pollen analysis.

The southern group of sites around Waiouru township are all characterized by pH values in excess of 6.0 with an average value for the area of 6.4. In this area the mantling of volcanic deposits above the underlying sedimentary rocks is relatively thin. The Taupo Tephra has tended to flow into the low points of the landscape such as stream beds and river valleys, leaving outcrops of mudstones and limestones uncovered. These rocks contain simple minerals such as calcium sulphate (gypsum) as well as calcium and magnesium carbonates (limestones), which are relatively easily dissolved in water or dilute solutions of carbonic acid (McLaren and Cameron 1996). Rainwater or soil water containing dissolved carbon dioxide will consequently leach these minerals from the sedimentary rocks as it runs off the higher ground to collect in the lower points of the landscape. The net effect of these dissolved minerals in the groundwater will be to increase soil pH (McLaren and Cameron 1996), in this instance in the deposits beneath the Taupo Tephra.

It is also possible that the different land use of the area has contributed to the the higher pH values beneath the Taupo Tephra. Much of the area south of the Desert Road and around Waiouru is in pasture. Adding lime to pasture soils is a common practice in New Zealand, mainly to neutralise soil acidity, overcome aluminium toxicity, and to increase the availability of elements such as molybdenum and phosphorus (McLaren and Cameron 1996).

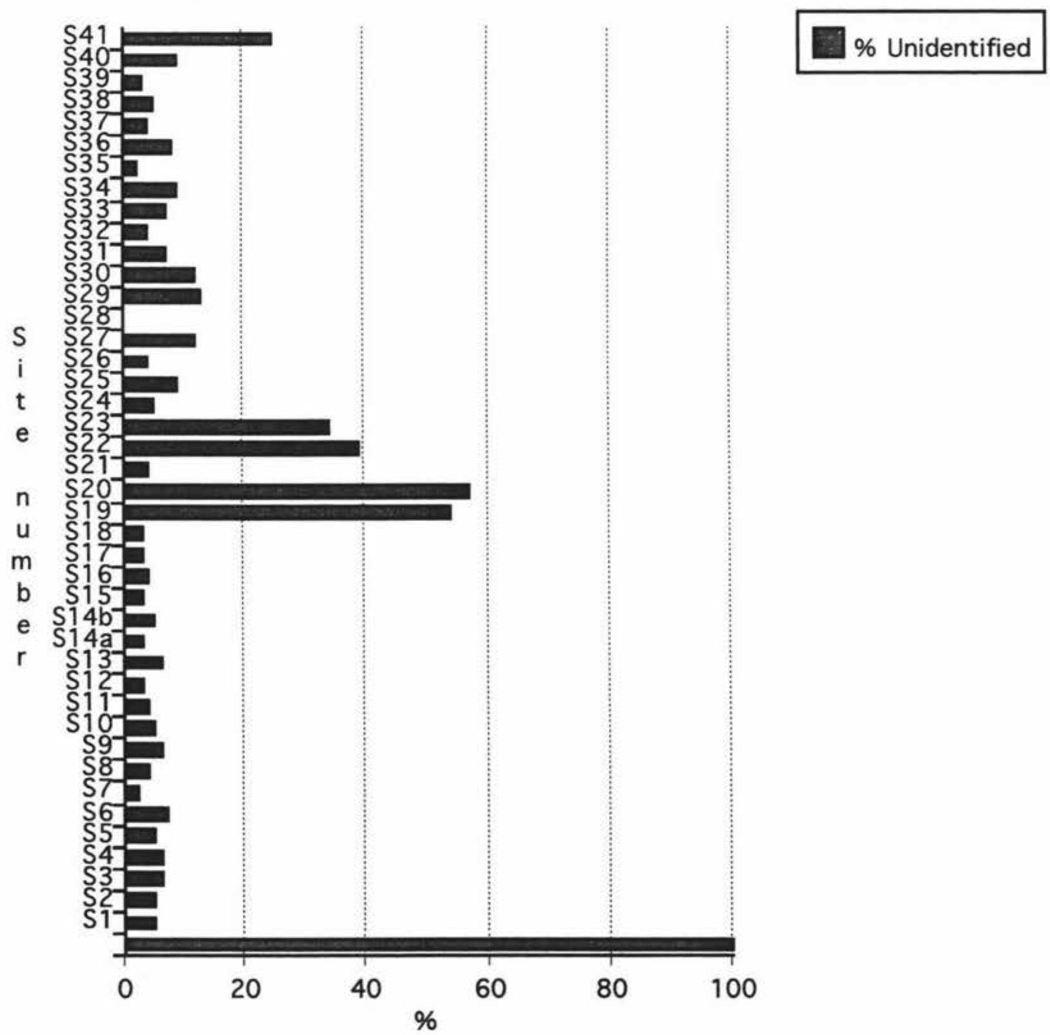
The northern group has a slightly lower average pH of 6.1. This group of sites is within the FDI zone, and it may be that the unwelded, porous nature of the fines-depleted ignimbrite has allowed a more oxidising environment to develop in deposits below the Taupo Tephra. Rainwater percolating through the Taupo Tephra would carry dissolved gases such as oxygen into the palaeosols which may have the net result of elevating the soil pH. The lack of preservation in this group is discussed more fully in section 4.6 of this chapter.

4.3 Unidentified pollen and spores

The general preservation status of each site was qualitatively graded as largely unaffected (1), intermediately affected (2) or severely affected (3) in line with the system described by Havinga (1971). This system is subjective and was based on the proportion of damaged grains in each sample. Where most grains were whole and entire the sample was regarded as largely unaffected, but where there was some degree of superficial corrosion or loss of distinctive characteristic features the sample was classed as intermediately affected. Those samples which were dominated by severely damaged and fragmented grains were considered severely affected.

Accurate identification of very degraded or damaged pollen and spores was often most difficult, and they were therefore recorded as unidentified. The relative frequency of this group within the pollen sum could therefore be used as part of the measure of the degree of preservation at the site. The processed data indicated that most sites scored less than 10% in this category (Fig. 4.1). This 10% score was then taken as the upper limit of reliability in interpreting the data. Generally those sites which were within the 10% limit were those which were also rated as largely unaffected or intermediately affected.

Figure 4.1: Unidentified pollen percentages.



Where a sample included significant numbers of damaged or corroded grains the results required very cautious interpretation, as this raises the possibility pointed out by a number of authors including Havinga (1971), Moore and Webb (1978), and Traverse (1988) that where some degree of corrosion has occurred it may have acted selectively. It is possible that some pollen types may have been corroded faster than others, and the differential susceptibility of some pollen types to decay must be considered. Conversely, Dimbleby (1957) makes the presumption that if few grains are in a decomposed state then breakdown is not very active, and therefore the possibility of differential preservation is greatly reduced.

Considerably higher scores of unidentified grains were recorded at four sites: Site 19 (West Waiouru, 54%), Site 20 (Waitangi Stream, 57%), Site 22 (South Waiouru, 39%), and Site 23 (Bates' Farm, 34%). These scores were so much higher than the rest that the results must be considered potentially unreliable in terms of an accurate record of the likely pre-eruption vegetation at these sites.

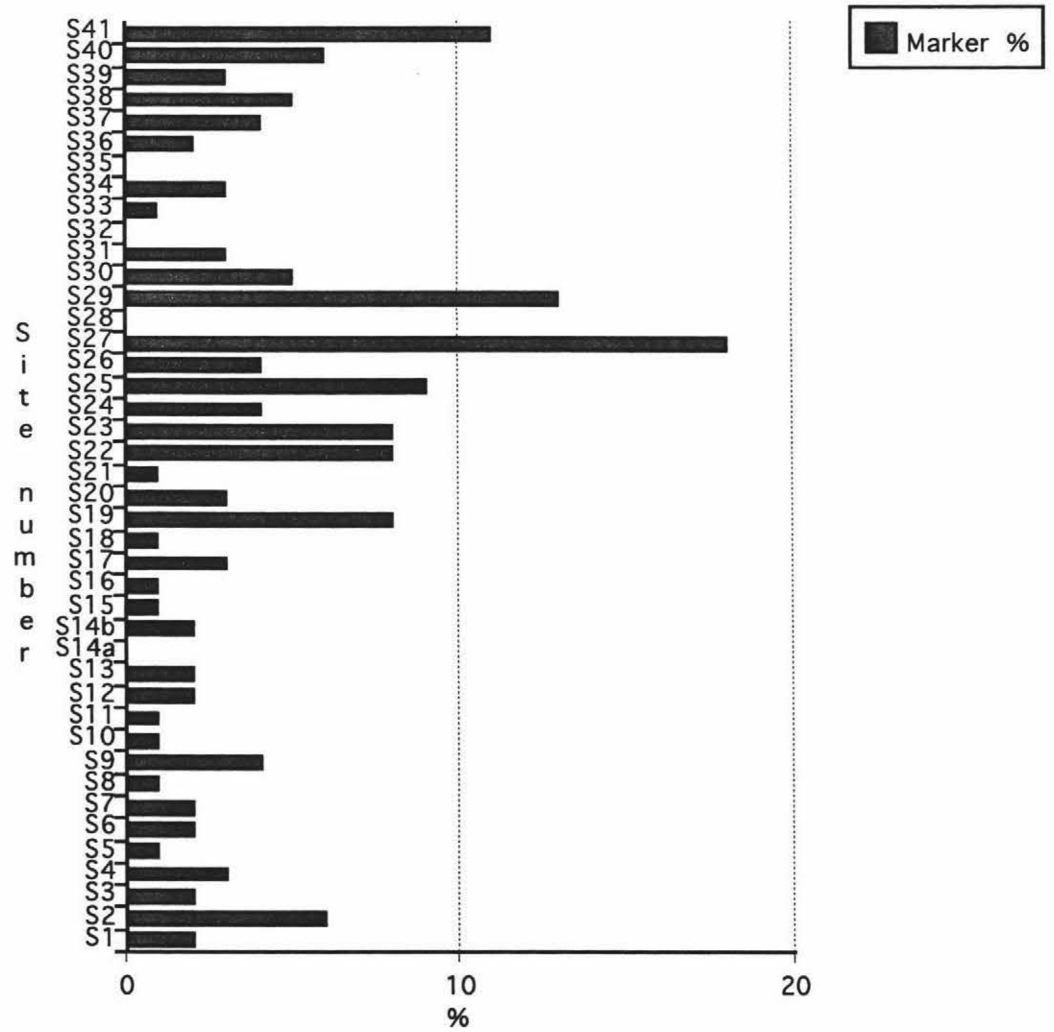
Marginally higher than 10% counts were recorded from Site 27 (Hautu Road, 12%), Site 29 (Otukou Quarry, 13%) and Site 30 (Mangaparuparu Stream, 12%). These results imply a lower state of preservation, but in the absence of other eliminating factors they might still provide some useful data. As Dimbleby (1957), noted, there are many areas where peats or sedimentary deposits are lacking and even the broadest conclusions produced by a study of soil pollen may be of great interest.

Some potential for bias of the pollen sum exists in those circumstances where preservation was less than perfect. At a number of sites Podocarpaceae grains were degraded so that the distinguishing features of cappa and sacci were obliterated. Although they could still be identified as far as family level more precise classification was impossible. The presence of more distinctive grains such *D. cupressinum* and *Halocarpus* thus tends to be emphasised at the expense of other species. Trilete fern spores also tended to distort results as they were identified only to type level, and were often still recognizable even when quite severely degraded. Consequently where these grains were abundant in a sample the unidentified percentage was often artificially depressed.

4.4 Pollen frequency and *Lycopodium* marker spores

The percentage of *Lycopodium* marker spores counted at each site was used as an indication of the relative abundance of pollens and spores. Nearly half the sampled sites (21 of the total 42) had very low counts of 0-2% of marker spores, implying a very high frequency of pollen grains. A further 13 sites scored at 3-4%, and another three at 5-6% (Fig. 4.2). Using these frequencies as a guide to the degree of preservation at each site, a score of more than 6% marker spores was taken as a benchmark beyond which the potential reliability of the results at the site must be examined carefully.

Figure 4.2: Marker spore percentages.



Site 19 (West Waiouru), Site 22 (South Waiouru), and Site 23 (Bates' Farm) had less plentiful pollen with a higher count of 8% marker spores recorded. Site 25 (Lower Karioi Forest) scored 9%, Site 27 (Hautu Road) 18%, Site 29 (Otukou Quarry) 13%, Site 40 (Wairehu Canal) 9% and Site 41 (Makiokio Stream) 11%.

The increasing count of marker spores at these sites presumably reflects a lower frequency of pollen grains at these sites. This may be due to either a poor state of preservation, or to an initial paucity of pollens and spores prior to the eruption. At those sites where there were other indications of a poor preserving environment (such as a high count of unknowns) this was considered to be sufficient reason to question the reliability of the data obtained.

4.5 Pteridophyte spores

"In New Zealand, pteridophytes represent an important proportion of the native flora." (Large and Braggins 1991).

In soil pollen analyses it is the vegetation growing on the site which contributes the bulk of the pollen (Dimbleby 1961). Within a forest canopy the influence of outside pollen is very limited; Dimbleby estimates it to be less than 3 per cent of the tree pollen. This specific site data provided by palaeosols indicates that it is appropriate to include pteridophyte counts as a percentage of the pollen sum, thus providing a more detailed description of the vegetation assemblage at each site. This procedure was also followed for the four peat samples in order to maintain consistency, these sites being Site 2 (Whakapapa Intake Road), Site 3 (Whakapapanui Bridge), Site 10 (Okupata Drop Shaft), and 14a (Erua Road).

As previously mentioned a number of sites in all groups, but particularly in the northern and southern groups, were characterized by high percentage counts of pteridophyte spores. These were recognizable as pteridophytes even though further identification was not possible as the spores were often damaged, and superficially degraded.

The reliability of those sites where the pteridophyte count was the single highest group was assumed to be questionable when interpreting site data.

Table 4.2: Comparison of pteridophyte spore and tree pollen percentages.

Table 4.2		Pteridophyte	Tree pollen	Higher spore
Site		spore %	%	count
S1	West Ketetahi	33	62	
S2	Whakapapa Intake Road	10	71	
S3	Whakapapanui Bridge	7	79	
S4	McDonnells Redoubt Road	73	17	X
S5	Desert Road (tank crossing)	4	88	
S6	Upper Tukino Road	2	88	
S7	Lower Tukino Road	2	93	
S8	Waipakihi Road	3	93	
S9	Okupata Intake Road	23	54	
S10	Okupata Drop Shaft	16	60	
S11	Pukeonake	5	89	
S12	Mangatepopo Valley	5	87	
S13	Poutu Canal	41	36	X
S14a	Erua Road (peat)	33	61	
S14b	Erua Road (palaeosol)	13	79	
S15	Whakapapaiti Bridge	4	89	
S16	Lahar Mounds	5	89	
S17	Whakapapa Road	7	87	
S18	Skotel, Whakapapa Village	6	93	
S19	West Waiouru	21	14	X
S20	Waitangi Stream	18	13	X
S21	Waihohonu Stream	5	90	
S22	South Waiouru	47	5	X
S23	Bates' Farm	34	23	X
S24	Upper Karioi Forest	5	86	
S25	Lower Karioi Forest	21	48	
S26	Burma Road	83	9	X
S27	Hautu Road	62	8	X
S28	Te Ponanga Saddle Road	96	4	X
S29	Otukou Quarry	28	34	
S30	Mangaparuparu Stream	53	28	X
S31	Mangahouhounui Stream	57	32	X
S32	Papakai	20	76	
S33	North National Park	49	37	X
S34	North Waiouru	24	58	
S35	Silica Springs Track	7	89	
S36	Umukarikari Track	11	79	
S37	Kaimanawa Road	77	16	X
S38	Mangatawai Stream	3	90	
S39	East National Park	11	86	
S40	Wairehu Canal	59	25	X
S41	Makiokio Stream	29	28	X

There are fifteen such sites (Table 4.2) but they do not include the four peat samples. Although two of the peat samples do have quite high spore counts (Site 10 and Site 14a), these are still substantially fewer than the tree pollen count.

There are several possibilities to be considered. Firstly, the high score may quite simply be the result of differential preservation (Dimbleby 1957, Havinga 1971, Traverse 1988). Dimbleby (1957) notes that when anaerobic fen peats become aerated, the pollen is for the most part destroyed leaving only the extremely resistant grains, notably fern spores; in fact, he also comments that high percentages of fern spores have been used as an indication of a period of aeration in a fen peat profile. If pteridophyte spores are more resistant to corrosion then they will have been better preserved in any sample. This may well be the situation where other evidence at the site implies a poor preservation environment. Such evidence might be an unidentified count in excess of 10%, especially if this is coupled with a score of more than 6% for *Lycopodium* marker spores.

There is a second possibility that the count may actually be a reflection of the site assemblage, in that prior to the eruption the site was dominated by pteridophytes. This is especially possible where there is no other evidence of poor preservation.

Of the fifteen sites where the pteridophyte count is the single highest scoring taxon, nine are within the FDI zone, and five are within the less acidic soils of the southern group. These are environments where the preservation of pollen and spores is generally rated as either intermediately affected or severely affected (Havinga 1971), and this increases the possibility that the high pteridophyte counts in these samples are the result of differential degradation. The remaining site outside these areas is Site 33 (North National Park) which is also classed as intermediately affected, but unfortunately there was not sufficient material available for pH testing.

4.6 Fines-depleted ignimbrite

Sites within a 15 - 24 km radius of the source of the eruption are usually covered by fines-depleted ignimbrite (FDI), as described by Walker *et al* (1980). This is a much more coarse deposit than normal ignimbrite (NM), is much more loosely packed, and is also characteristically unwelded. The resulting coarse, loose pumice deposit is very free-draining which may result in a more oxidising environment in the palaeosol below, with a corresponding deterioration in the pollen and spores contained within it.

Another potential cause of deterioration at these sites may have been the heat intensity of the pyroclastic flow during the eruption. As these sites are closer to the source they were potentially exposed to higher temperatures, and the resulting prolonged baking effect may have caused some damage to buried pollen and spores. Most of the sites sampled in this study were chosen where the overlying pumice was less than 1 m thick in order to minimise this thermal effect. Although it is known that sporopollenin can withstand high temperatures (Faegri 1971), this exposure to heat may have implications for long term preservation. Brooks (1971) showed that pollen grains kept at temperatures of 100°C for one week showed slight changes in appearance, but more drastic changes occurred at higher temperatures (150 - 200°C) in a much shorter time. These changes also involved chemical changes in the sporopollenin of the exine with the loss of hydroxyl groups and increased aromaticity of the material.

Samples were collected from 11 sites within the FDI zone (Table 4.3). These are Site 2 (Whakapapa Intake Road), Site 4 (McDonnells Redoubt Road), Site 13 (Poutu Canal), Site 26 (Burma Road), Site 27 (Hautu Road), Site 28 (Te Ponanga Saddle Road), Site 29 (Otukou Quarry), Site 30 (Mangaparuparu Stream), Site 31 (Mangaparuparu Stream), Site 37 (Kaimanawa Road) and Site 40 (Wairehu Canal). Sites 4, 26, 27, 29, 30, 31 and 40 are in the northern group; 13 and 37 are in the eastern group, and Site 2 is in the western group.

Of these 11 sites within the FDI zone only Site 2 (Whakapapa Intake Road) is not regarded as being potentially unreliable. This sample represents a peat, not a palaeosol, and has a markedly lower pH value than other FDI sites. The damper, more acid peat would seem to have provided a better preservation environment than did the soils within the FDI zone. This may be due to the the damper environment suffering less heat damage.

The unwelded FDI was also initially regarded as possibly being porous to groundwater which might carry contemporary pollens down to the palaesol. The investigation of the Dessert Road pumice profiles indicated this was unlikely, as pumice appears to act as a most efficient filter of pollen. This is further corroborated in that none of the sites investigated were found to contain any adventive species, despite their prevalence in the contemporary landscape.

Table 4.3: Site results from within the FDI zone.

Site No.	Northern group	>10% not identified	>6% marker spores	High fern count	Havinga preservation rating	pH	Not reliable sites
4	McDonnells Redoubt Road	6%	3%	73%	3		X
26	Burma Road	4%	4%	83%	3		X
27	Hautu Road	12%	18%	62%	3	6.14	X
28	Te Ponanga Saddle Road	0%	0%	96%	2		X
29	Otukou Quarry	13%	13%		3	6.24	X
30	Mangaparuparu Stream	12%	5%	53%	3	6.12	X
31	Mangahouhounui Stream	7%	3%	57%	3		X
40	Wairehu Canal	9%	9%	59%	3	6.32	X
Eastern group							
13	Poutu Canal	8%	5%	41%	3		X
37	Kaimanawa Road	4%	0%	77%	2		X
Western group							
2	Whakapapa Intake Road	5%	2%		1	5.54	peat

From these results it becomes apparent that the count of unidentified pollen and spores is not always a good indicator of the standard of preservation of the sample. Pteridophyte spores dominate these samples, and since they not only are differentially better preserved, but are also identified only as far as type this will artificially lower the unidentified count. This differential preservation is reflected in some instances by a slightly higher count of *Lycopodium* marker spores, although other sites appear to be particularly rich in spores anyway. It is possible that Site 28 (Te Ponanga Saddle Road) and Site 37 (Kaimanawa Road) are in this second category and represent areas where ferns were the dominant vegetation. This assumption is further supported by the Havinga preservation rating as these sites are classed as intermediately affected.

4.7 Summary of data contributing to the determination of potentially unreliable sites

Table 4.4		% not identified	% marker spores	Higher fern spore count	Havinga preser-vation rating	Within FDI zone	pH	Potentially unreliable sites
Site								
1	West Ketetahi	5%	2%		1		5.9	
2	Whakapapa Intake Road	5%	2%		1	FDI	5.54	
3	Whakapapanui Bridge	6%	2%		1			
4	McDonnells Redoubt Road	6%	3%	73%	3	FDI		X
5	Desert Road	5%	2%		1			
6	Upper Tukino Road	7%	2%		1			
7	Lower Tukino Road	2%	2%		1			
8	Waipakahi Road	4%	1%		1			
9	Okupata Intake Road	6%	4%		2		5.42	
10	Okupata Drop Shaft	5%	2%		1		5.69	
11	Pukeonake	4%	1%		1			
12	Mangatepopo Valley	5%	2%		1		5.59	
13	Poutu Canal	8%	5%	41%	3	FDI		X
14a	Erua Road (peat)	3%	0%		1			
14b	Erua Road (palaeosol)	5%	2%		1			
15	Whakapapaiti Bridge	3%	1%		1			
16	Lahar Mounds	4%	1%		1			
17	Whakapapa Road	3%	3%		1			
18	Skotel, Whakapapa Village	3%	1%		1			
19	West Waiouru	54%	8%	21%	3		6.28	X
20	Waitangi Stream	57%	3%	18%	3		6.3	X
21	Waihohonu Stream	4%	1%		1			
22	South Waiouru	39%	8%	47%	3		6.38	X
23	Bates' Farm	34%	8%	34%	3		6.4	X
24	Upper Karioi Forest	5%	4%		2		6.19	
25	Lower Karioi Forest	9%	9%		2		5.94	X
26	Burma Road	4%	4%	83%	3	FDI		X
27	Hautu Road	12%	18%	62%	3	FDI	6.14	X
28	Te Ponanga Saddle Road	0%	0%	96%	2	FDI		X
29	Otukou Quarry	13%	13%		3	FDI	6.24	X
30	Mangaparuparu Stream	12%	5%	53%	3	FDI	6.12	X
31	Mangahouhounui Stream	7%	3%	57%	3	FDI		X
32	Papakai	4%	0%		1			
33	North National Park	7%	1%	49%	2			X
34	North Waiouru	9%	3%		3			
35	Silica Springs Track	2%	0%		1			
36	Umukarikari Track	8%	2%		2			
37	Kaimanawa Road	4%	0%	77%	2	FDI		X
38	Mangatawai Stream	5%	1%		1		5.96	
39	East National Park	3%	0%		1		6.08	
40	Wairehu Canal	9%	6%	59%	3	FDI	6.32	X
41	Makiokio Stream	25%	11%	29%	3		6.49	X

Poor pollen preservation environments, and therefore potentially unreliable data, can be measured by a number of parameters. These parameters, as previously described, include counts of more than 10% unidentified pollens and spores, more than 6% *Lycopodium* marker spores, and a count of fern spores which is higher than other taxa (Table 4.4). These parameters usually concur with and complement the modified site rating system suggested by Havinga (1971). Where the pH value of the sample is known, it can be seen that a pH value above 6.0 is almost always a contributing factor to poor pollen preservation. Sites from within the FDI zone also frequently give potentially unreliable data. When all factors are considered a total of 17 sites would seem to be potentially unreliable, while the data from the remaining 25 appear to be suitable for analysis.

4.8 Peats and palaeosols

"One cannot argue that because a certain species is only present in very small quantities it never grew on the site, but on the other hand, if any species is represented in considerable quantities it almost certainly did grow there." (Dimbleby 1957).

Samples for analysis were taken from the layer directly below the contact with the Taupo Tephra. These samples were classed as either palaeosols or peats. A peat is defined as partly decomposed plant remains in a water-saturated environment, such as a bog (Molloy 1988) and is therefore entirely organic in origin. A soil has an inorganic component, and is defined as the naturally occurring thin layer of unconsolidated material on the Earth's surface that has been influenced by parent material, climate and relief, in addition to physical, chemical and biological agents (Whittow 1984). Any sample which is not entirely organic in origin is therefore classed as a soil, not a peat.

The sample obtained at the majority of sites is from a palaeosol rather than a peat, and these results are more likely to reflect a dry land forest assemblage than a swamp association. Where the pollen count reflects a forest or other relatively dense vegetation, then the likelihood is that the pollen present had originated in the immediate area, rather than being the result of long distance transport. Dimbleby (1961) comments that where soils are analysed, the bulk of the pollen in the sample has been contributed by vegetation growing on the site. He estimates the influence of outside pollen within a forest canopy to be less than 3 percent of the tree pollen. The results of pollen analysis from palaeosols can therefore be assumed to be a reflection of vegetation growing on or very near the sampling site, rather than an indication of the regional pollen rain.

The more open swamps and mires from which peat samples are derived are more likely to contain pollens brought in by long distance transport, especially by wind. This is supported by Randall (1990) who notes deposition of greater amounts of pollen in open sites in a study of modern pollen rains across the Southern Alps.

For any site which accumulates peat, and which does not have an inflowing stream, pollen influx is described as local if the source is within 20 m, extra-local from plants growing between *c.* 20 - 300 m distance, and regional from plants more than 300 m away (Jacobson and Bradshaw 1981). The model proposed by Jacobson and Bradshaw (1981) predicts that with small closed sites (such as shrub-covered peat bogs and basins of less than 1 ha within forest), the major source of pollen will still be local, but the proportion of regional pollen will increase with the diameter of the site. Faegri and Iversen (1989) consider long-distance transport of regional pollen to be a subordinate factor in most cases, as the quantity of pollen produced by local vegetation is generally so immense that long-distance pollen remain proportionally relatively insignificant.

The peat sites certainly tend to have a greater number of species represented than many of the palaeosol sites (especially in the small tree and shrub group), but this may be an artificial result since the peat sites (Sites 2,3,10 and 14a) are all at relatively low altitudes in the western group (Figure 2.4). The western sites tend to be more species rich and varied in composition than the relatively uniform beech forests which predominate to the north and east (Tables 3.47 and 3.48).

Among the sites investigated only Site 2 (Whakapapa Intake Road), Site 3 (Whakapapanui Bridge), Site 10 (Okupata Drop Shaft), and 14a (Erua Road), were of peats. These samples were also significantly higher in the number of taxa of both pollen and spores recorded than most of the palaeosols. They also tended to be relatively rich in pollen with low percentage scores of *Lycopodium* marker spores counted. This was particularly evident with Site

10 and Site 14a, and may be a reflection of the preservation of a regional, rather than a local pollen rain by peats, or it may reflect a better preserving environment in peat, or even be the result of a combination of both factors. The two sites on Erua Road (14a and 14b) therefore provide an interesting comparison in that they are only 500 m apart, but 14b is a palaeosol. Another useful comparison can be made between Site 3 (Whakapapanui Bridge) which is just over 2 km from Site 16 (Lahar Mounds), while Site 10 (Okupata Drop Shaft) is also within 2 km of the palaeosol at Site 9 (Okupata Road). Unfortunately Site 2 (Whakapapa Intake Road) is a considerable distance from a palaeosol at a similar altitude.

The major difference between the two Erua Road sites is that the peat sample had a greater representation of taxa which possibly represent the regional pollen rain. This is especially the case with small tree and shrub taxa where six genera were represented as minuscule amounts in the peat, but only one in the palaeosol. The peat also included very small amounts of tree pollen from four genera which were absent in the palaeosol. However, the major difference between the two samples was the presence of 21% *Gleichenia* spores in the peat which were entirely absent from the palaeosol. Pollen and spores were plentiful in both samples, although the peat was somewhat richer with no *Lycopodium* marker spores counted as opposed to the 2% recorded in the palaeosol.

The two sites at Okupata have relatively minor differences in the taxa represented as well as their relative frequencies within the pollen sum. The major difference between the two sites is probably one of preservation as the peat sample contained pollen and spores which were much better preserved than those in the palaeosol.

The comparison between Site 3 (Whakapapanui Bridge) and Site 16 (Lahar Mounds), is rather more difficult as the 2 km distance which separates the sites also involves a 120 m increase in altitude up the side of Ruapehu. This increase in altitude may be sufficient in itself to explain the differences between the sites. The sites are, however, reasonably similar in the taxa represented, although once again the peat site has preserved more representatives. The only major difference is in the quantity of *N. menziesii* which is much more frequent (26%) at the higher altitude palaeosol site than in the peat (9%). As there is a similar frequency (10%) of *N. menziesii* in the neighbouring peat at Site 2 (Whakapapa Intake Road) this would appear to support the lower frequency at the lower altitude. The higher proportion at the higher altitude site may reflect the actual relative composition of the pre-Taupo forest, or it may be simply denote a local presence of *N. menziesii* at the site.

The taxa which tend to be less well represented in the palaeosol samples are those of the subcanopy species, that is small trees and shrubs. The increased number of these taxa recorded from peat samples may be the result of either the better preserving environment provided by wet, acid and non-oxidising conditions, or it may be due to (as previously discussed) the more open situation providing representatives of the regional pollen rain. In those palaeosol samples where pollen and spores appear to be well preserved and in high concentrations it seems reasonable to assume that the lack of this group is due to the filtering effects of the closed canopy, rather than the result of differential pollen preservation. This is especially likely in those sites where the results indicate the vegetation was dominated by tree species.

4.9 Pollen representativity

"If canopy species have behaved individualistically through time, then it is clearly unwise to press analogies based on the modern vegetation too closely when inferring past associations." (Macphail and McQueen 1983).

Bearing the above caution in mind, interpretation of the data obtained from the sites sampled depends upon an assumption that the data is a reflection of the original vegetation present at or near the site before the Taupo eruption. The composition of the pollen record obtained from each site will be dependent firstly upon the original pollen rain which was deposited at that site, and secondly upon the survival of that pollen over time and under the conditions operating at that site (Faegri and Iversen 1989). The first of these is the representativity of the site (Macphail and McQueen 1983) and the second is the preservation environment of the site.

A major problem with the interpretation of data from each site is the difficulty in distinguishing local pollen from more distant pollen sources. Studies of modern pollen rain indicate that there is a significant relationship between the existing vegetation and on-site pollen percentages for some taxa, but McGlone and Moar (1997) conclude that more work is needed before these relationships could be used for the quantitative reconstruction of past vegetation. Within the limits of this study, although it is impossible to be entirely certain that the pollen and spores analysed are from the vegetation growing on the site prior to the eruption, the use of palaeosol samples has increased the likelihood of this being the case. It may therefore, be appropriate to assume that the site frequencies are thus a reflection of the site representativity; where representativity is defined by Macphail and McQueen (1983) as a measure expressing the relationship between species abundance and amount of pollen recorded at a particular location. Unfortunately the exact nature of this relationship is not known, but New Zealand pollen rain studies have shown that the proportion of a given taxon in the surface samples does not bear a linear relationship to its representation in the vegetation (McGlone and Wilson 1996, Elliott 1999).

Macphail and McQueen (1983) recognise the following qualitative representativity values:

i) *Over-represented:* pollen percentage is greater than the percentage of the source plants within the vegetation.

ii) *Well-represented:* pollen percentage is approximately equal to the percentage of source plants within the vegetation.

iii) *Under-represented:* pollen percentage is markedly smaller than the percentage of source plants within the vegetation, or zero.

Within the New Zealand flora Macphail and McQueen (1983) note that few indigenous taxa have intrinsically high powers of pollen dispersal, and that this over-represented group includes: *Cyathea smithii*-type, *Dacrydium cupressinum, Nothofagus fusca*-type, *Coprosma* and Gramineae. The dispersal ability of *Nothofagus fusca*-type is illustrated by McGlone and Moar (1997) who found this was the most commonly recorded and abundant long-distance pollen type among the modern pollen rain on the Auckland Islands.

Also noted are a group of some 25 pollen and spore types which although they have lesser powers of dispersal, are frequently encountered due to the source plants being widespread across the country. Members of this well-represented group are: Compositae, *Phyllocladus, Prumnopitys ferruginea, P. taxifolia, Podocarpus totara*-type, *Halocarpus biformis/bidwillii,* *Lagarostrobus colensoi, Nothofagus menziesii, Quintinia, Ascarina, Metrosideros, Weinmannia, Elaeocarpus, Griselinia, Pseudopanax, Myrsine, Pennantia, Leptospermum, Dicksonia, Cyathea dealbata*-type, *Phymatodes, Histiopteris,* Monolete fern spores, *Lycopodium* spp and *Dacrycarpus dacrydioides.*

There is also a small group which is almost never represented, and this group includes *Beilschmiedia tawa* and *B. tarairi.*

Many of the taxa prominent in the data from both peat and palaeosol sites do belong to the group described as over-represented by Macphail and McQueen (1983), especially *Nothofagus fusca*-type and *Dacrydium cupressinum.* The deterioration of many Podocarpaceae grains, however, made identification to species level difficult. While their presence was recorded at many sites and does indicate the presence of tall forest vegetation, comments on their actual species representation within the pre-Taupo forests are consequently not appropriate. However, the presence of such large quantities of these species as well as other tree species from the well-represented group (notably *N. menziesii, Halocarpus,* and *Podocarpus*) at any site does support the view that the sample was taken from a site which was under forest prior to the Taupo eruption. In this event of a closed canopy, not only is the likelihood of long distance pollen transport reduced, but also, with the large quantities recorded from these species, even a 3% outside influence is reduced to a small proportion of the pollen sum. This view is supported by Faegri and Iversen (1989), who concluded that the quantity of pollen produced by local vegetation is generally so immense that the quantities deriving from long-distance transport are relatively insignificant. McGlone and Moar (1997) in a study of modern pollen rain on the Auckland Islands, suggest that a closed canopy probably limits the incorporation of pollen into the turbulent upper air which therefore greatly reduces the amounts being carried more than a few tens of metres from the plant source. The more open situation of the peat sites in this study is therefore more likely to include representative regional pollen and thus provides an interesting contrast with the those palaeosol sites which are in close proximity.

The relative under representation of the small tree and shrub group is supported by the findings of McGlone and Wilson (1996), and by Elliott (1999). These authors concluded that most small hardwood trees, scrub species and tree ferns are well represented in pollen rain only when they are close to or dominating the local site, but are at low levels otherwise, even when they are abundant in the local area. In a study of modern pollen rain under a closed canopy on the Auckland Islands, McGlone and Moar (1997) also noted the absence of a regional pollen rain. Two factors may therefore contribute to the under representation of the small tree and shrub group, firstly that the group as a whole is not well dispersed, and secondly that distribution is further restricted beneath a closed canopy. The absence of evidence from this group is not necessarily evidence of its absence.

4.10 Environments of preservation in palaeosols

"The preservation of spores/pollen in sediment is the result of complex factors, not just sporopollenin content alone." (Traverse 1988).

The 42 sites sampled include four sites where the sample taken was from a peat and 38 where the sample was of a palaeosol. Preservation of pollen and spores in the peat samples was generally good and no peat sample has been graded as being potentially unreliable.

The 38 palaeosol sites, however, include 17 sites which are considered to be potentially unreliable. The possible effects of the FDI environment and higher soil pH values on pollen and spore preservation have already been discussed, and these two factors appear to have contributed to poor preservation environments in ten sites within the FDI zone, as well as all five sites of the southern group. The two remaining sites are Site 25 (Lower Karioi Forest) with a *Lycopodium* marker spore count of 9%, and Site 33 (North National Park) where pteridophytes are the highest scoring single taxon with 49% of the pollen sum.

A number of sites were characterised by pollen and spores with specific patterning of the exine which was recognizable as being caused by microbiological activity. Such degradation of the exine which results in definite patterns or scars is attributable to the higher bacteria (Actinomycetes) and true fungi (Elsik 1971). (Appendix A, Figure 5)

Elsik (1971) notes that there are several types of degradation pattern, and that more than one type of pattern may be found on an individual specimen. The scars produced are very regular and Elsik (1971) describes two types, firstly perforate scars, produced by organisms primarily degrading the microspore cell contents, and secondly pit, rosette or branching scars produced by micro-organisms primarily involved with degradation of the exine. Both types of patterning were observed in a number of samples, particularly on the exine of fern spores. This superficial degradation may be reduced in those soils where there is less biological activity.

4.11 Disqualified sites

"There are few better careers than Quaternary palynology for the determined overinterpreter, the chronic circular arguer or the athletic bandwagon-jumper." (Flenley 1994).

There are 17 sites which are outside the various measures of reliability used in this study, as summarised in Table 4.5.

Table 4.5: Data from potentially unreliable sites.

Site		>10% not identified	>6% marker spores	Havinga preser-vation rating	Higher fern spore count	Within FDI	pH value	Potentially unreliable zone
4	McDonnells Redoubt Road			3	73%	FDI		X
13	Poutu Canal			3	41%	FDI		X
19	West Waiouru	54%	8%	3	21%		6.28	X
20	Waitangi Stream	57%		3	18%		6.3	X
22	South Waiouru	39%	8%	3	47%		6.38	X
23	Bates' Farm	34%	8%	3	34%		6.4	X
25	Lower Karioi Forest		9%	2			5.94	X
26	Burma Road			3	83%	FDI		X
27	Hautu Road	12%	18%	3	62%	FDI	6.14	X
28	Te Ponanga Saddle Road			2	96%	FDI		X
29	Otukou Quarry	13%	13%	3		FDI	6.24	X
30	Mangaparuparu Stream	12%		3	53%	FDI	6.12	X
31	Mangahouhounui Stream			3	57%	FDI		X
33	North National Park			2	49%			X
37	Kaimanawa Road			2	77%	FDI		X
40	Wairehu Canal		9%	3	59%	FDI	6.32	X
41	Makiokio Stream			3	29%		6.49	X

These potentially unreliable sites are of some interest, as they may well give some indication of which pollen and spores are most resistant to decay among the New Zealand flora, in that where site preservation has been poor, the grains present will be the resistant ones. There is, however, unlikely to be much useful data gained from those four sites where the deterioration has been such that the count of unidentified spores is above 20% of the pollen sum. Additionally, fifteen sites are dominated by high counts of pteridophyte spores, and in those instances where these counts are more than 50% of the pollen sum it is difficult to draw any other conclusion than the obvious one that pteridophyte spores are very resistant to decay. Consequently, an examination of the species present at the remaining four possibly useful sites, although limited, may provide some useful information (Table 4.6).

Table 4.6: Possibly useful disqualified sites

Site		>10% not identified	>6% marker spores	Fern spore count	Havinga preservation rating	Within FDI zone	pH value
Northern group							
29	Otukou Quarry	13%	13%		3	FDI	6.24
Eastern group							
13	Poutu Canal			41%	3	FDI	
25	Lower Karioi Forest		9%		2		5.94
Western group							
33	North National Park			49%	2		

Site 29 (Otukou Quarry) is in the northern group with a vegetation assemblage dominated by trilete fern spores, but with a small representation from a number of small tree and shrub taxa (Fig. 4.3). The tree pollen present suggest a mixed beech and conifer assemblage. The most represented taxa, and therefore possibly the most resistant to decay are *D. cupressinum*, *Nothofagus spp*, and *Myrsine*. The nearest sites with reliable data are Site 1 (West Ketetahi) and Site 32 (Papakai). Both of these sites are dominated by *Nothofagus* with a very small representation from Podocarpaceae species.

Although Site 13 (Poutu Canal) is in the eastern group (Fig. 4.4), it is geographically very much closer to the previous site, Site 29, than it is to Site 25 (Lower Karioi Forest) which is the other site under consideration in the eastern group. The vegetation at the Poutu Canal site is similar to the previous one with trilete fern spores the dominant group, and some representation from small tree and shrub taxa, particularly *Neomyrtus*-type and *Myrsine*. The tree pollen, however, contains less *D. cupressinum* than Site 29, and is predominantly *Nothofagus* with *Myrsine* and *Neomyrtus*-type

Figure 4.3: Site 29 - Otukou Quarry total pollen values

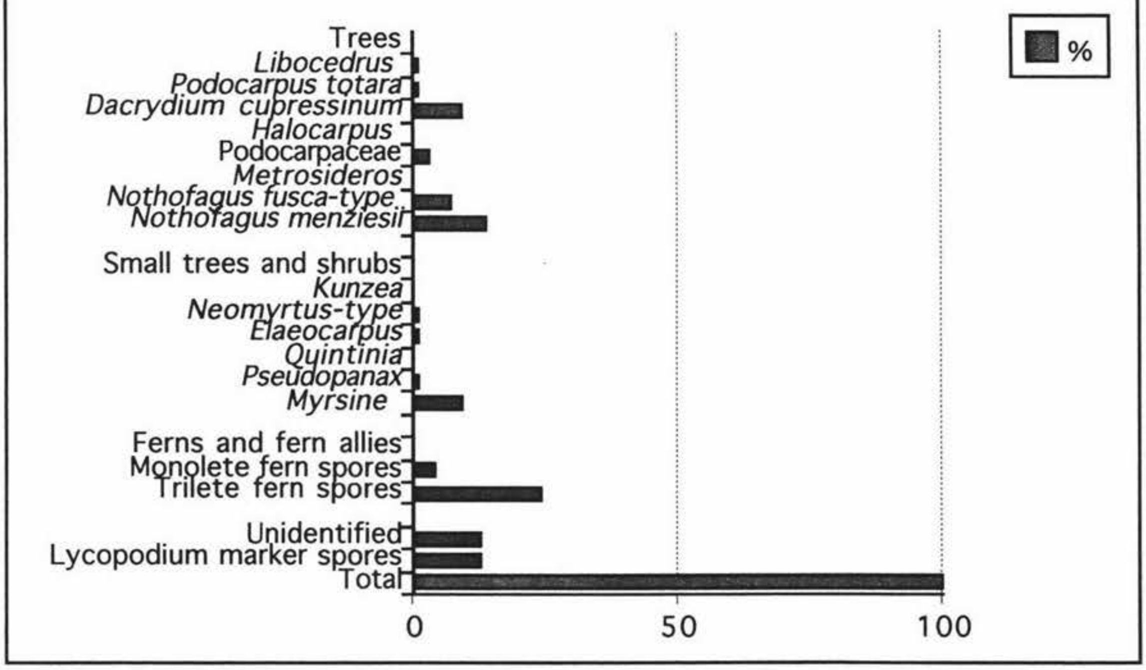
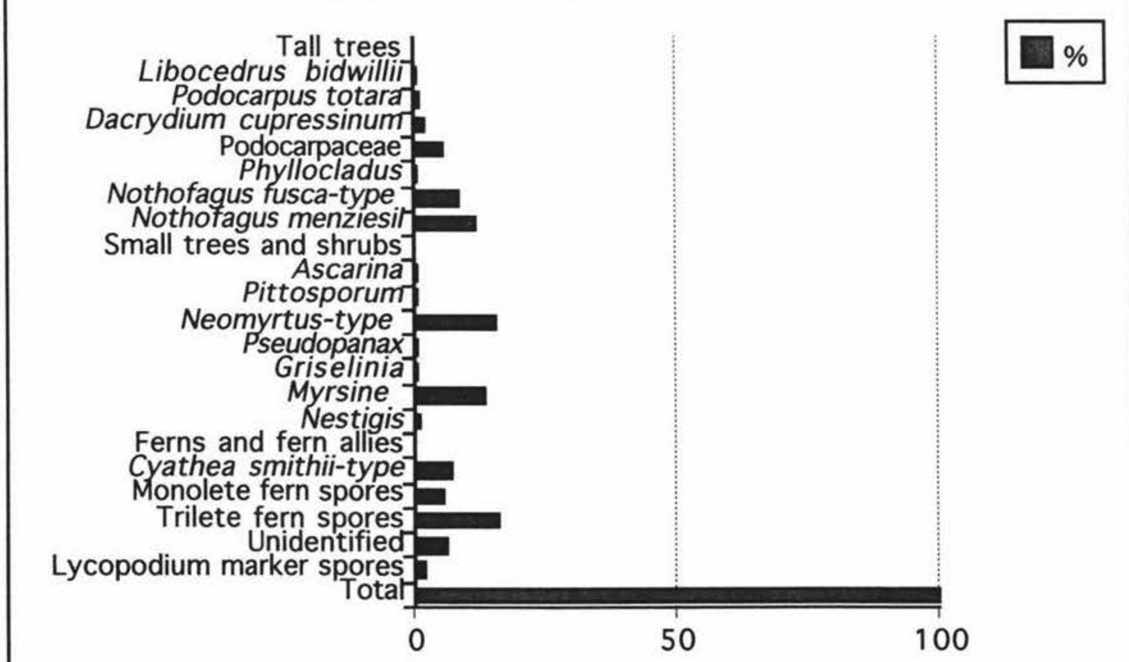


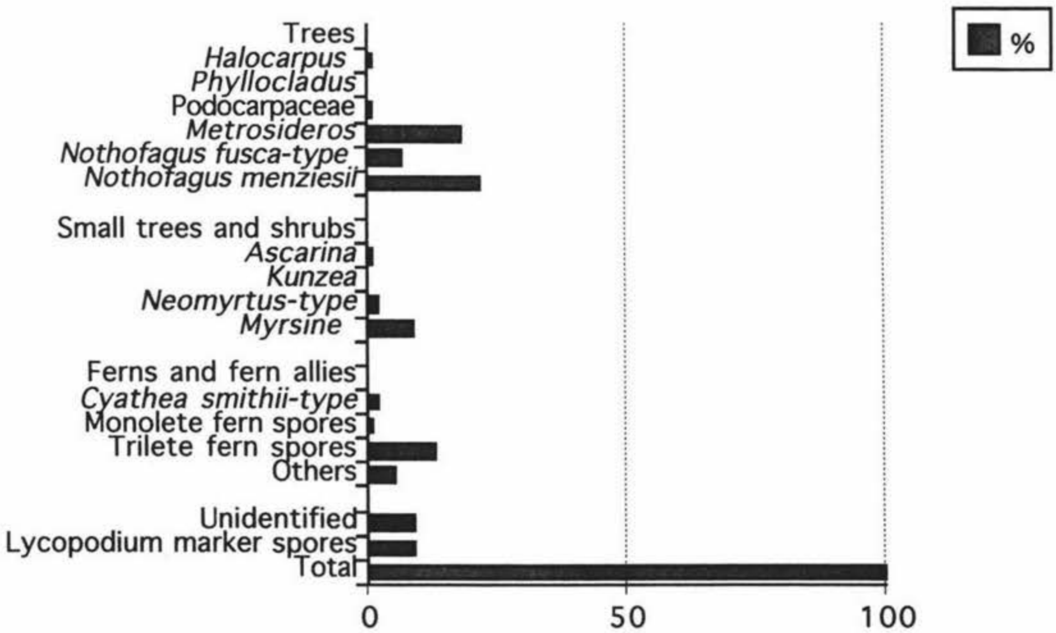
Figure 4.4: Site 13 - Poutu Canal total pollen count



also relatively well represented. The nearest reliable sites are Site 36 (Umukarikari Track) and Site 38 (Mangatawai Stream) which are approximately 4 and 6 km away respectively. Although Site 38 is almost entirely beech pollen (81% of the pollen sum), *D. cupressinum* comprises 10% of the total at Site 36.

Site 25 (Lower Karioi Forest) is considered potentially unreliable due to a count of *Lycopodium* marker spores which is marginally outside the imposed limit for this study. The pollen diagram (Figure 4.5) indicates a mixed assemblage with beech and *Metrosideros* the main tree species. *Myrsine* is also relatively abundant, as are trilete spores. The nearest reliable sites are Site 24 (Upper Karioi Forest) and Site 34 (North Waiouru) which are both approximately 6 km away. Site 24 is in the lower alpine climatic zone (Wardle 1964) and appears to represent beech forest with beech pollen comprising 81% of the pollen sum. Site 34 appears to be a mixed conifer hardwood forest association with both beech and podocarp species represented.

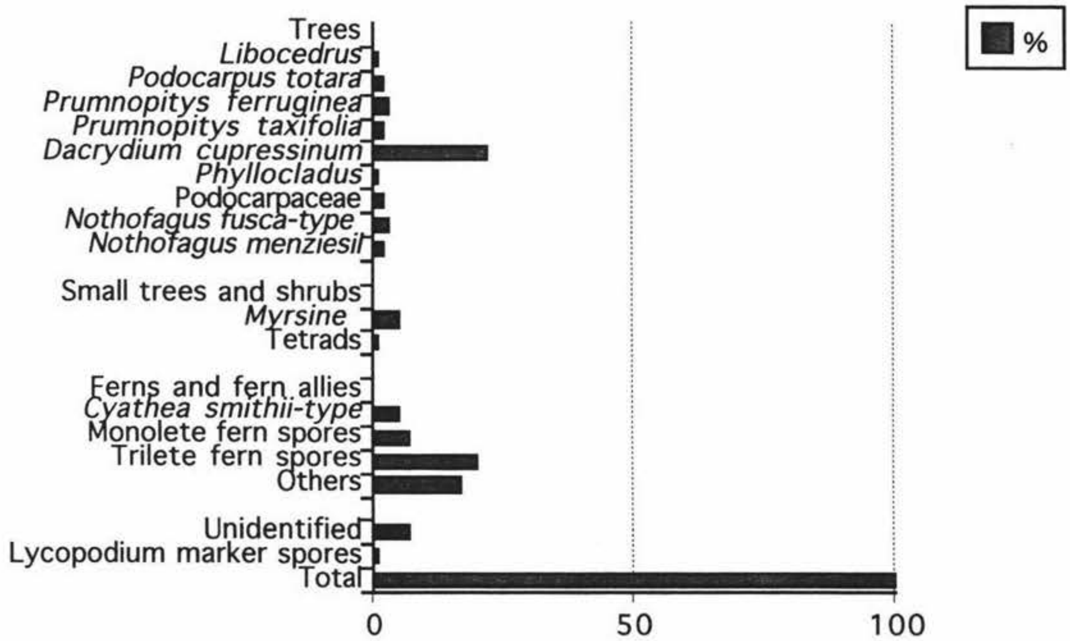
Figure 4.5: Site 25 - Lower Karioi Forest total pollen count



Site 33 (North National Park) is considered potentially unreliable due to a high count of fern spores, 49% of the total. The pollen sum (Figure 4.6) is indeed dominated by pteridophyte spores, especially trilete spores, but 17% of the total also comes from Hymenophyllaceae spores. *Cyathea smithii*-type and some monolete spores are also present. The tree pollen contains minor amounts of beech pollen but is otherwise composed of Podocarpaceae species,

especially *D. cupressinum.* It is possible that in this case, the count may actually be a reflection of the site assemblage prior to the eruption, as the site may have been montane podocarp forest with abundant pteridophytes. The closest reliable site, however, is Site 39 (East National Park) just under 3 km away, and the pollen sum from this site is dominated by beech with only a very small podocarp contribution.

Figure 4.6: Site 33 - North National Park total pollen count



Only the very broadest conclusions could possibly be drawn from the above data which represents only four sites. However, in terms of the differential degradation of pollen and spores in the New Zealand flora, it does seem that the same taxa are relatively well represented at these four sites, and that these might, therefore, be more resistant than others. Pteridophyte spores certainly seem to be able to resist decay. Both *Nothofagus* and *D. cupressinum* appear to preserve quite well, although it must be remembered that these groups are often over represented in pollen sums (Macphail and McQueen 1983). *Metrosideros,* although less abundant in the study area, is also in the same category. The exception is *Myrsine*, which Macphail and McQueen (1983) regard as under-represented, but which is reasonably abundant at three of these four sites. It is possible that if *Myrsine* is more resistant to decay then as other grains deteriorate the swamping effect from other taxa will be minimised, allowing more resistant grains to become more prominent in the pollen sum.

4.12 Site analysis

"It is impossible to say exactly what proportion of the pollen of any species is indicative of the presence of that species in a given site." (Dimbleby 1957).

Site 1: West Ketetahi (Northern group, 725 m a.s.l.)

Tree pollen comprises 62% of the pollen sum at this site. The forest association appears to have been dominated by *Nothofagus* species, especially the *N. fuscospora* group which accounts for 39% of the total. There are virtually no representatives from small trees and shrubs which suggests a typically "pure beech" stand, although there are a number of spores from various pteridophytes totalling 31% of the whole which may indicate a ground cover of ferns at the site.

Site 2: Whakapapa Intake Road (Western group, 880 m a.s.l.)

Although this site is within the FDI zone the sample represents a peat rather than a palaeosol, and as such has a lower pH than other sites in the this area. This is the only sample from within the FDI zone which is not classed as being potentially unreliable. The damper, more acidic and anaerobic peat swamp may have provided a better preservation environment.

The vegetation assemblage recorded may be more indicative of a regional pollen rain. Several of the species present (notably *Nothofagus fusca*-type, and *Dacrydium cupressinum*) are among the pollen types which are generally considered to be over-represented due to their ease of dispersal (Macphail & McQueen 1983).

The tree pollen present accounts for 71% of the pollen sum and includes *Libocedrus* (16%), *Dacrydium cupressinum* (17%), *N. fusca*-type (14%) and *N. menziesii* (10%). The presence of these species indicates a mixed conifer hardwood forest association. Pollen from small trees and shrubs comprises 12% with ferns and fern allies at 10% of the total sum.

Site 3: Whakapapanui Bridge (Western group, 840 m a.s.l.)
The sample at this site also represents a peat rather than a palaeosol. Tree pollen accounts for 79% of the pollen sum with *N. fusca*-type predominant at 54% of the total. There are smaller amounts of *N. menziesii* (9%) and *Dacrydium cupressinum* (8%). At this altitude of 840 m, the forest represented may have been predominantly montane beech (*N.solandri var. solandri*, and *N. solandri var. cliffortioides*).

There are very few small trees and shrubs, although the group is represented, and very few ferns and fern allies. Most of the species recorded from both these groups are usually well represented due to their being widespread across the country (Macphail and McQueen 1983). The very small percentages of the flowering plants in particular, may be the result of their being representatives of regional rather than local pollen.

Site 4: MacDonnell's Redoubt Road (Northern group, 600 m a.s.l.)
This site lies within the FDI zone and preservation of pollen and spores was poor as analysis showed a great many fragmented grains. Nonetheless, the site appears to be reasonably rich in pollens as *Lycopodium* marker spores were only 3% of the total pollen count. The highest scoring group was trilete fern spores (61%), many of which showed some signs of degradation, and this is sufficient reason to regard this site as being potentially unreliable. Although the possibility of differential degradation must be considered, when the low frequency of marker spores and relative richness of the site is considered, it is also possible that the site may represent an area where ferns were naturally abundant, such as a light well or regeneration gap.

Site 5: Desert Road - tank crossing (Eastern group, 1040 m a.s.l.)
The site is dominated by tree pollen, principally *N. fusca*-type (44%), although N. menziesii (14%) is the next highest scoring group. There is a significant representation from the Podocarpaceae, particularly with *Dacrydium cupressinum* , *Phyllocladus* and *Halocarpus* contributing a total of 24% to the score. At this altitude of just over 1000 m above sea level beech is often a major forest component (Wardle 1984). The lack of pollen representatives of under story species is supportive of an association dominated by beech, although there is obviously also a significant podocarp element at this site.

Site 6: Upper Tukino Road (Eastern group, 1280 m a.s.l.)
The site is completely dominated by *Nothofagus* pollen from both species types as this comprises 77% of the total count. Since this was the highest sites sampled at just under 1300 m in altitude, the interpretation of the data as a high altitude "pure beech" stand (Wardle 1984) is appropriate.

Site 7: Lower Tukino Road (Eastern group, 1180 m a.s.l.)
The site analysis is very similar to the previous one on the upper part of Tukino ski field road. Although this site is 100 m lower in altitude the results are very comparable with both species of *Nothofagus* dominating, and at this site representing 85% of the total pollen count. There were a very few grains recorded from the Podocarpaceae, but this is a very minor contribution as none individually scored over 3%, and even collectively the total was still only 8%. Pollen from other taxonomic groups such as small trees and shrubs, as well as ferns and fern allies was also virtually absent. The data from both this site and the previous one appear to represent high altitude forest which is virtually pure beech.

Site 8: Waipakihi Road (Eastern group, 920 m a.s.l.)
The site is dominated by *Nothofagus fusca*- type, with a lesser amount of *N. menziesii* recorded. Taken together, beech represents 88% of the pollen recorded and virtually all of the tree pollen. There were almost no under-story species represented with no small tree or shrub species found, and ferns comprising only 3% of the total count. The site data is representative of a pure beech forest.

Site 9: Okupata Intake Road (Western group, 620 m a.s.l.)
The pollen diagram at this site indicates a mixed forest assemblage which is dominated by podocarps, especially *Dacrydium cupressinum*. Both species of beech are also represented, as well as a number of small trees and shrubs (14%) together with ferns and fern allies (23%), which is consistent with a mixed conifer hardwood association.

Site 10: Okupata Drop Shaft (Western group, 700 m a.s.l.)
The pollen diagram at this site, as at the previous one on Okupata Road,

indicates a mixed forest assemblage, which in this case is dominated by *Dacrydium cupressinum.* Again, both species of beech are also represented, as well as a number of small trees and shrubs (17%) together with ferns and fern allies (16%), which is consistent with a mixed conifer hardwood association. The pteridophytes include some Hymenophyllaceae which also supports a forest association. The sample at this site is from a peat and probably reflects a regional pollen rain, as indicated by the higher number of scoring taxa.

Site 11: Pukeonake (Western group, 1225 m a.s.l.)
The vegetation assemblage is consistent with a montane forest of virtually pure beech, with 50% recorded as *Nothofagus fusca*-type, and 30% as *N. menziesii.* Small amounts of various podocarp pollen were recorded, the most frequent being *Halocarpus* pollen (4%), but small trees and shrubs are almost completely unrepresented. This is one of the highest sites sampled and the presence of *Lycopodium* and *Pteridium* spores supports the interpretation of a more open canopy.

Site 12: Mangatepopo Valley (Western group, 1080 m a.s.l.)
The assemblage is dominated by tree pollen, particularly beech, with 41% *Nothofagus fusca,* and 34% *N. menziesii.* The podocarp pollen tended to be less well preserved and was more difficult to identify to species level, as indicated by a Podocarpaceae count of 5% of the total. The low counts of small trees and shrubs, as well as ferns and fern allies implies a beech stand.

Site 13: Poutu Canal (Eastern group, 580 m a.s.l.)
The high count of ferns and fern allies at this site (41%) and the location of the site within the FDI zone make this a potentially unreliable site. Tree pollen is reduced to 36% of the total count and reflects a mixed assemblage of beech and podocarps. Some small tree and shrub pollen (*Neomyrtus*-type and *Myrsine*) is also present and comprises 10% of the total.

Site 14a: Erua Road - peat sample (Western group, 730 m a.s.l.)
The sample at this site is of a peat and probably reflects a regional pollen rain, as indicated by the higher number of scoring taxa (21 in total),

especially from small trees and shrubs. Pteridophyte spores account for 33% with a significant number of *Gleichenia* spores occurring which make up 21% of the total pollen count. *Gleichenia* is dominant on acid bogs and is not well dispersed (Macphail & McQueen 1983) which further supports this site as an open bog or mire, rather than a closed canopy.

Tree pollen dominates the site with 61% of the total count and *Nothofagus fusca*- type being the single highest scoring taxon with 23%. Other high scores were recorded from *Dacrydium cupressinum* at 13%, and from *Halocarpus* at 7%. The presence of *Halocarpus* here could also provide further evidence of a low-growing swamp or bog vegetation in the area prior to the Taupo eruption.

The presence of *Gleichenia* and *Halocarpus* in significant numbers provides evidence that at least some swamp vegetation existed on the river flats prior to the Taupo eruption. The sample taken was also a peat, rather than a palaeosol and this evidence for the presence of a peat swamp conflicts with the view expressed by Horrocks and Ogden (1998b) that prior to the eruption the Erua Swamp was probably a dryland vegetation type of *Nothofagus* and Phyllocladus forest on river flats.

The composition of the tree pollen suggests a mixed conifer hardwood association within the region, possibly dominated by beech with smaller amounts of *Dacrydium cupressinum* and other podocarps.

Site 14b: Erua Road - palaeosol (Western group, 730 m a.s.l.)
This sample was taken only 500 m along Erua Road from the previous site. It is noticeably less varied with only 11 scoring taxa in contrast to the 21 in the peat sample. Some of these are conspicuous by their absence as no *Gleichenia* spores were recorded, and the overall count of pteridophyte spores was reduced from 33% to 13%.

Tree pollen comprise 79% of the count with *Nothofagus fusca*- type the most abundant at 36%, and smaller amounts of a variety of podocarps. The lack of *Phyllocladus* pollen, however, is at variance with Horrocks and Ogden (1998b), who suggest a dryland forest association of *Nothofagus* and *Phyllocladus* on the river flats.

The implication from the data obtained in this survey is that this was a dryland site with a closed forest canopy, as indicated by a very small representation from small trees and shrubs. This is further supported by the change in score of *Dacrydium cupressinum* from 13% of the peat sample to only 5% of the palaeosol. The more open mire or bog environment could be expected to receive more pollen from such a widely dispersed and over represented species (Macphail & McQueen 1983).

Site 15: Whakapapaiti Bridge (Western group, 860 m a.s.l.)
This site is dominated by tree pollen which comprises 89% of the pollen sum. *Nothofagus fusca*- type is the most abundant taxon representing 63% of the total, while *N. menziesii* represents a further 16%. Taken together, beech then represents 79% of the site score.

The vegetation assemblage is consistent with a montane forest of virtually pure beech. Small amounts of various podocarp pollens were recorded, the most frequent being 4% of *Dacrydium cupressinum*, but small trees and shrubs are almost completely unrepresented.

Site 16: Lahar Mounds (Western group, 960 m a.s.l.)
This site is dominated by tree pollen which comprises 89% of the total. Although beech pollen is responsible for 75% of the total there is a higher proportion of *N. menziesii* at 26% and *N. fusca*- type at 49%. This reflects a mixed beech assemblage with only small contributions from various podocarp species.

Site 17: Whakapapa Road (Western group, 1015 m a.s.l.)
The vegetation assemblage here appears to be a high altitude mixed beech forest, dominated by *N. menziesii* (49%) with substantial *N. fusca*- type (25%). Tree pollen is responsible for 87% of the total pollen count, with virtually no representation from small trees and shrubs, and few pteridophytes (7%). Podocarpaceae pollen contributes 12% of the pollen sum.

Site 18: Skotel, Whakapapa Village (Western group, 1140 m a.s.l.)
The pollen count at this site indicates a high altitude forest with tree pollen

representing 93% of the pollen sum. *N. menziesii* (22%) and *N. fusca*-type (57%) appear to be the major components with some *Dacrydium cupressinum* and very small amounts of other podocarp pollen.

Site 19: West Waiouru (Southern group, 800 m a.s.l.)
Data from this site are regarded as potentially unreliable with 54% unidentified, 8% of *Lycopodium* marker spores, and a higher pteridophyte count (21%) than any other identified taxon. The high soil pH of 6.3 may indicate a poor preservation environment as Dimbleby (1957), in working on soil pH as it relates to the preservation of pollen, has concluded that soils whose pH is above 6 are virtually useless for pollen analysis.

Site 20: Waitangi Stream (Southern group, 720 m a.s.l.)
As in the case of the previous site, the data here are also potentially unreliable with 57% unidentified, and a higher pteridophyte count (18%) than any other identified taxon. The pH at 6.3 is above the limit at which soils usually provide useful pollen for analysis.

Site 21: Waihohonu Stream (Eastern group, 900 m a.s.l.)
The site data are dominated by tree pollen (90%) with very small amounts of pteridophytes and virtually no under story species. Both species of beech are well represented with slightly higher numbers of *N. menziesii* (45%) over *N. fusca*- type (38%). This may well indicate a high altitude forest of almost pure beech.

Site 22: South Waiouru (Southern group, 800 m a.s.l.)
The pH of 6.4 at this site is above the limit at which soils generally provide useful pollen for analysis. Preservation here has been very poor with counts of unidentified grains at 39% and marker spores at 8% of the total. There is a high count of both monolete and trilete pteridophyte spores (47% in total) and the site is potentially unreliable.

Site 23: Bates' Farm (Southern group, 730 m a.s.l.)
Data from this site are also potentially unreliable. The pH is high at 6.4 and

there has been considerable deterioration in the pollens and spores found in the sample. Many grains are degraded and fragmented, and the unidentified count is high at 34%. The site is not particularly abundant with *Lycopodium* marker spores at 8% of the total. The pteridophyte count is also high at 34%.

Site 24: Upper Karioi Forest (Eastern group, 1180 m a.s.l.)
The high pH of this site (6.2) is surprising in view of the reasonable state of preservation and abundance of the pollens and spores in the sample. The high altitude may mean that the colder temperatures and increased precipitation have resulted in an improved preservation environment by limiting biological activity in the palaeosol.

The vegetation assemblage is dominated by tree pollen (86%), particularly beech, with *N. fusca*- type (45%) and *N. menziesii* (36%) both present. Almost all other groups are very reduced in frequency, and the vegetation assemblage appears to be a high altitude stand of beech forest.

Site 25: Lower Karioi Forest (Eastern group, 920 m a.s.l.)
The pH value of 5.9 is slightly lower than the previous sample, but the preservation of pollens and spores does not appear to have been as good. The high count of *Lycopodium* marker spores in particular makes this a potentially unreliable site. This is reinforced by consideration of the degraded appearance of the grains and the marginally high unidentified count.

Site 26: Burma Road (Northern group, 440 m a.s.l.)
Preservation at this site was poor with almost all pollen and spores damaged in some way. The site lies within the FDI zone and the highest scoring group was trilete fern spores which made 61% of the pollen sum. The unidentified count was relatively low at 4%, and *Lycopodium* marker spores at 4% indicate that the site was reasonably abundant in pollens and spores. However, the high count of pteridophyte spores at 83% of the total is sufficient reason to regard this site as being potentially unreliable.

Site 27: Hautu Road (Northern group, 480 m a.s.l.)
This site is regarded as potentially unreliable with 12% unidentified, 18% of *Lycopodium* marker spores, and a very high pteridophyte count of 62% of the pollen sum. The sample has a soil pH of 6.1 and lies within the FDI zone.

Site 28: Te Ponanga Saddle Road (Northern group, 580 m a.s.l.)
Although this was a particularly rich and reasonably well preserved sample with no *Lycopodium* marker spores or unidentified grains counted, it is potentially unreliable in view of the predominance of trilete fern spores. It is possible, however, that it may represent an area where ferns were naturally abundant. The site lies within the FDI zone.

Site 29: Otukou Quarry (Northern group, 610 m a.s.l.)
This site is potentially unreliable in view of the high counts of unidentified pollens and spores (13%) as well as a high count of *Lycopodium* marker spores (13%). The soil pH value is 6.2, and the site lies within the FDI zone.

Site 30: Mangaparuparu Stream (Northern group, 660 m a.s.l.)
This site lies within the FDI zone and has a pH value of 6.1. It is potentially unreliable in that it has a high count (12%) of unidentified pollens and spores, as well as a high count (53%) of pteridophyte spores.

Site 31: Mangahouhounui Stream (Northern group, 580 m a.s.l.)
There is a high count of pteridophyte spores at this site, comprising 57% of the pollen sum, which makes the site data potentially unreliable. The site lies inside the FDI zone.

Site 32: Papakai (Northern group, 680 m a.s.l.)
The vegetation assemblage at this site is dominated by tree pollen which accounts for 76% of the total pollen sum. *N. fusca*-type is the single highest scoring taxon with 42%, and *N. menziesii* is slightly less well represented with 29% of the pollen sum. The assemblage includes 20% of pteridophytes, but small trees and shrubs do not feature at all. The dominance of both species of *Nothofagus* suggests a closed canopy pure beech forest, with some

ferns.

Site 33: North National Park (Western group, 780 m a.s.l.)
The high pteridophyte count of 49% of the pollen sum makes this a potentially unreliable site. However, the abundance of pollen and spores in the sample, together with an acceptable level of unidentified grains suggests that this may represent an assemblage where ferns are naturally plentiful. The tree pollen component is dominated by *Dacrydium cupressinum* (22%) with smaller amounts of other Podocarpaceae pollen and *Nothofagus*. This could be interpreted to suggest a mixed conifer hardwood association of dense bush in which ferns might well be plentiful, particularly when the high count of Hymenophyllaceae spores (17%) is considered.

Site 34: North Waiouru (Eastern group, 880 m a.s.l.)
Tree pollen accounts for 58% of the pollen sum at this site with 10% *D. cupressinum*, 12% *N. fusca*-type, and 15% *N. menziesii*. Other podocarp species are also represented here, although the general deterioration of pollen and spores at this site means that they are not all identified to species level. There is a small contribution of 6% from small trees and shrubs and 24% from ferns and fern allies. The data is consistent with a mixed conifer hardwood forest association.

Site 35: Silica Springs Track (Western group, 1240 m a.s.l.)
This was the highest altitude site sampled on the western side of the volcanoes. The sample is dominated by tree pollen (89%) with *Phyllocladus* (20%), and *N. fusca*-type (30%) the major components. There are smaller, but significant amounts of *N. menziesii* and *D. cupressinum* (12% each) with small amounts of other podocarps. Small trees and shrubs form a very minor part of the assemblage (2%), with ferns and fern allies comprising 7% of the total. The vegetation assemblage appears to be a mixed high altitude association of beech and *Phyllocladus* forest with some pteridophytes.

Site 36: Umukarikari Track (Eastern group, 640 m a.s.l.)
The sample is dominated by tree pollen which comprises 79% of the total sum. The major components are *N. menziesii* (41%) and *N. fusca*-type (26%) with

10% *D. cupressinum.* The almost complete lack of any small tree and shrub representation suggests a beech forest with some pteridophyte undergrowth as ferns and fern allies contribute 11% of the pollen sum.

Site 37: Kaimanawa Road (Eastern group, 640 m a.s.l.)
This site is potentially unreliable as the sample is dominated by pteridophyte spores which comprise 77% of the total count. The site is within the FDI zone.

Site 38: Mangatawai Stream (Eastern group, 860 m a.s.l.)
The data from this site comprise 90% tree pollen and are dominated by *N. fusca*-type which represents 62% of the pollen sum. *N. menziesii* accounts for 19% of the total, with small amounts also from a variety of podocarps. Once again, the almost complete lack of any small tree and shrub representation suggests a beech forest. The pteridophyte count is also very low at only 3% of the total.

Site 39: East National Park (Western group, 845 m a.s.l.)
Although the pH value of the sample is slightly high at 6.1, the sample appears to have been well preserved since the counts of both *Lycopodium* marker spores and unidentified pollens and spores are well within the desirable limits. Tree pollen accounts for 86% of the total, with *N.fusca*-type the most abundant group comprising 50% of the pollen sum. *N. menziesii* accounts for 28%, and there is a small podocarp contribution. No pollen was recorded from small tree and shrub species, while pteridophyte spores account for 11% of the total. The data suggest a beech forest with some fern and fern allies present.

Site 40: Wairehu Canal (Northern group, 610 m a.s.l.)
Although the counts of unidentified pollen and spores as well as *Lycopodium* marker spores are both only marginally acceptable, the pteridophyte count of 59%, as the single highest scoring taxon, is sufficient reason to regard this site as potentially unreliable. The site also lies within the FDI zone and has pH value of 6.3.

Site 41: Makiokio Stream (Southern group, 810 m a.s.l.)
This site is also potentially unreliable with unacceptably high counts of unidentified pollens and spores (25%), *Lycopodium* marker spores (11%), and pteridophyte spores (29%). The sample has a pH value of 6.5.

4.13 Vegetation trends within the Tongariro region

"Quaternary pollen analysts have long had two complementary roles. The first is the reconstruction of past vegetation using pollen and spores preserved in sediment and unconsolidated sediments ranging from calcareous loess to peat. The second is the ecologic interpretation of palaeo vegetation in terms of past environments, usually climate." (Macphail and McQueen 1983)

A major difficulty in reconstructing vegetation assemblages of the past is the problem of relating the relative values of pollen and spores obtained in peat and palaeosols to the relative proportions of the plants which originally produced them. Modern pollen rain studies in New Zealand show that the pollen representation at sampling sites is not in the order of proportion of the source species in the vegetation (Pocknall 1982). The mode of pollination is one of the main contributing factors here, as the canopy tree species tend to be anemophilous, and therefore produce large quantities of well dispersed pollen. Pollen from most New Zealand trees is therefore usually well to over-represented in pollen records.

i) Tree pollen (Fig. 3.87)

At all the sampled sites where the data were considered to be reliable the pollen sum was heavily dominated with tree pollen between 54% and 93% of the total, suggesting the area was densely forested prior to the Taupo eruption. The regionally predominant groups are *Nothofagus,* and conifers, as represented by the Podocarpaceae (Figures 3.88 and 3.89).

Sites on both the western and eastern sides of the Tongariro Volcanic Centre are dominated by tree pollen even at the highest altitudes sampled, suggesting that the tree line was above these sites. The highest sites sampled in this study were Site 6 (Upper Tukino Road) at 1280 m altitude on the east flank of Mt. Ruapehu, as well as Site 11 (Pukeonake) at 1225 m and Site 35 (Silica Springs Track) at 1240 m altitude in the west. These sites are all below the current tree line, and represent the highest suitable exposures of the Taupo Tephra found in this study. Horrocks and Ogden (1994) in their study of the tree line on Mt. Hauhungatahi clearly indicate that at no time in the Holocene did forest extend to altitudes higher than those at which tree growth is climatically possible in the area at present.

ii) Beech pollen (Fig. 3.88)

The majority of reliable sites were dominated by *Nothofagus* pollen, with the subsequent interpretation that the pre-Taupo forests were predominantly beech. This is consistent with the view expressed by Wardle (1984) that *Nothofagus* forms a major element in most New Zealand forests and is particularly prominent in the montane regions and in the south.

Wardle (1984) noted certain ecological characteristics which are shared by the various *Nothofagus* species in that they almost always occur as elements of rain-forest, but they are usually better able to grow on harsh sites than most other rain-forest trees. The *Nothofagus* species tend therefore, to increase along the environmental gradients which lead away from the moist, mild, fertile optimum for growth, often forming extensive, relatively uniform forests in montane regions, while giving way at lower altitudes to the more competitive hardwoods and softwoods (Wardle 1984). At lower altitudes beech is limited to low fertility and poorly drained soils, dry sites such as ridge crests, or areas of recent forest disturbance (Wardle 1984). The relatively uniform beech forest structure identified in this study is a possible explanation for the lack of small tree and shrub representative pollen at most sites.

The frequencies of *Nothofagus* pollen recorded at many sites in this study suggest that there may have been high altitude beech stands forming the tree line in many parts of the area. Counts in excess of 70% are recorded at all sites in the sub alpine zone in the west, and at all but one site in the east. This certainly supports the view of Steel (1989) that *Nothofagus* forest, specifically *Nothofagus solandri,* was the dominant vegetation in the west Ruapehu region 2000 years ago. Horrocks and Ogden (1998b) also obtained very high *Nothofagus fusca*-type values (up to 48%) from the Erua swamp and suggest the presence of extensive regional beech forests.

At lower altitudes in the montane zone beech is relatively less well represented in the west, falling to below 30% of the pollen sum at five sites, but only at one site in the east. The two sites in the north both contain significant quantities of beech as it is in excess of 50% of the pollen sum.

iii) Conifer distribution (Fig. 3.89)

The bulk of Podocarpaceae pollen was found at the western sites with four sites recording counts in excess of 40%. Three of these sites Site 9 (Okupata Intake Road), Site 10 (Okupata Drop Shaft), and Site 2 (Whakapapa Intake Road), were dominated by *D. cupressinum* and are within 10 km of each other. Site 10 and Site 2 are both of peat samples which may reflect a more regional pollen rain. The fourth site is Site 35 (Silica Springs Track) at 1240 m altitude, but here the count was dominated by *Phyllocladus* at 20% of the pollen sum.

Conifer pollen is less well represented in the north and east at *c.* 10% of the pollen sum at all but two sites in the subalpine zone.

iv) Beech and conifer pollen comparison (Fig. 3.93)

The forests of the region appear to have been dominated by a mixture of these two groups, with *Nothofagus* forest generally more prominent to the east, and the Podocarpaceae forming a rather larger component in the west. In the north and east *Nothofagus* is the dominant taxon at all sampled sites, while in the west Podocarpaceae pollen dominates at six of the 14 sites. These are all within the montane zone, with the exception of Site 35 (Silica Springs Track). This suggests that the montane forests of the west were mainly of mixed podocarps, with beech less important in the forest assemblage than it was in the north and east.

v) *Nothofagus fusca*-type (Fig. 3.91)

The fuscospora group occurred at all sampled sites and was frequently present in considerable quantities. It was especially well represented in the eastern group where it exceeded 60% of the pollen sum at three sites. This is consistent with pollen analysis by Rogers and McGlone (1989) from the northern Ruahine Ranges, where the vegetation immediately prior to the Taupo eruption was dominated by *N. fusca*-type at 65% of the pollen sum.

vi) *N. menziesii* (Fig. 3.92)

Silver beech was also found at all sampled sites in considerable quantities, although never at more than 50% of the total. It appeared to be more consistently distributed in the north and east while it was generally less abundant at lower altitudes in the west. The Tongariro area is towards the north of the latitudinal range of this species and Wardle (1984) indicates that here silver beech is generally restricted towards montane and subalpine forests as a component of the wetter beech forests near and to the west of the main axial ranges.

vii) *Dacrydium cupressinum* (Fig. 3.94)

Rimu also occurred in all sampled sites although it appeared to be most abundant at the lower altitudes in the west. It was present in very small quantities (<3% of the pollen sum) in the north and never exceeded 10% at any site in the east. In the west the greatest frequency was 24% in the peat sample from Site 10 (Okupata Drop Shaft). Macphail and McQueen (1983) consider this species to be well represented as it is easily dispersed by wind, and this may explain a surprisingly high count of 12% of the pollen sum in the lower alpine zone at Site 35 in the west.

viii) *Libocedrus* (Fig. 3.95)

Although *Libocedrus* pollen occurred at several sites in the north and east it was in minute quantities. The apparent distribution is in the west between 600-900 m altitude but even here it was not a particularly well represented species with a maximum frequency of 16% of the pollen sum in the peat sample from Site 2 (Whakapapa Intake Road).

ix) Small trees and shrub species

Most of the broad-leaved angiosperms which compose this group are entomophilous and therefore characterized by production of only small amounts of pollen. Representation from this group was very low at almost all sites. A comparison of the relative proportions of beech and conifer pollen (Figure 3.90) indicates that the northern and eastern sites tend to have higher relative values of beech with a corresponding decrease in the sum of conifer pollen. These sites also have very small percentage values of small tree and shrub pollen (Table 3.47), suggesting that the forests to the east and north of the area were relatively uniform in their composition and dominated by beech. The western forests have slightly lower relative values of beech pollen (Figure 3.90) with a corresponding increase in the pollen component from conifers as well as from small trees and shrubs (Table 3.47). This suggests a more complex and species rich structure in the forests to the west, perhaps one which was similar in composition to the buried forest at Pureora (Clarkson *et al* 1988). This is particularly well illustrated at Sites 9 (Okupata Road) and 10 Okupata Drop Shaft), the two low montane sites in the west (Table 3.48). These are the only sites where the relative values of small tree and shrub pollen exceeds 10% of the pollen sum.

As a group, small tree and shrub pollen is more frequent in the peat samples than in the palaeosols (Tables 3.47 and 3.48). This is probably a reflection of the more open nature of peat sites and a higher proportion of regional pollen rain in the samples. The group is also better represented at lower altitude sites and in those forests where beech is not the dominating taxon. The relative absence of pollen from this group could be explained in that it may actually reflect a physical absence of small trees and shrubs in the Tongariro Volcanic Centre prior to the eruption. However, the macrofossil evidence from the buried forest at Pureora (Clarkson *et al* 1988) indicates a wide range of such understorey plants. The under representation is therefore more likely to be due to the poor pollen dispersal of these species (McGlone and Wilson 1996) as well as to the lack of regional pollen under a closed canopy (McGlone and Moar 1997). This further supported by Randall (1990) who found that entomophilous understorey species were poorly represented even where they formed a major component of the vegetation at the site. Elliott (1999) in a study of modern pollen rain in Northland, has concluded that angiosperm species in the New Zealand flora are extremely under-represented, and that this is major problem for pollen analyses.

Within the New Zealand flora the majority of tree species have very wide environmental tolerances (Macphail and McQueen 1983). This would appear to be particularly true within the limits of this study for tree species, with beech in particular being widely represented within the Tongariro Volcanic Centre. Pollen from the Podocarpaceae is also well represented within the area. The taller podocarps, in particular, are also very long-lived and will influence forest composition over considerable periods of time (Macphail and McQueen 1983). The presence of these pollens in the samples taken during this study is a function of the actual presence of these trees in the area, together with their ability to disperse pollen over large distances, and the resistance of these pollens to degradation once deposited in peats or palaeosols.

4.14 The post-Taupo forests

"The degree and nature of vegetation disturbance above the Taupo Tephra varied according to the thickness of ashfall, local topographic features and probably the vigour of the forest." (Wilmshurst and McGlone 1996).

The final stage of the Taupo eruption ejected *c.* 30 cubic kilometres of ignimbrite over an area with a radius of 70-90 km, centred on Lake Taupo. Wilson and Walker (1985) suggested that the ignimbrite flow was ejected over 6-7 minutes as an extremely hot pyroclastic cloud which travelled at very high velocities over the landscape. Forests which lay in its path would have been completely annihilated, while even at the edges of the flow trees would have been seared and blasted. The full effect of the damage to forests in the area is summarised by Wilmshurst and McGlone (1996) using data obtained from three sites which were covered by the ignimbrite flow.

The first of these sites is Ongarue which represents the dominant montane podocarp/hardwood forests of the west Taupo region. The pollen record shows a decline of tall podocarp tree pollen from 85% to 16% of the pollen sum combined with a decline in *Fuscospora* pollen. There is an increase in the pollen of seral taxa, herbs, and grasses, while *Pteridium* increases from 0% below to 60% of the dryland pollen sum above the Taupo Tephra.

The second and third sites examined by Wilmshurst and McGlone (1996) are at Wairehu and Three Kings which represent beech dominated forests. The pollen record at these sites shows a decline in *Fuscospora* pollen as well as the Podocarpaceae forest component. As at the previous site, there is an increase in the pollen of seral taxa, herbs, and grasses, while *Pteridium* increases from 0% below to 10% of the dryland pollen sum above the Taupo Tephra.

The approximate period for recovery at these three sites is estimated by the authors to have been 120 radiocarbon years. Regeneration and revegetation in the area devastated by the Taupo Tephra proceeded rapidly after the eruption, and in most cases Wilmshurst and McGlone (1996) consider that the post-eruption vegetation which became established was generally similar in composition to the pre-eruption forests. There are some exceptions, however, as one effect of the Taupo eruption has been to retard the expansion of *Nothofagus* forest on the Volcanic Plateau (McGlone and Topping 1977).

The Three Kings area is also an exception to the general recovery (Rogers and McGlone 1989), as there was no apparent substantial recovery in *Nothofagus* cover at this site in the 800 years before extensive deforestation of the region by humans. While there was an expansion of conifer-broadleaved forest at lower altitudes, the Three Kings site regenerated to subalpine shrubland. Clarkson *et al* (1986) also note that both beech and *Libocedrus* became rare in the west Taupo mires of the Pureora area after the eruption, while the previously unrepresented tawa (*Beilschmiedia tawa*) became a more significant component of the vegetation.

The macrofossils recovered from the buried forest at Pureora provide evidence of significant differences with the composition of the present-day forest at similar altitude and on similar terrain in the adjoining Pikiariki Ecological Area (Clarkson *et al* 1988). Although both forest types were or are tall podocarp forests, the buried forest was dominated by *Dacrydium cupressinum* and *Phyllocladus,* while matai (*Prumnopitys taxifolia*) and *Dacrydium cupressinum* are dominant at Pikiariki. Other present day species which were not recorded from the buried forest include tawa, kamahi (*Weinmannia racemosa*), mahoe (*Melicytus ramiflorus* ssp. *ramiflorus*) and the fern *Asplenium bulbiferum.*

South of Mt Ruapehu, Horrocks and Ogden (1998a) conclude from the pollen record from Gibson's Swamp that the Ohakune-Horopito area was sheltered from the pyroclastic flow and the worst effects of the Taupo eruption. *Nothofagus fusca*-type pollen does not show an immediate post-Taupo decrease in the area and the results also indicate that the local forest was not subjected to Polynesian burning, remaining unmodified until European milling commenced *c.* AD 1850. Some changes are, however, evident in the forest composition at Hauhungatahi. Horrocks and Ogden (1998c) consider that the Taupo eruption was a major determinant of forest composition in this area, with the rapid post-eruption expansion of *Libocedrus bidwillii* into montane and subalpine forest.

Some of the changes in forest composition since the eruption may be the result of changes in climate. McGlone and Topping (1977) suggest that conditions in the period up to the Taupo eruption from *c.* 3500 to 1800 B.P. may have been slightly wetter and perhaps milder than those of the present day. Another contributing factor may also be the changes in the drainage and nutrient status of the soils which formed on the parent material provided by the Taupo Tephra. Clarkson *et al* (1988) suggest that the ecological characteristics of the main species found in the Pureora buried forest indicate that the pre-Taupo soils were poorly drained and low in fertility when compared with present-day soils in the area.

CHAPTER 5: CONCLUSION

"Decay of pollen and spores depends, among other things, on soil type, soil pH, and climate." (Havinga 1971).

5.1 Movement of pollen and spores through pumice

The Taupo Tephra in its ignimbrite form appears to provide an effective barrier to the downward movement of pollen and spores into underlying peats or palaeosols. The pollen data obtained in this investigation is therefore pre-Taupo eruption in origin, and represents the pollen deposited immediately prior to the eruption in c.232 AD.

5.2 Environments of preservation in peats and palaeosols

Peat generally provides a good preservation environment in that it is anaerobic and acidic, but in the absence of suitable peats for pollen analysis palaeosols may preserve pollen and spores in substantial numbers. Preservation in a soil environment depends primarily on an acidic pH value, and where the pH exceeds a value of 6.0 there will be an increasing degree of damage and degradation to pollen and spores. Where there was sufficient material available for pH analysis, sites in the northern and southern groups were found to have pH values in excess of 6.0 and were not suitable for analysis. Within the southern group the elevated pH values may be from the regular inwash of lime carried by rain water washing over the outcropping sedimentary rocks in the area, although there may also be a recent influence from farming practices such as liming pasture.

Sites from the northern group inside the fines-depleted ignimbrite zone (the FDI zone) within approximately 24 km of the vent also tended to have higher pH values and were not suitable for analysis. The higher pH values may have developed under the very free-draining pumice deposit as a result of a more oxidising environment. Another potential cause of deterioration at these sites may have been the heat intensity of the pyroclastic flow during the eruption. As these sites are closer to the source they were potentially exposed to higher temperatures, and the resulting prolonged baking effect may have caused some damage to buried pollen and spores.

Some comparisons between peat and neighbouring palaeosol sites were possible and indicated that not only were pollen and spores in peat samples better preserved, but they also included a more regional representation of the vegetation. The palaeosol samples contained fewer taxa and were more representative of a localised pollen rain from under a closed canopy.

5.3 Assessment of the preservation status of pollen and spores

The degree of preservation within a sample could be assessed both qualitatively, by a description of the external characteristics of the grains, and quantitatively by calculating the percentage of grains too damaged for accurate identification as a percentage of the pollen sum. At those sites where there was a high percentage of unidentified grains combined with a poor state of preservation within the sample, the data was considered to be unreliable.

The percentage of *Lycopodium* marker spores within a sample could also be used to assess the preservation at a site, as where the marker spore count was high, there was an increased degree of degradation within the sample. In most samples there was usually other evidence to corroborate this assumption, such as high counts of unidentified pollen and spores.

The pollen sum in each sample included pteridophyte spores as a means of investigating the likely vegetation assemblage at the site. The prevalence of these spores within degraded samples indicates their resistance to decay and also provides an indication that active breakdown may have occurred.

Of the 42 samples taken in this investigation 17 were not sufficiently well preserved to be suitable for analysis, but the data from the remaining 25 appears to be potentially reliable and generally concurs with the findings of previous authors.

5.4 Differential degradation of pollen and spores

The possibility of differential degradation was examined when investigating site scores where active breakdown had occurred. Some tentative conclusions can be drawn in that both species of *Nothofagus* , as well as *D.*

cupressinum and *Myrsine* may be relatively resistant to decay, while pteridophyte spores appear to be very resistant to decay. Conversely, most of the Podocarpaceae appear to degrade readily in that the distinguishing features of cappa and sacci are frequently corroded beyond recognition.

5.5 The pre-Taupo eruption forests of the Tongariro Region

Although there are difficulties in interpreting the data obtained in terms of the actual representativity of various species, the sites sampled do seem to suggest a closed forest canopy at the reliable sites. This provides the opportunity to build up a mosaic of site assemblages which reflect local vegetation, and draw some regional inferences from these.

The region was heavily forested prior to the Taupo eruption and the forests appear to have been dominated by a mixture of both *Nothofagus* species and various members of the Podocarpaceae, particularly *D. cupressinum.* In the montane regions relatively uniform *Nothofagus* forest was generally more prominent in the north and east, with more species rich podocarp forests better represented in the west. Recovery from the devastation caused by the eruption is considered to have been complete within 300 years of the event when tall forests once again covered the area. The present day tussock grassland vegetation of the Desert Road, east of the Tongariro Volcanic Centre, did not exist prior to the eruption and is probably the result of uncontrolled burning by early Polynesians. Prior to the eruption this eastern area was in beech forest which was probably similar in structure and composition to the present day neighbouring beech forests in the Kaimanawa Ranges. Beech also appears to have been the dominant forest type at higher altitudes in sub alpine and lower alpine zones within the area.

The structure of forests in the area appears to have been characterized by a lack of small trees and shrubs. This is probably an apparent rather than an actual absence, as this group produces small quantities of generally poorly dispersed pollen, and distribution is further restricted beneath a closed canopy. The group is better represented in the pollen sum from the peat samples which represent more open sites.

REFERENCES

Allan, H.H. (1961): *Flora of New Zealand. Vol. 1.* Government Printer, Wellington.

Beijerinck, W. (1993): Die micropalaontologische Untersuchung aolischer Sedimente, etc. *Verh. Kon. Akad. Wet. Amst. 36,* 106-115.

Blakemore, L.C.; Searle, P.L.; Daly, B.K. (1981): *Soil Bureau Laboratory Methods. A. Methods for chemical analysis of soils.* N.Z. Soil Bureau Scientific Report 10A (revised).

Brooks, J.; Grant, P.R.; Muir, M.D.; van Gijzel, P; Shaw, G. (*eds*) (1971): *Sporopollenin.* Academic Press, London.

Brooks, J. (1971): Some chemical and geochemical studies on sporopollenin. *In* Brooks *et al (1971).*

Brookes, D.; Thomas, K.W. (1967): The distribution of pollen grains in microscope slides, Part 1, the non-randomness of the distribution. *Pollen et Spores 9,* 621-629.

Bussell, M.R. (1988): Modern pollen rain, central-western North Island, New Zealand. *New Zealand Journal of Botany, 26,* 297-315.

Christiansen, R.L. (1980): Eruption of Mt. St. Helens: volcanology. *Nature 285,* 531-33.

Clarkson, B.D., Clarkson, B.R., McGlone, M.S., (1986): Vegetation history of some west Taupo mires. *In* Veale, B., Innes, J., (Eds.): *Ecological Research in the central North Island volcanic plateau region,* pp 34-37. Proceedings of a New Zealand Forest Service workshop. Forest Research Institute, Rotorua.

Clarkson, B.R.; Patel, R.N.; Clarkson, B.D. (1988): Composition and structure of forest overwhelmed at Pureora, central North Island, New Zealand, during the Taupo eruption (c. AD 130). *Journal of the Royal Society of New Zealand Vol.18,* 417 - 436.

Clarkson, B.R.; Clarkson, B.D.; Patel, R.N. (1992): The pre-Taupo eruption (c. AD 130) forest of the Benneydale-Pureora district, central North Island, New

Zealand. *Journal of the Royal Society of New Zealand 22,* 61-76.

Cole, A.O. (1996): *A dynamical systems framework for modelling plant community organisation.* Unpublished Ph.D. thesis, Massey University, Palmerston North.

Cole, J.W.; Graham, I.J.; Hackett, W.R.; Houghton, B.F. (1986): Volcanology and petrology of Quaternary composite volcanoes of the Tongariro Volcanic Centre, Taupo Volcanic Zone. *In* I.E. Smith (*Ed.*): *The Royal Society of New Zealand bulletin 23,* 224-250.

Colinvaux, P (1993): *Ecology 2.* John Wiley and Sons, Inc. New York.

Connor, H.E.; Edgar, E. (1987): Name changes in the indigenous New Zealand flora, 1960 - 1986 and nomina nova IV, 1983 - 1986. *New Zealand Journal of Botany 25,* 115 - 170.

Cranwell, L.M. (1939): Southern beech pollens. *Records of the Auckland Institute and Museum 2,* 175-196.

Cranwell, L.M. (1940): Pollen grains of the New Zealand conifers. *New Zealand journal of science and technology 22B,* 1-17.

Cranwell, L.M. (1952): New Zealand pollen studies; The Monocotyledons. *Bulletin of the Auckland Institute and Museum 3.* Harvard University Press.

Cranwell, L.M.; von Post. L. (1936): Post-Pleistocene pollen diagrams from the Southern Hemisphere: I. New Zealand. *Geografisca Annaler 3-4,* 308-347.

Cunningham, A. (1964): Notes on carbonised wood and leaf fragments occurring in Taupo pumice in the vicinity of the Kaweka Range. *New Zealand Journal of Botany 2,* 107-119.

de Lisle, J.F. (1962): Climate and weather. *In* "Bay of Plenty Region". Chapter 4. Natural Resources Survey Part II. Government Printer, Wellington, *pp.* 45-46.

Department of Conservation - *Te Papa Atawhai* (2000): *Tongariro Parkmap* 273-04 Edition 5 1996 (Limited Revision 2000).

Dewers, F. (1936): Probleme der Flugsandbildung in Nordwestdeutschland. *Abh. Nat. Ver. Bremen, 29,* 234-366.

Dimbleby, G.W. (1957): Pollen analysis of terrestrial soils. *New Phytologist 56,* 12-28.

Dimbleby, G.W. (1961): Soil Pollen Analysis. *Journal of Soil Science, Vol.12, No. 1.*

Dimbleby, G.W. (1985): *The palynology of archaeological sites.* Academic Press, Inc. London.

Dimbleby, G.W.; Speight, M.C.D. (1969): Buried soils. *Advancement of Science 26,* 203-6.

Donoghue, S.L.; Neall, V.E.; Palmer, A.S. (1995): Stratigraphy and chronology of late Quaternary andesitic tephra deposits, Tongariro Volcanic Centre, New Zealand. *Journal of the Royal Society of New Zealand, 25,* 115-206.

Elder, N.L. (1963): Evidence of climatic change from the vegetation of the North Island. *Proceedings of the New Zealand Ecological Society 10,* 45-48.

Elliott, M.B. (1999): Modern pollen-vegetation relationships in Northland, New Zealand. *New Zealand Journal of Botany, 37,* 131-148.

Elsik, W.C. (1971): Microbiological degradation of sporopollenin. *In* Brooks *et al* (1971).

Erdtman, G. (1924): Studies in micropalaeontology IV. Peat from the Chatham Islands and Otago District. *Geologiska Foreningens Forhandl 46,* 679-681.

Erdtman, G. (1943): Pollen spectra from Swedish plant communities. Addendum: Pollen analytical soil studies in southern Lapland. *Geol. Foren. Forhandl. 65,* 37-66.

FAEGRI, K. (1971): The preservation of sporopollenin membranes under natural conditions. *In* Brooks *et al* (1971).

Faegri, K.; Iversen, J. (1975): *Textbook of pollen analysis, third revised edition.* Blackwell Scientific publications, Oxford.

Faegri, K.; Iversen, J. (1989): *Textbook of pollen analysis. 4 th edition.* John Wiley and Sons, New York.

Fisher, R.V.; Schmincke, E, H.-U. (1984): *Pyroclastic Rocks.* Springer-Verlag, Berlin.

Flenley, J.R. (1994): Pollen in Polynesia: the use of palynology to detect human activity in the Pacific islands. *In* Hather, J.G. (*ed.*) (1994): *Tropical archaeobotany: applications and new developments,* 203-214.

Foth, H.D. (1984): *Fundamentals of Soil Science (7th Ed.)* John Wiley & Sons.

Froggatt, P.C.; Lowe, D.J. (1990): A review of late Quaternary silicic and some other tephra formations from New Zealand: their stratigraphy, nomenclature, distribution, volume, and age. *New Zealand Journal of Geology and Geophysics, 33,* 89-109.

Grange, L.J. (1931): Volcanic-ash showers. *New Zealand Journal of Science and Technology 12,* 228-40.

Havinga, A.J. (1971): An experimental investigation into the decay of pollen and spores in various soil types. *In* Brooks *et al* (1971).

Horrocks, M. (1994): The forest history of M. Hauhungatahi, Tongariro National Park. Unpublished PhD thesis, The University Of Auckland, Auckland.

Horrocks, M.; Ogden, J. (1994): Modern pollen spectra and vegetation of Mt. Hauhungatahi, central North Island, New Zealand. *Journal of Biogeography 21,* 637-649.

Horrocks, M.; Ogden, J. (1998a): Fine resolution palynology of Gibson's Swamp, central North Island, New Zealand, since c. 13 000 B.P. *New Zealand Journal of Botany, 36,* 273-283.

Horrocks, M.; Ogden, J. (1998b): Fine resolution palynology of Erua Swamp, Tongariro, New Zealand, since the Taupo Tephra eruption of c. 1718 B.P. *New Zealand Journal of Botany,36,* 285-293.

Horrocks, M.; Ogden, J. (1998c): The effects of the Taupo Tephra eruption of c.1718 BP on the vegetation of Mt Hauhungatahi, central North Island, New Zealand. *Journal of Biogeography 25,* 649-660

Jacobson, G.L.; Bradshaw, R.W.H. (1981): The selection of sites for paleovegetation studies. *Quaternary Research 16,* 80 - 96.

Large, M.F.; Braggins, J.E. (1991): *Spore atlas of New Zealand ferns and fern allies.* SIR Publishing, Wellington.

Lees, C.M. (1987): Late Holocene Changes in the vegetation of western Taranaki investigated by soil palynology. Unpublished Ph. D. thesis, Massey University, Palmerston North.

McIntyre, D.J. (1963): Pollen morphology of New Zealand species of Myrtaceae. *Transactions of the Royal Society of New Zealand - Botany 2,* 83-107.

McLaren, R.G.; Cameron, K.C. (1996): *Soil Science - Sustainable production and environmental protection.* Oxford University Press, Oxford.

McGlone, M.S.; Moar, N.T. (1997): Pollen-vegetation relationships on the subantarctic Auckland Islands, New Zealand. *Review of Palaeobotany and Palynology 96,* 317-338

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

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

McGlone, M.S.; Wilson, H.D. (1996): Holocene vegetation and climate of Stewart Island. *New Zealand Journal of Botany 34,* 123-144.

McKelvey, P.J. (1963): The synecology of the West Taupo indigenous forest. *New Zealand Forest Service Bulletin 14. 127 p.*

Macphail, M.K.; McQueen, D.R. (1983): The value of New Zealand pollen and spores as indicators of cenozoic vegetation and climates. *Tuatara 26,* 37-60.

Marshall, P. (1935): Notes on some volcanic rocks of the North Island, New Zealand. *Transactions of the Royal Society of New Zealand 64,* 323-366.

Moar, N.T. (1993): *Pollen grains of New Zealand dicotyledonous plants.* Manaaki Whenua Press, Christchurch.

Molloy, L. (1988): *Soils in the New Zealand Landscape.* Mallinson Rendel in association with the New Zealand Society of Soil Science.

Moore, P.D.; Webb, J.A. (1978): *Pollen Analysis.* Hodder and Stoughton.

Nicholls, J. (1985): A descriptive overview of the central North Island volcanic upland. *In* Veale, B., Innes, J. (1985).

Ogden, J.; Horrocks, M.; Palmer, J.G.; Fordham, R.A. (1997): Structure and composition of the subalpine forest on Mount Hauhungatahi, North Island, New Zealand, during the Holocene. *The Holocene 7,1 pp* 13-23.

Palmer, J.G.; Ogden, J.; Patel, R.N. (1988): A 426-year floating tree-ring chronology from *Phyllocladus trichomanoides* buried by the Taupo eruption at Pureora, central North Island, New Zealand. *Journal of the Royal Society of New Zealand 19,* 407-415.

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

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

Pocknall, D.T. (1981b): Pollen morphology of *Phyllocladus* L.C. et A. Rich. *New Zealand Journal of Botany, 19,* 259-266

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

Pocknall, D.T. (1982): Modern pollen spectra from mountain localities, South Island, New Zealand. *New Zealand Journal of Botany, 20,* 361-371.

Poole, A.L.; Adams, N.M. (1990): *Trees and Shrubs of New Zealand. Revised ed.* DSIR Publishing, Wellington.

Randall, P.M. (1990): *Pollen dispersal across the Southern Alps, South Island, New Zealand.* Unpublished M.Sc. thesis, University of Canterbury, Christchurch.

Rogers, G.M. & McGlone, M.S. (1989): A postglacial vegetation history of the southern-central uplands of North Island, New Zealand. *Journal of the Royal Society of New Zealand, 19,* 229 - 248.

Sparks, R.J.; Melhuish, W.H.; McKee, J.W.A.; Ogden, J.; Palmer, J.G.; & Molloy, B.P.J. (1995): ^{14}C calibration in the southern hemisphere and the date of the last Taupo eruption: evidence from tree-ring sequences. *Radiocarbon, 37,* 155-163.

Steel, M.G. (1989): Mountain beech forest on Mount Ruapehu: dynamics, disturbance, and dieback. Unpublished Ph.D. thesis, University of Auckland.

Stevens, G.; McGlone, M.; McCulloch, B. (1988): *Prehistoric New Zealand.* Heinemann Reed, Auckland.

Stockmarr, J. (1971): Tablets with spores used in absolute pollen analysis. *Pollen et Spores, 13,* 615-621.

Thorarinsson, S. (1974): The terms *tephra* and *tephrachronology.* Pp.xvii-xviii *in* : Westgate, J.A.; Gold, C.M. ed. *World bibliography and index of Quaternary tephrachronology.* Edmonton, University of Alberta.

Topping, W.W. (1973): Tephrostratigraphy and chronology of late Quaternary eruptives from the Tongariro Volcanic Centre. *New Zealand journal of geology and geophysics 16,* 397-423.

Traverse, A. (1988): *Palaeopalynology.* Unwin Hyman, Wellington

von Post, L. (1916): Om skogstradpollen i sydsvenka torfmosslagerfoljder. *Geol. foren. Stockh. forh. 38,* 384 - 390.

Veale, B., Innes, J., (Eds.) (1985): *Ecological Research in the central North Island volcanic plateau region.* Proceedings of a New Zealand Forest Service workshop. Forest Research Institute, Rotorua.

Walker, G.P.L.; Wilson, C.J.N.; Froggatt, P.C. (1980): Fines-depleted ignimbrite in New Zealand: product of a turbulent pyroclastic flow? *Geology 8,* 245-249.

Wallace, R.C. (1987): *The mineralogy of the Tokomaru silt loam and the occurrence of cristobalite and tridymite in selected North Island soils.* Unpublished Ph.D. thesis, Massey University, Palmerston North.

Wardle, J. (1984): *The New Zealand beeches - Ecology, utilisation and management.* N.Z. Forest Service 1984.

Wardle, P. (1964): Facets of the distribution of forest vegetation in New Zealand. *New Zealand Journal of Botany 2,* 352-66.

Wardle, P. (1991): *Vegetation of New Zealand.* Cambridge University Press, Cambridge.

Webb, C.J.; Sykes, W.R.; Garnock-Jones, P.J. (1988): *Flora of New Zealand. Vol. IV.* Christchurch, DSIR, Botany Division.

Whitten, D.G.A; Brooks, J.R.V. (1972): *The Penguin dictionary of Geology.* Penguin Books Ltd, Australia.

Whittow, J. (1984): *Dictionary of Physical Geography.* Allen Lane.

Wilmshurst, J.M.; McGlone, M.S. (1996): Forest Disturbance in the central North Island, New Zealand, following the 1850 BP Taupo eruption. *The Holocene 6,* 399-411.

Wilson, C.J.N.; Walker, G.P.L. (1985): The Taupo eruption, New Zealand 1. General aspects. *Philosophical Transactions of the Royal Society London, 314,* 199-288.

Wilson, C.J.N. (1993): Stratigraphy, chronology, styles and dynamics of late Quaternary eruptions from Taupo volcano, New Zealand. *Philosophical Transactions of the Royal Society London, 343,* 205-306.

APPENDIX A: SOME PRE-TAUPO POLLEN AND SPORES

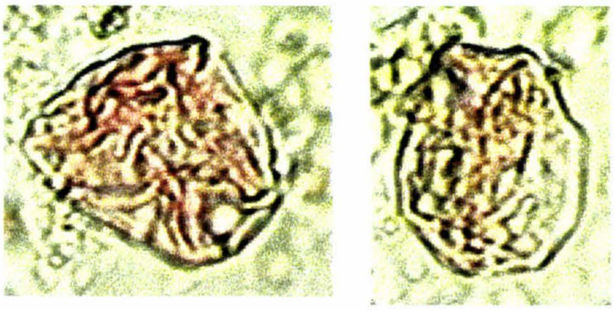
Figure 1

Halocarpus (Site 14a)

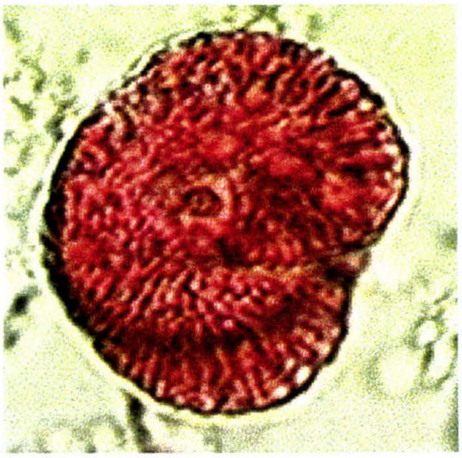
Gleichenia (Site 14a)

Epacridaceae-type tetrad (Site 14a)

Coprosma (Site 14a)



Nothofagus menziesii (Site 6)



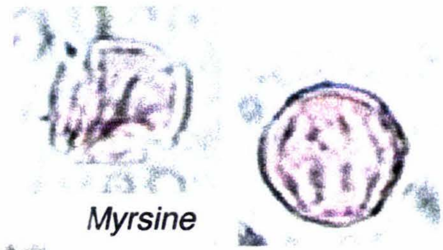
Dacrydium cupressinum (Site 6)

APPENDIX A: SOME PRE-TAUPO POLLEN AND SPORES

Figure 2: Site 10 - Okupata Drop Shaft

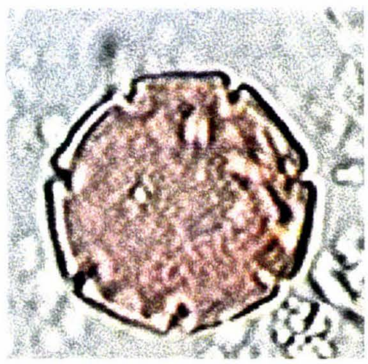
Neomyrtus- type

Elaeocarpus



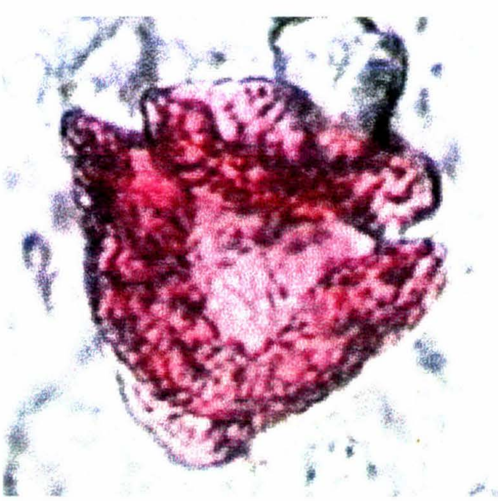
Myrsine

Leptospermum- type

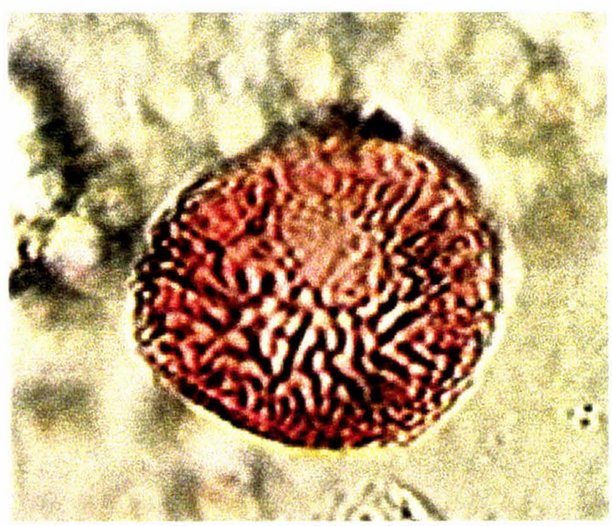


Nothofagus fusca -type

Libocedrus

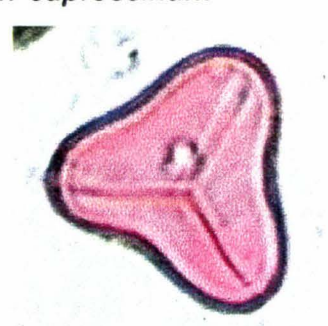


Dacrycarpus dacrydioides



Dacrydium cupressinum

Corroded trilete spore

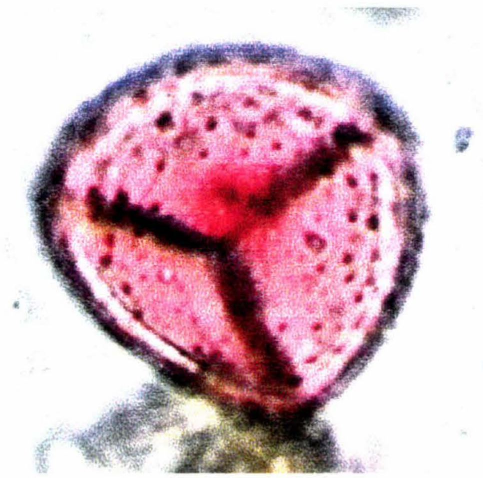


Cyathea smithii- type

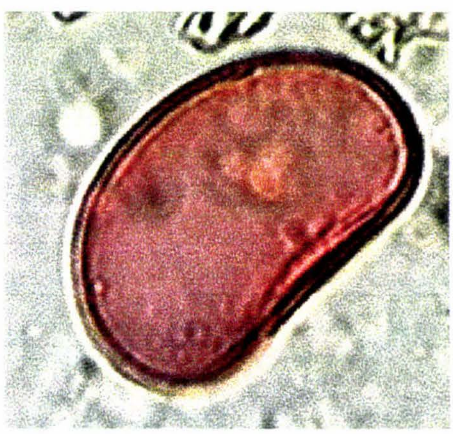
APPENDIX A: SOME PRE-TAUPO POLLEN AND SPORES

Figure 3: Site 10 - Okupata Drop Shaft

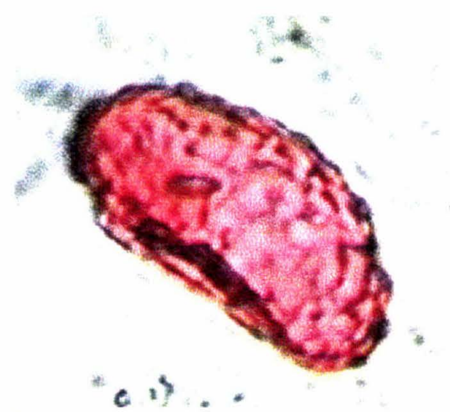
Lycopodium marker spore



Lycopodium varium



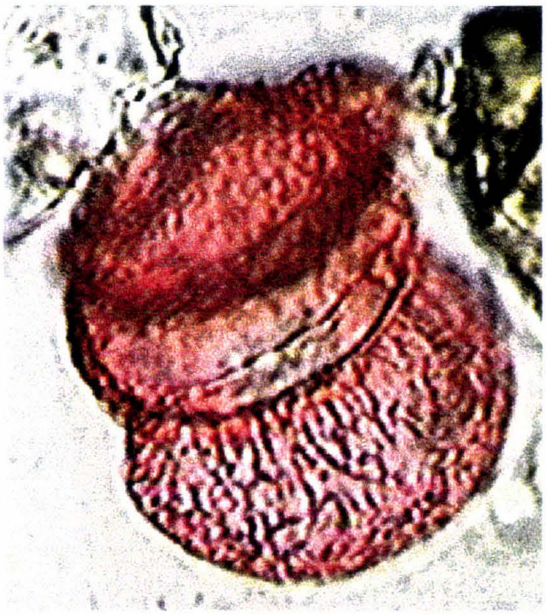
Monolete fern spore



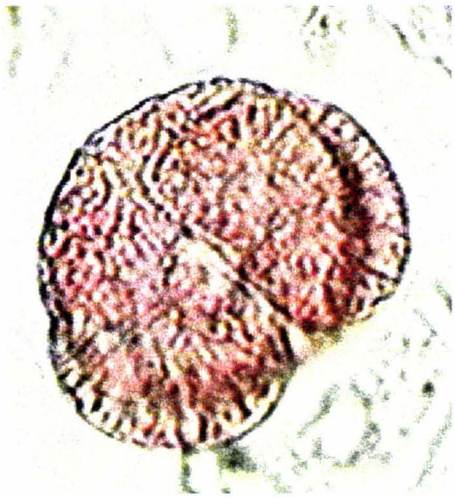
Histiopteris

APPENDIX A: SOME PRE-TAUPO POLLEN AND SPORES

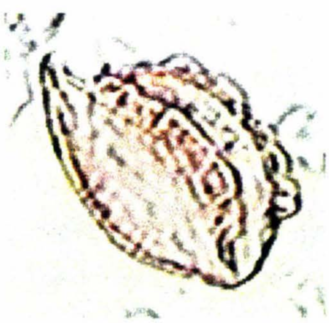
Figure 4:



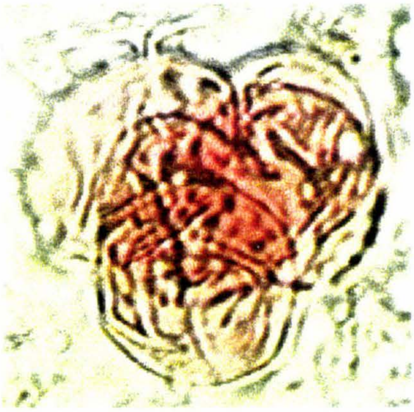
Podocarpus hallii (Site 35)



Halocarpus (Site 35)



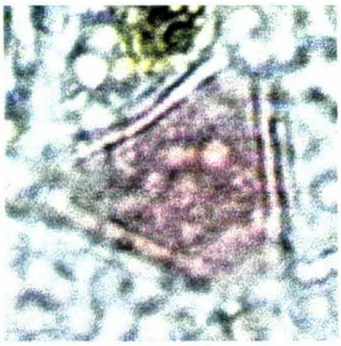
Phyllocladus (Site 35)



Tetrad pollen (Site 18:)

Myrtaceae pollen (Site 1)

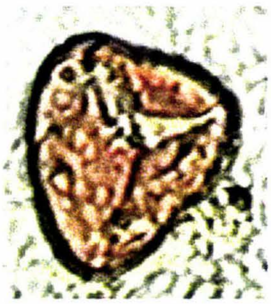
Coprosma (Site 9)



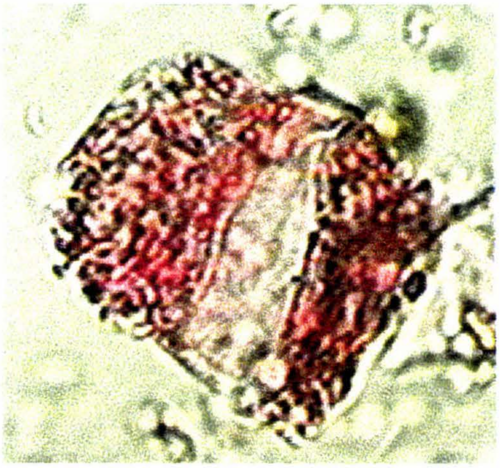
Site 11: *Knightia excelsa*

APPENDIX A: EXAMPLES OF BADLY PRESERVED POLLEN AND SPORES
Figure 5

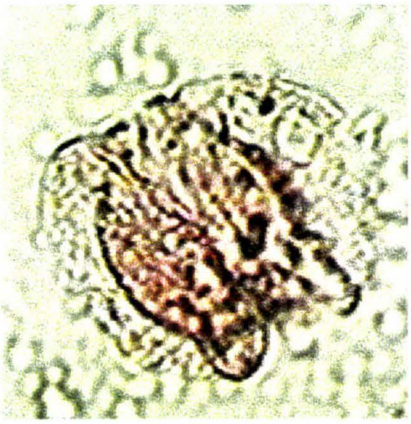
Site 1: superficial corrosion on trilete fern spore



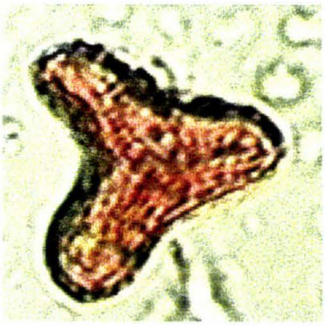
Site 41: split and torn trilete fern spore

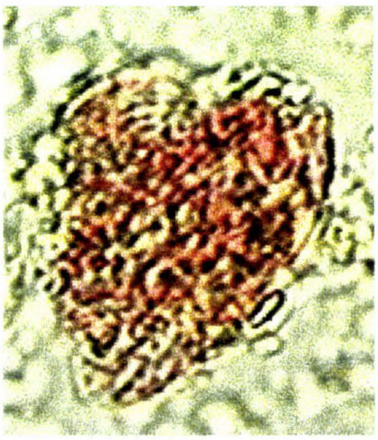


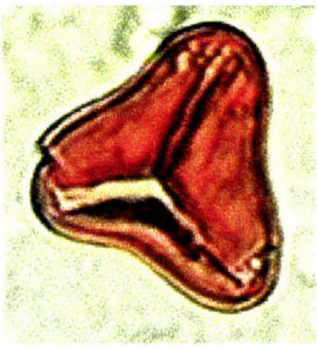
Site 6: degraded podocarp pollen



Site 41: degraded podocarp pollen

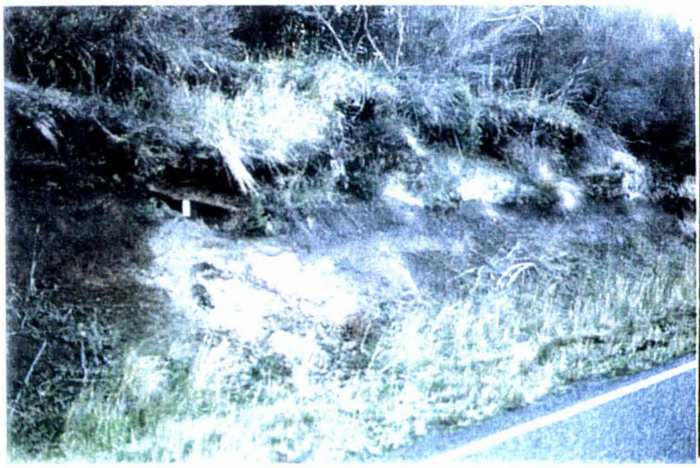






Site 4: corroded and fragmented trilete fern spores

APPENDIX B: SITE LOCATION PHOTOGRAPHS



Site 1: West Ketetahi

Site 2: Whakapapa Intake

Site 3: Whakapapanui Bridge

Site 4: McDonnell's Redoubt Road

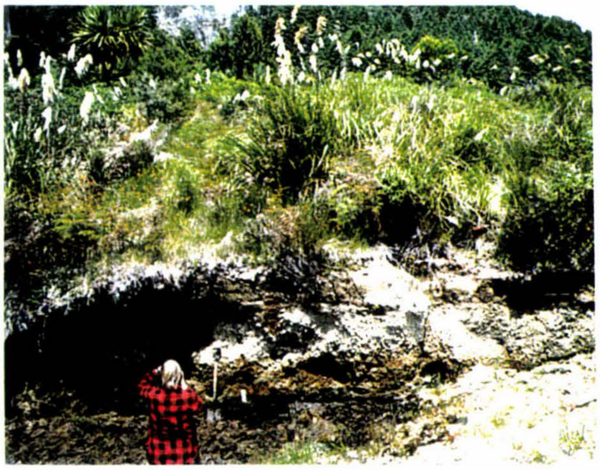
Site 5: Desert Road (tank crossing)

Site 6: Upper Tukino Road

Site 7: Lower Tukino Road

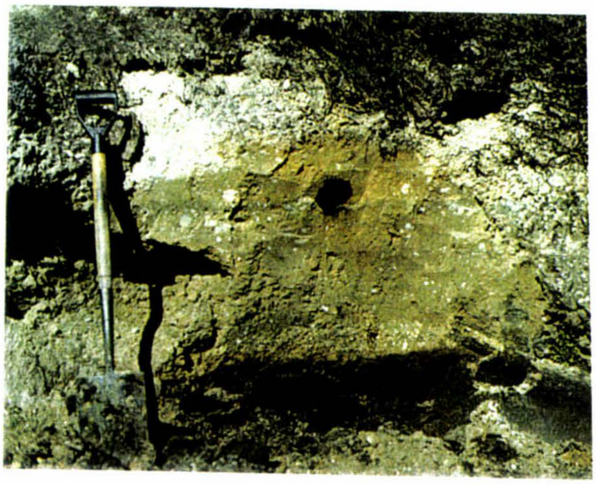
Site 8: Waipakahi Road

Site 9: Okupata Intake Road



Site 10: Okupata Drop Shaft

Site 11: Pukeonake



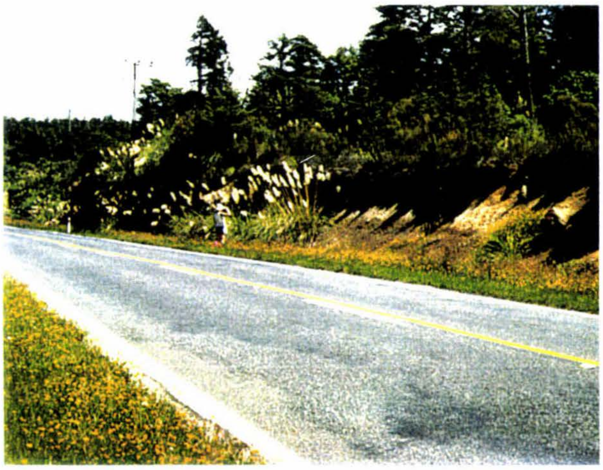
Site 12: Mangatepopo Valley

APPENDIX B: SITE LOCATION PHOTOGRAPHS

Site 13: Poutu Canal

Site 14a: Erua Road (peat)

Site 14b: Erua Road (palaeosol



Site 15: Whakapapaiti Bridge

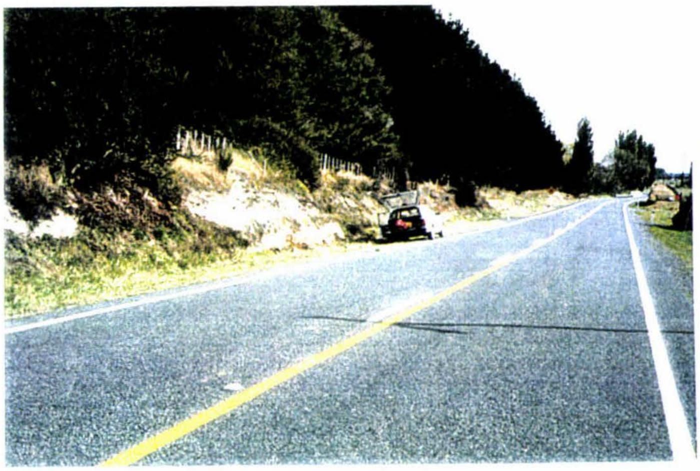
Site 16: Lahar Mounds

Site 17: Whakapapa Road

APPENDIX B: SITE LOCATION PHOTOGRAPHS

Site 18: Skotel Building, Whakapapa Village

Site 19: West Waiouru



Site 20: Waitangi Stream

Site 21: Waihohonu Stream

Site 22: South Waiouru

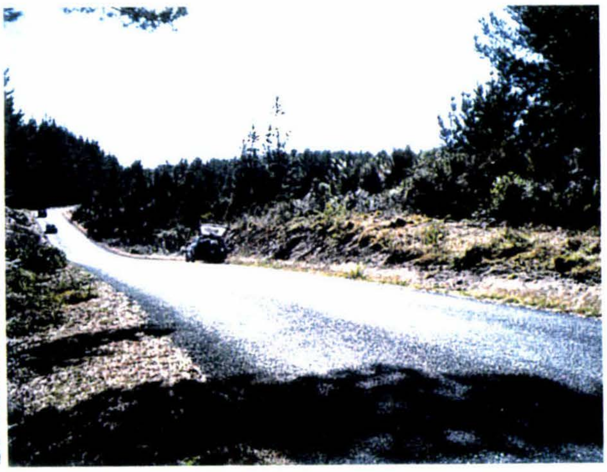
Site 23: Bates' Farm

APPENDIX B: SITE LOCATION PHOTOGRAPHS

Site 24: Upper Karioi Forest

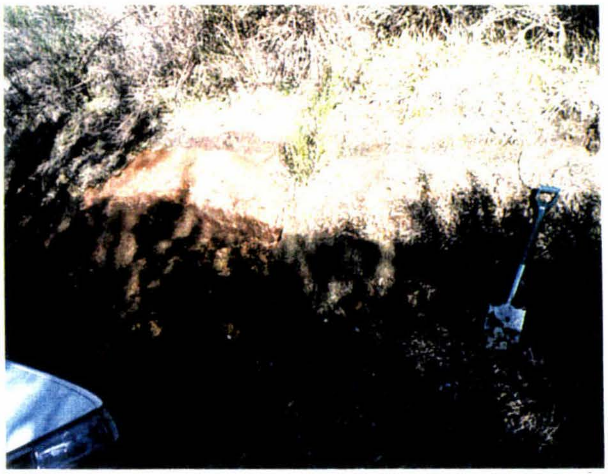
Site 25: Lower Karioi Forest

Site 26: Burma Road



Site 27: Hautu Road

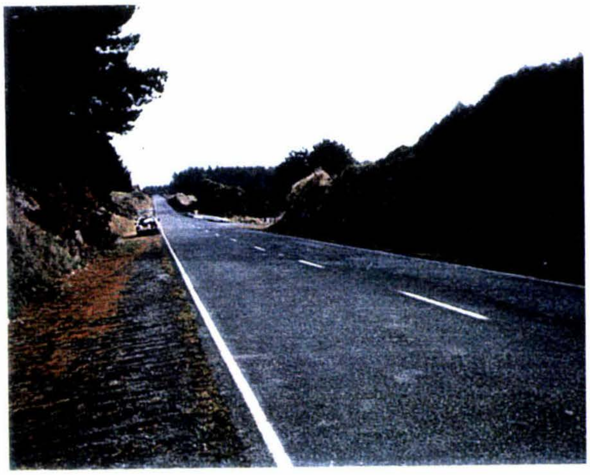
Site 28: Te Ponanga Saddle Road



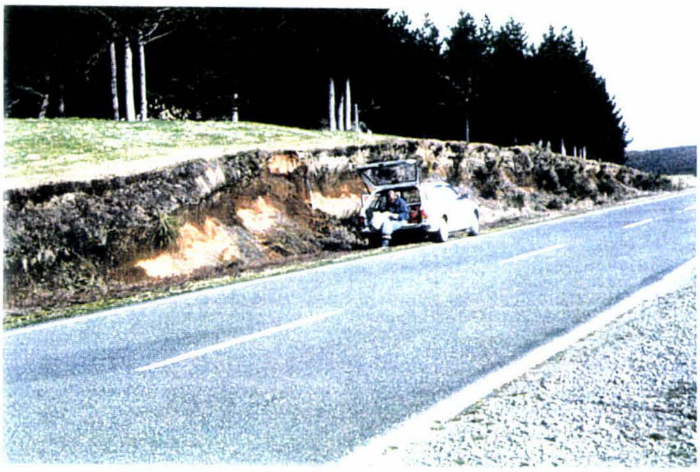
Site 29: Otukou Quarry

APPENDIX B: SITE LOCATION PHOTOGRAPHS

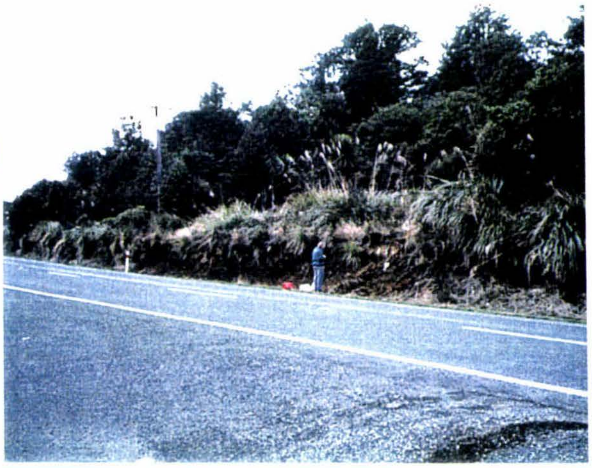
Site 30: Mangaparuparu Stream



Site 31: Mangahouhounui Stream



Site 32: Papakai

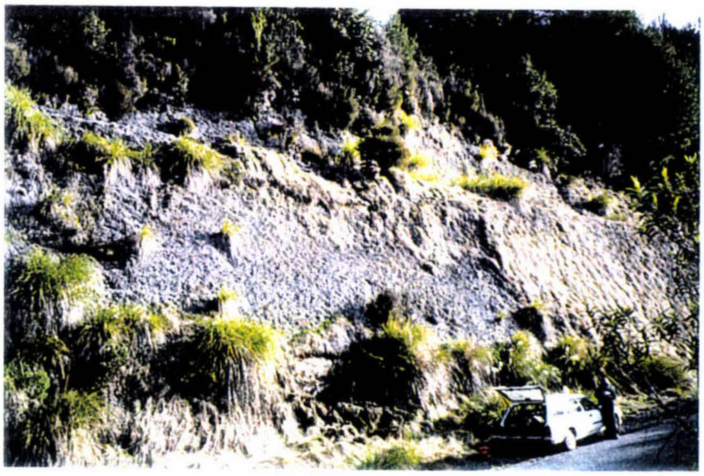


Site 33: North National Park

Site 34: North Waiouru

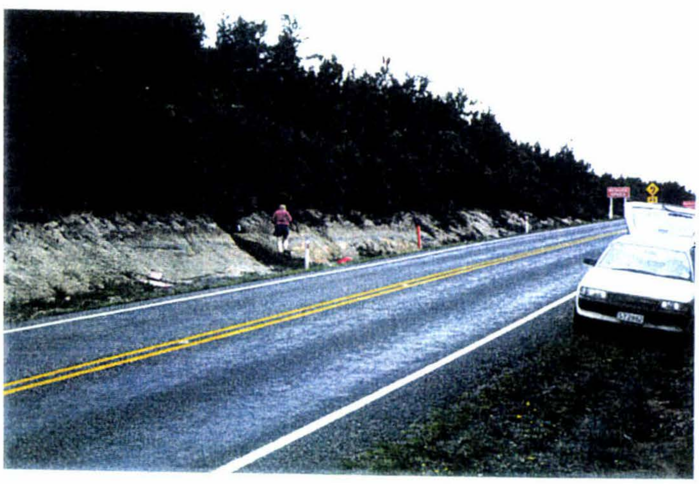
Site 35: Silica Springs Track

APPENDIX B: SITE LOCATION PHOTOGRAPHS



Site 36: Umukarikari Track

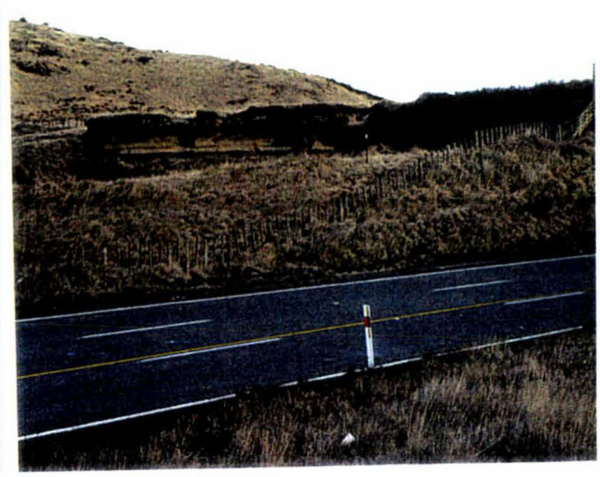
Site 37: Kaimanawa Road



Site 38: Mangatawai Stream

Site 39: East National Park

Site 40: Wairehu Canal



Site 41: Makiokio Stream

APPENDIX C: GLOSSARY OF GEOLOGICAL TERMS

allophanic: soils dominated by the mineral allophane (McLaren and Cameron 1996)

clast: fragment, i.e. clastic rocks are those built up from fragments of pre-existing rocks (Whitten and Brooks 1972)

diagenesis: those processes affecting a sediment while it is at or near the Earth's surface, i.e. at low temperature and pressure. (Whitten and Brooks 1972).

ignimbrite: a genetic term for the primary deposit of a pyroclastic flow or flows (Marshall 1935). As ignimbrite has two common lithological states it is usually convenient to qualify the term with welded or unwelded as appropriate (Froggatt and Lowe 1990).

lapilli: fragments of pyroclastic rocks measuring between 4 and 32 mm (Whitten and Brooks 1972).

lithic: a descriptive term applied to rock fragments occurring in later formed rock (Whitten and Brooks 1972).

palaeosol: a soil which formed at the land surface and subsequently was buried by other material (Molloy 1988). Also, a once-exposed geological substrate in which biological activity has taken place and which is now under a later deposit (Dimbleby and Speight 1969).

peat: partly decomposed plant remains in a water-saturated environment, such as a bog (Molloy 1988)

pyroclastic: a collective term for clastic or fragmentary materials ejected from a volcanic vent (Fisher and Schmincke 1984).

soil: (1) the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (2) the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of *parent material*, *climate* (including moisture and temperature effects), *macro-* and *microorganisms*, and *topography*, all acting over a period of *time* and producing a product - soil - that differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics. (Foth 1984)

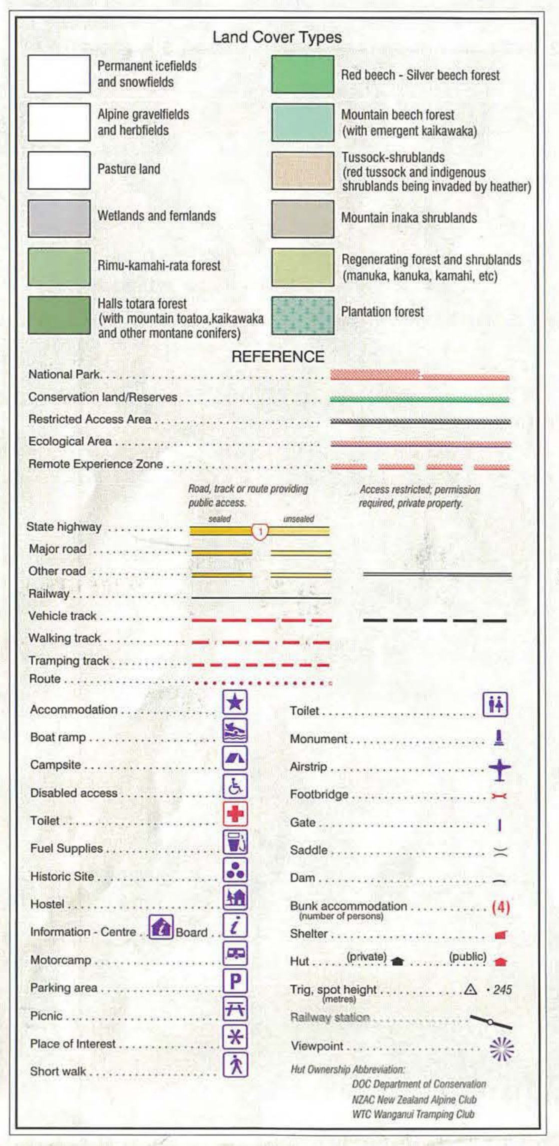
tephra: A collective term for all the unconsolidated, primary pyroclastic products of a volcanic eruption (Thorarinsson 1974).

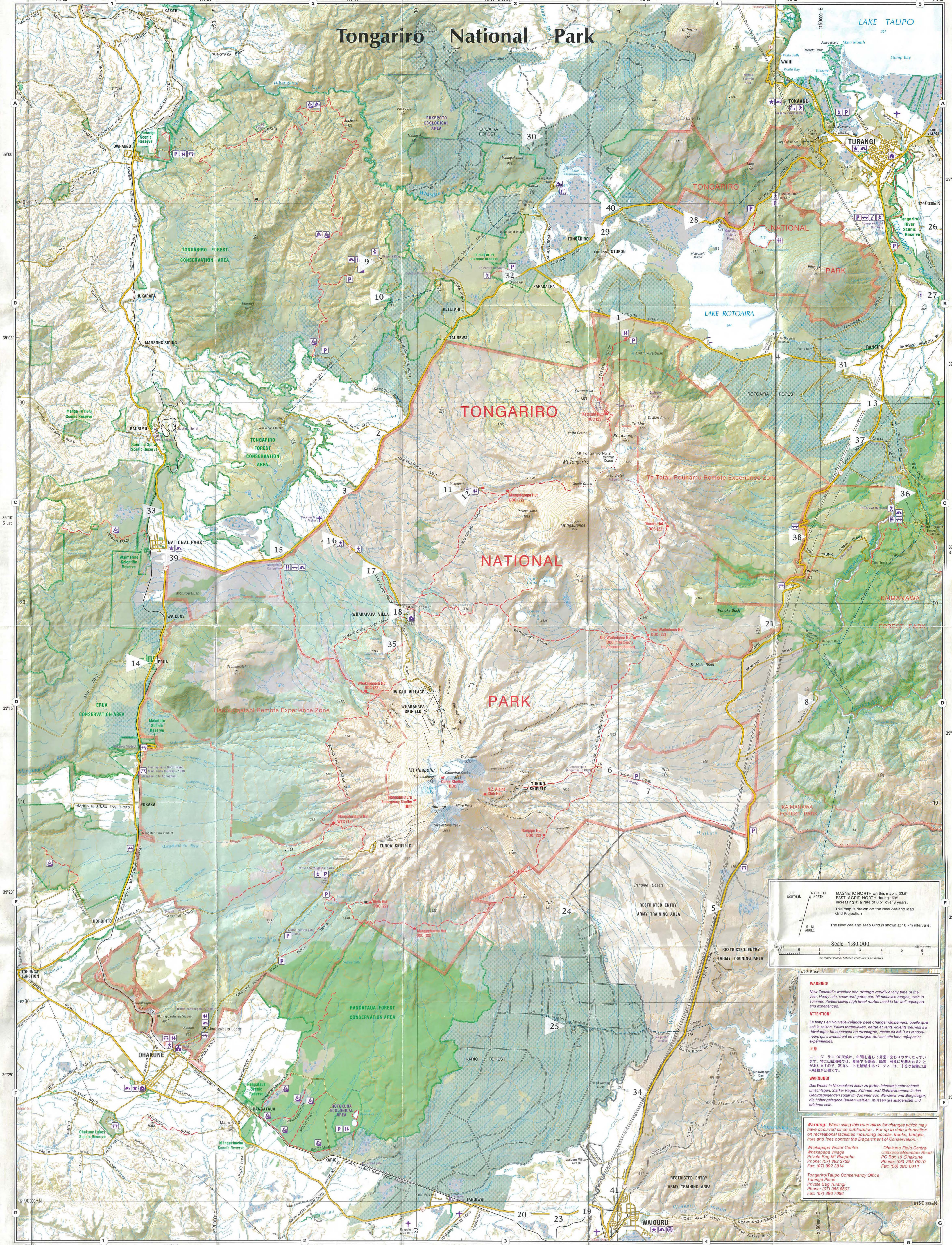
APPENDIX D: GLOSSARY OF PLANT NAMES

Alectryon excelsus	titoki
Ascarina lucida	hutu
Asplenium bulbiferum	hen and chicken fern
Astelia solandri	kowharawhara
Beilschmiedia tawa	tawa
Blechnum discolor	piupiu, crown fern
Brachyglottis repanda	rangiora
Carpodetus serratus	putaputaweta, marbleleaf
Calluna vulgaris	heather
Coprosma foetidissima	stinkwood
Coriaria arborea	tutu
Cortaderia sp.	toetoe
Cyathea colensoi	tree fern
Cyathea smithii	katote
Cytisus	broom
Dacrycarpus dacrydioides	kahikatea
Dacrydium cupressinum	rimu
Dodonaea viscosa	akeake
Elaeocarpus dentatus	hinau
Elaeocarpus hookerianus	pokaka
Empodisma minus	jointed rush
Eucalyptus spp.	Eucalyptus, gum
Freycinetia baueriana ssp. *banksii*	kiekie
Fuchsia excorticata	tree fuchsia, kotukutuku
Gahnia xanthocarpa	cutty grass
Gaultheria depressa	snowberry
Gleichenia microphylla	tangle fern
Griselinia littoralis	kapuka, broadleaf
Halocarpus bidwillii,	bog pine
Halocarpus biformis	pink pine
Hebe spp.	hebe
Knightia excelsa	rewarewa
Kunzea ericoides	kanuka
Lagarostrobus colensoi	silver pine
Leptospermum scoparium	manuka
Leucopogon fasciculatus	mingimingi
Libocedrus bidwillii	kaikawaka, pahautea, cedar

Melicytus ramiflorus ssp. *ramiflorus*	mahoe
Metrosideros	rata
Microlaena avenacea	bush rice grass
Myrsine divaricata	weeping mapou, weeping matipo
Neomyrtus pedunculata	rohutu
Nothofagus	beech
Nothofagus fusca-type	includes red, hard, black and mountain beech
Nothofagus solandri var. *solandri*	black beech
Nothofagus solandri var. *cliffortioides*	mountain beech
Nothofagus menziesii	silver beech
Olearia spp.	leatherwood
Passiflora tetranda	kohia
Phormium sp.	flax
Phyllocladus asplenifolius var. *alpinus*	mountain toatoa (previously *Phyllocladus alpinus*
Phyllocladus trichomanoides	tanekaha
Pinus spp.	pine
Podocarpus hallii	Hall's totara
Podocarpus nivalis	snow totara
Podocarpus totara	totara
Prumnopitys ferruginea	miro
Prumnopitys taxifolia	matai
Pseudopanax crassifolius	horoeka, lancewood
Pseudopanax simplex	haumakaroa
Pseudopanax spp.	five-finger
Pseudowintera colorata	mountain horopito, pepper tree
Pteridium esculentum	aruhe, bracken fern
Quintinia serrata	tawheowheo
Ripogonum scandens	kareao, supplejack
Ulex europaeus	gorse
Weinmannia racemosa	kamahi

Tongariro National Park





CLASSIFICATION OF DOC TRACKS

Short Walk - well formed with easy grades. Suitable for people of all ages, fitness levels, abilities and experience. Constructed to allow for wheelchair access or to "walking shoe" standard.

Walking Track - defined and well formed. Suitable for people of most ages, fitness levels, abilities and experience. Constructed to "walking shoe" standard.

Tramping Track - limited formation, often with steep grades, generally marked. Suitable for moderately fit, experienced and properly equipped people, wearing tramping boots.

Route - lightly cut through bush and scrub; may include tramping tracks no longer maintained. Above bushline, generally marked with poles or cairns. Riverbed routes are generally unmarked but symbol on map indicates the best route in normal river conditions. Suitable for fit, well equipped people with a high degree of experience, and with navigating and river crossing abilities.

Public Access to Conservation Land

Conservation lands are managed by the Department of Conservation (DOC) for a wide variety of conservation and recreation purposes.
Generally visitors have freedom of access, except for a limited number of special areas which are usually of significant wildlife or cultural value.

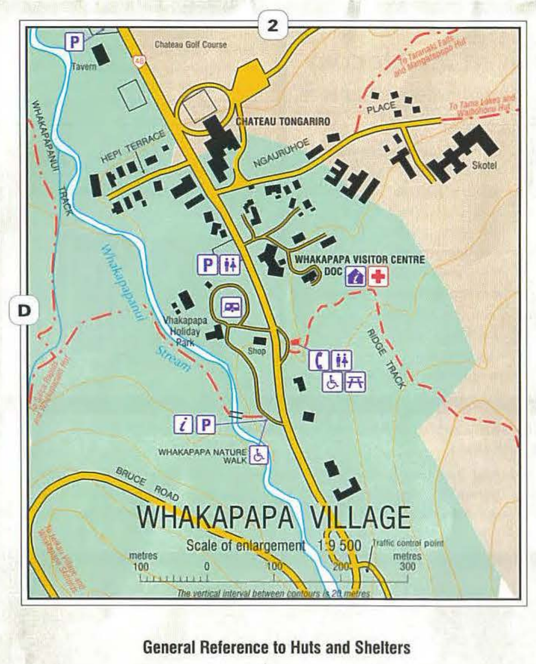
Permits may be granted for entry to some of these special areas.

All conservation lands (and their indigenous wildlife and plants) are protected. Accordingly, some types of visitor activities (eg., entry with dogs, horse travel, mountain-biking, 4WD and other off-road vehicle recreation) may be restricted, or confined to particular localities. If in doubt about any proposed activity, contact the nearest DOC office listed on the map.

The following types of protected areas and management zones are shown on this map:

* **national parks, forest parks and national reserves**
  generally large natural areas, usually with a network of hut and track facilities; few restrictions on access on foot or by boat.
* **scenic, historic and recreation reserves; conservation areas**
  reserves are generally smaller areas with no entry restrictions; many back-country conservation areas are large natural areas with limited facilities.
* **ecological areas and sanctuaries**
  relatively large areas of conservation land which are representative of the ecology of the district; open for public use but generally without hut and track facilities.

CAUTION:
Only tracks maintained by DOC and recommended for recreational use are shown on this map. Many of the open tops and riverbeds are widely used as routes by experienced trampers and hunters but as they are unmarked on the ground the are not shown on this map. For navigating these unmarked routes Topographic Map 260s (at scale 1:50 000) should be used.



GRID NORTH — MAGNETIC NORTH — G - M ANGLE

MAGNETIC NORTH on this map is 22.5° EAST of GRID NORTH during 1995 increasing at a rate of 0.5° over 8 years.

This map is drawn on the New Zealand Map Grid Projection

The New Zealand Map Grid is shown at 10 km intervals.

Scale 1:80 000

metres 1000 0 1 2 3 4 5 6 kilometres

The vertical interval between contours is 40 metres

WARNING!

New Zealand's weather can change rapidly at any time of the year. Heavy rain, snow and gales can hit mountain ranges, even in summer. Parties taking high level routes need to be well equipped and experienced.

ATTENTION!

Le temps en Nouvelle-Zélande peut changer rapidement, quelle que soit la saison. Pluies torrentielles, neige et vents violents peuvent se développer brusquement en montagne, même en été. Les randonneurs qui s'aventurent en montagne doivent être bien équipés et expérimentés.

注意

ニュージーランドの天候は、年間を通じて非常に変わりやすくなっています。特に山岳地帯では、夏場でも豪雨、降雪、強風に見舞われることがありますので、高山ルートを踏破するパーティーは、十分な装備と山の経験が必要です。

WARNUNG!

Das Wetter in Neuseeland kann zu jeder Jahreszeit sehr schnell umschlagen. Starker Regen, Schnee und Stürme kommen in den Gebirgsgegenden sogar im Sommer vor. Wanderer und Bergsteiger, die höher gelegene Routen wählen, müssen gut ausgerüstet und erfahren sein.

***Warning:** When using this map allow for changes which may have occurred since publication . For up to date information on recreational facillities including access, tracks, bridges, huts and fees contact the Department of Conservation:-*

Whakapapa Visitor Centre
Whakapapa Village
Private Bag Mt Ruapehu
Phone: (07) 892 3729
Fax: (07) 892 3814

Ohakune Field Centre
Ohakune Mountain Road
PO Box 10 Ohakune
Phone: (06) 385 0010
Fax: (06) 385 0011

Tongariro/Taupo Conservancy Office
Turanga Place
Private Bag Turangi
Phone: (07) 386 8607
Fax: (07) 386 7086

Parkmap TONGARIRO
EDITION 5 1996 Limited Revision 2000
Published under the authority of the Director General Department of Conservation

Tongariro National Park

Tongariro was declared New Zealand's first national park in 1887, only the fourth area in the world to be protected in this way. Throughout the world, national parks are rapidly becoming ecological islands within areas of development and settlement. They represent glimpses of the way our environment once was. They are also cultural icons which connect people to the land.

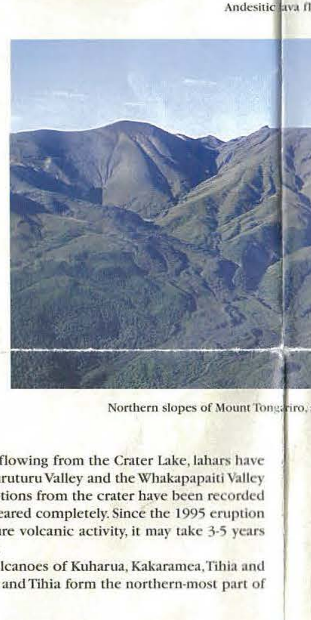
Mount Ruapehu in eruption, from the north-east across the Rangipo Desert. Photo: Lloyd Homer, IGNS.

WORLD HERITAGE STATUS

Mount Ruapehu and Tama Lakes from summit of Mount Ngauruhoe.

THE VOLCANOES

Andesitic lava flows from Mount Ngauruhoe. Photo: Chris Rudge.



Northern slopes of Mount Tongariro, showing Ketetahi Springs and Te Maari lava flows.

WILDLIFE

VEGETATION

eruption, but have developed subsequently, though reduced in area by later fires. One sector of the park, extending from Hauhungatahi to Rangataua, escaped the hot pumice-flows and was mantled only by a thin layer of air-fall pumnice which, by the time it reached the ground, was too cool to start fires. Forest evidently survived the eruption on these western and southern slopes of Ruapehu.

Red tussock shrublands showing the increasing dominance of introduced heather. *Photo: Les Molloy.*

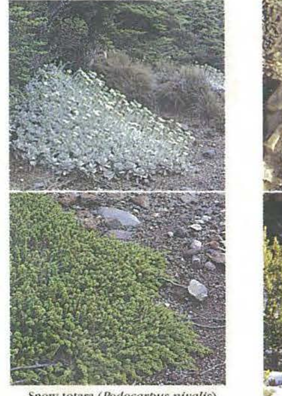
Mountain beech forest is the most widespread forest type in Tongariro National Park. It occurs as an almost continuous belt around the western and southern slopes of Ruapehu, but is missing from the northern and western slopes of Tongariro and Ngauruhoe. The distinctive 'forest islands' in the shrublands in the north-western sector of the park often consist of mountain beech on patches of better-drained soils. Mountain beech has a distinctive tiered appearance resulting from its horizontal branching. The other, very distinctive, component of this forest is kaikawaka, their dark green conical crowns showing very clearly above the mountain beech canopy.

Mountain beech forest with emergent kaikawaka (*Libocedrus bidwillii*). *Photo: J.W. Dryden.*

The silver and red beech species make up another forest vegetation zone. They tend to be much larger in stature than their mountain relatives, their rigidity making them susceptible to upper crown damage from heavy snowfalls. This zone occurs in isolated patches on the eastern slopes of Tongariro but is very extensive on the southern slope of Ruapehu, especially the Rangataua lava flow just outside the park.

Hardwood and podocarp species such as rimu, kamahi, kahikatea and rata can be found in Tongariro National Park in scattered areas between elevations of 600 and 900m, especially on the Ruapehu ringplain south of Horopito and on the lower slopes of the northern volcanoes, especially lining the Te Ponanga Saddle Road (SH 47) between Lake Rotoaira and Tokaanu. Some of the trees in these forests are over 500 years old, as evidenced by their height and mass. Many of the more common native bird species live in this vegetation zone and the understorey generally supports abundant insect life.

Lava formations of Oturere Valley, with clumps of bristle tussock and mountain inaka (*Dracophyllum recurvum*). *Photos: Les Molloy.*



Snow totara (*Podocarpus nivalis*), foreground, and snow daisy (*Celmisia incana*). *Photo: Les Molloy.*

Taranaki Falls, a popular half-day walk near Whakapapa Village. *Photo: Les Molloy.*

HISTORY OF THE PARK

The Beginning

The three great mountains of Ruapehu, Ngauruhoe and Tongariro, have special significance for the two major tribes that live in their shadow: the Ngati Tuwharetoa and the Ngati Rangi.

Ngatoroirangi, ancestor of the Ngati Tuwharetoa (and the navigator of Te Arawa canoe, one of the first to arrive on the shores of Aotearoa), was the first to reach Ngauruhoe's summit in a bid to survey the surrounding country. The idea of climbing the sacred volcanoes of Tongariro merely to admire the view was foreign to Maori, and in certain circumstances the Tuwharetoa would refuse to even look at the mountain for fear of breaking its tapu (sacredness).

Early explorers risked the wrath of local Maori if they attempted to climb the sacred mountains. However, in 1839 John Bidwell made the first recorded European ascent of Ngauruhoe and while he was rewarded with the knowledge that he had stood where no other European had been, his insensitive action greatly angered the Ngati Tuwharetoa chief, Te Heuheu Mananui.

The Gift

Te Heuheu Tukino IV (Horonuku), paramount chief of the Ngati Tuwharetoa was, like his forefathers, a man who led his people through times of conflict and change. This was at a time when there was considerable pressure on the central North Island land from farmers, logging and rival tribal claims. Loss of this land would have meant the loss of the sacred volcanoes and a loss of mana for the Ngati Tuwharetoa.

"If our mountains of Tongariro are included in the blocks passed through the court in the ordinary way, what will become of them? They will be cut up and sold, a piece going to one Pakeha and a piece to another. They will become of no account, for the "tapu" will be gone. Tongariro is my ancestor, my "tupuna" it is my head; my "mana" centres around Tongariro, You know how my name and history are associated with Tongariro, I cannot consent to the court passing these mountains through in the ordinary way. After I am dead, what will be their fate?"

Te Heuheu Tukino IV, 1885.

Te Heuheu Tukino IV. *Photo: Ruapehu Area Office, DOC.*

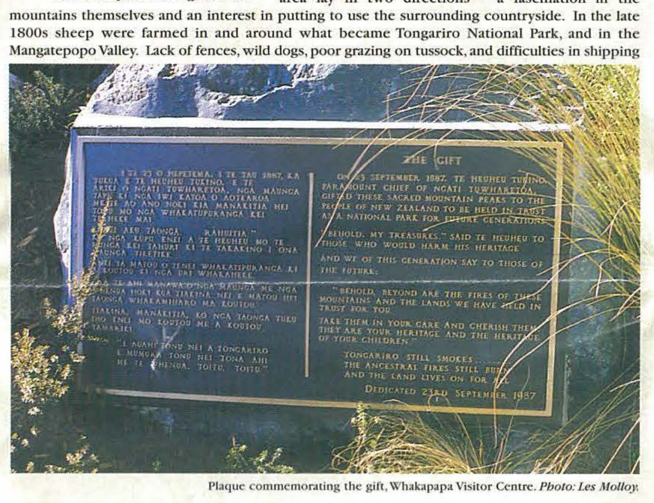
On 23 September 1887, Te Heuheu gifted the sacred volcanoes of Tongariro, Ngauruhoe and Ruapehu to the Crown and to the people of New Zealand, " ...in memory of Te Heuheu and his tribe".

Tongariro National Park was formally established by an Act of Parliament in 1894 and gazetted as such in 1907. The original gift area, of 2630 hectares, has been increased over the years, by government purchase of surrounding land, to create a national park of 79598 hectares.

Use of the land has changed considerably in the years since the gift, but even now, the tapu still remains and it requires respect from the visitor for the elements, and life of these mountains.

Farming Endeavours and Early Conservation Conflicts

Early European interest in the Tongariro National Park area lay in two directions - a fascination in the mountains themselves and an interest in putting to use the surrounding countryside. In the late 1800s sheep were farmed in and around what became Tongariro National Park, and in the Mangatepopo Valley. Lack of fences, wild dogs, poor grazing on tussock, and difficulties in shipping



Plaque commemorating the gift, Whakapapa Visitor Centre. *Photo: Les Molloy.*

wool out of the district led to the end of sheep farming in the area by the 1920s.

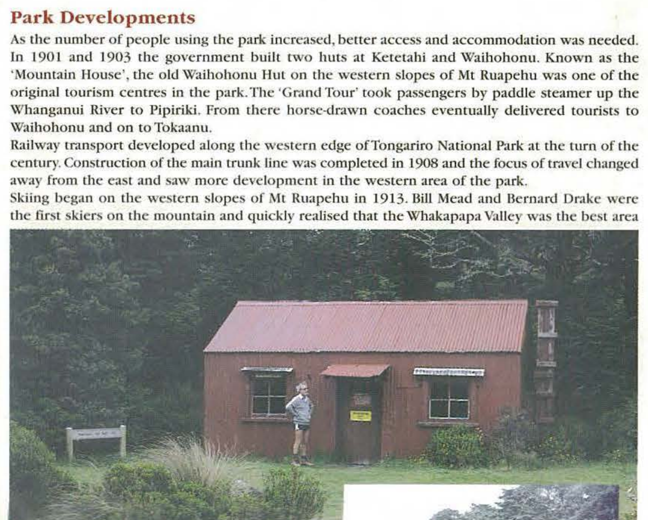
One of New Zealand's first environmental debates began over a proposed tourism venture for the park. John Cullen, the first ranger-equivalent for Tongariro National Park believed the park could be a gamebird hunting ground to rival the heaths and moorlands of Scotland. In 1922 parliament approved the introduction of grouse, woodcock and ptarmigan into the park. However, tussock was not a desirable foodstuff for gamebirds, and areas were cleared so that tastier varieties of heather could be planted. Public opinion flared, both against the introduction of gamebirds, and the planting of heather. These activities eventually ceased. The gamebirds which were released inevitably perished as they were not able to adjust to the harsh Tongariro climate. The heather however, thrived. An efficient coloniser, it competes with native species, often displacing them. Today, the Department of Conservation continues research into weed control programmes in an attempt to lessen its invasion.

Park Developments

As the number of people using the park increased, better access and accommodation was needed. In 1901 and 1903 the government built two huts at Ketetahi and Waihohonu. Known as the 'Mountain House', the old Waihohonu Hut on the western slopes of Mt Ruapehu was one of the original tourism centres in the park. The 'Grand Tour' took passengers by paddle steamer up the Whanganui River to Pipiriki. From there horse-drawn coaches eventually delivered tourists to Waihohonu and on to Tokaanu.

Railway transport developed along the western edge of Tongariro National Park at the turn of the century. Construction of the main trunk line was completed in 1908 and the focus of travel changed away from the east and saw more development in the western area of the park.

Skiing began on the western slopes of Mt Ruapehu in 1913. Bill Mead and Bernard Drake were the first skiers on the mountain and quickly realised that the Whakapapa Valley was the best area



The original Waihohonu Hut in the early 1990s. *Photo: Les Molloy.* Inset: Visitors to Waihohonu Hut in the early 20th Century.

to practice the new sport. As a result of Bill Mead's persistence, the Department of Tourist and Health Resorts was persuaded to fund an access road to Whakapapa in 1919. The popularity of the sport grew during the 1920s and as access and skill improved, the need for accommodation grew. Numerous huts were built in and around Whakapapa and the four-storey Chateau hotel was built in 1929. The first rope tow was installed in 1938 and skiing became a popular winter sport resulting in the development of two further ski areas. Turoa on the western side of the mountain and Tukino, a small club field on the eastern side of Ruapehu.

GENERAL INFORMATION

Vehicle Security

Do not leave valuables in parked cars and if possible arrange alternative transport to and from tracks. Leaving vehicles overnight, especially in more isolated car parks, is not recommended.

Water

Giardia is present in Tongariro National Park and it is recommended that all water in the Park used for drinking, be treated. Water from the upper Mangatepopo Stream, Emerald Lakes and Ketetahi Springs is not suitable for drinking due to high mineral content.

In times of volcanic activity water tanks at huts may be disconnected to avoid ash contamination. Streams and rivers could also become contaminated. Be prepared to carry your own supply.

Weather

The climate of Tongariro National Park is strongly influenced by the prevailing westerly winds, laden with moisture from the Pacific Ocean. The winds are forced to rise as they reach the mountains and in doing so, lose a large part of their load. By the time the air mass reaches the east, much of the moisture has been lost as rain and snow on the western slopes.

Even though the prevailing wind is westerly, the mountains of Tongariro National Park are exposed to all winds and their massif contributes to and modifies the climate of the surrounding landscape. There is no wet or dry season or month in the park. The weather pattern is highly unpredictable and rain and snow can fall at any time. **Always check weather forecasts before you set out.**

Hotels, Motels and Motor Camps

Camp Sites

Transport Services

Whakapapa Visitor Centre

HUTS AND SHELTERS

Park Huts

Other Huts

Ski Club Lodges

Emergency Shelters

TRACKS AND WALKS

Snow and Avalanches

MOUNT RUAPEHU

The Peaks of Ruapehu

Crater Lake

North and Central Craters

Glaciers

Pinnacles

Whakapapa Skifield

Skiing at Whakapapa skifield on Mount Ruapehu. Photo: Chris Rudge.

Turoa Skifield

Tukino Skifield

River Crossings

Volcanic Hazards

Mountain Summit Trips

Longer Tracks

Short Walks and Day Trips in Tongariro National Park

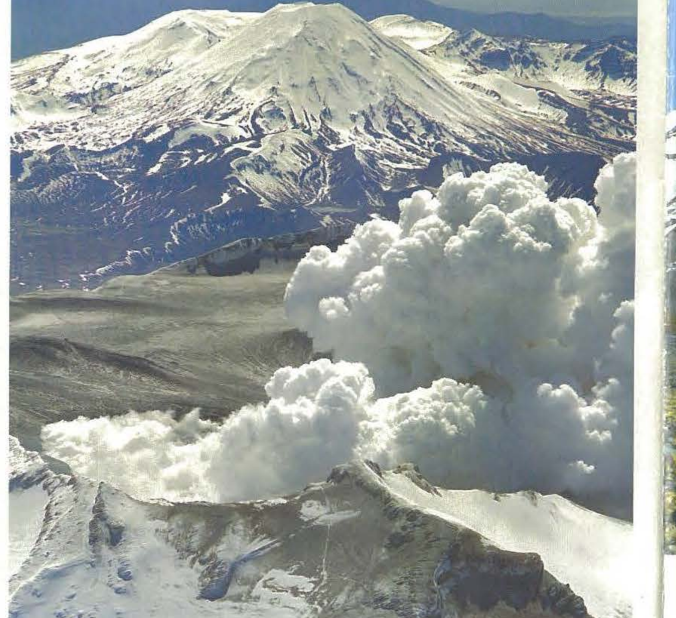
THE GREAT WALKS SYSTEM

NATIONAL PARKS PURPOSE STATEMENT

NEW ZEALAND ENVIRONMENTAL CARE CODE

1995/1996 Eruptions

Almost exactly 50 years to the day since its last eruption in 1945, Mt Ruapehu burst into life on 23 September 1995 following several months of low to moderate tremours. The drama of the late afternoon eruption of steam, lake silt, rocks and ash was witnessed by thousands of skiers leaving the two commercial skifields. Lahars (mud flows) flowed down the Whangaehu, Mangaturuturu and Whakapapanui valleys. Three and a half weeks of eruptive activity followed during which the Crater Lake disappeared and the skifields were closed. A period of large gas emissions followed and by December the volcano entered a quiet phase which lasted until 17 June 1996 when Ruapehu once again erupted dramatically with very large ash eruptions, fire fountains and sonic booms. Extensive ash cover closed the two commercial skifields for a period of time.



1995 eruption of Mount Ruapehu, looking north towards Mount Ngauruhoe and Lake Taupo. *Photo: Lloyd Homer, IGNS.*

TONGARIRO CROSSING

Mangatepopo Hut to Emerald Lakes (3½ hours)

Emerald Lakes to Ketetahi Hut (2 hours)

Emerald Lakes to Oturere Hut (1½ hours)

Mangatepopo Lava Flows

Pukekaikiore (1737m)

Soda Springs

South Crater

KETETAHI HOT SPRINGS

Red Crater

Emerald Lakes

Te Maari Craters

Ketetahi Forest

Mt Ngauruhoe (2291m)

Looking across the Central Crater of Tongariro towards Red Crater and Ngauruhoe.

Mt Tongariro (1967m) and northern

Whanganui River

Tongariro

Parkmap 273-04

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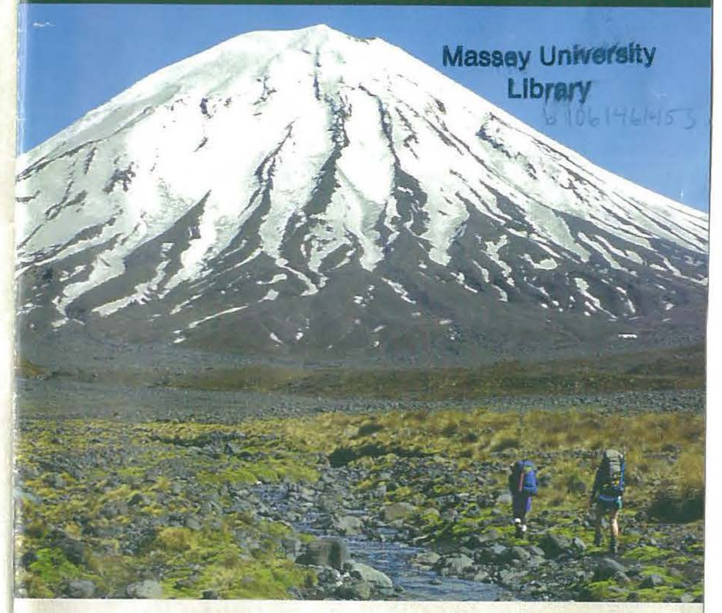

Department of Conservation
Te Papa Atawhai