CHAPTER 8 OTAKAIRANGI SWAMP, NORTHLAND

Sections 8.1-3 concern the Northland peninsula south of Kaitaia (Fig. 8.1a). The physical setting, indigenous vegetation and paleobotanical evidence of the far north is described in Chapter 9.

8.1 NORTHLAND PHYSICAL SETTING

8.1.1 Geology and physiography (Fig. 8.1b)

Northland is a narrow peninsula, 300 km long and up to 100 km wide. It is the northernmost region of New Zealand, lying mostly between latitudes 34 and 36° S. It is characterised by comparatively low relief (Fig. 8.1c) with most areas below 150 m a.s.l., although the highest points in the ranges exceed 600 m a.s.l.

Much of the region is rolling country and sand dunes with volcanic ranges standing out above Northland allochthon rocks (Ballance & Spörli, 1979; Fig. 8.1c) that form the slopes and valleys. Block faulting and westward tilting has enhanced erosion in the east, where deeply weathered, complexly folded, greywackes of Permian to Jurassic age (Thompson, 1961) are today exposed at the surface (Ballance & Williams, 1982). As a result of westwards tilting, much of the modern drainage is to the west. For example the Kaipara Harbour/Northern Waipoa River watershed, which includes this study site (Otakairangi Swamp), stretches to within a few kilometres of the east coast (Fig. 8.1a).

Parallel to both coastlines are rocks derived from two chains of island arc volcanoes active during the mid to late Miocene (Ballance & Williams, 1982). In the west, andesitic lavas, breccias, and conglomerates form the Waitakere Range, and sheets of solid basaltic lava underlie the Waipoua Plateau (see Ch. 5). In the east, Miocene volcanic rocks, mostly andesitic, form several ranges from Coromandel Peninsula to Whangaroa.

Quaternary volcanism was on a smaller scale and consisted of shifting fields with intermittent eruptions. These fields were centred on Auckland isthmus (see Ch. 9) and in the Whangarei - Bay of Islands region where scoria cones and their associated lavas are prominent features today. In Northland, two phases are recognised (Thompson, 1961). The Horeke Basalts, from the earlier phase, are more extensive and more deeply weathered. Horeke Basalt from the bed of the Wairua River (near the study site; Fig 8.1a)) was K/Ar dated as 0.52 Ma (Stipp & Thompson, 1971). The more recent, and probably still active phase, has produced the late Pleistocene to Holocene Taheke Basalts (Thompson, 1961). Quaternary basalt flows have filled valley floors in the Whangarei area and these contribute to the incidence of flash flooding by impeding groundwater movement (Wells, 1983).

Several raised coastal terraces occur at broadly similar heights over much of Northland; the highest occur at c.180 m a.s.l. (Brothers, 1954; Ballance, 1968; Richardson, 1985; see also Ch. 11). These were probably formed during interglacial high sea levels.
Fig. 8.1 Northland physical environment: (a) localities mentioned in text; (b) simplified geology (after Kadar, 1989); (c) relief.
Successively higher altitudes for older terraces suggest that regional uplift has continued for at least the latter part of the Quaternary, at a rate averaging 0.3 mm/yr (Chappell, 1975). Considerable areas of the coast were drowned by postglacial sea level rise.

Deforestation during the human era has led to slope instability and sand dune migration (Ballance & Williams, 1982). There is also evidence for earlier landscape instability in association with Quaternary sea level fluctuations (Hicks, 1975; Schouten, 1976).

### 8.1.2 Soils

Soil development in most parts of Northland has probably continued uninterrupted since the Miocene under a warm, moist climate, in the absence of glaciation, and on a landscape of low relief. (Fleming, 1962; Hay, 1965). The soils are generally strongly leached, contain heavy clays, and have thin topsoils and low subsoil fertility. Soil development has also been influenced by bedrock. In the west, clay loams are derived from andesitic and basaltic lithologies, whereas less fertile clay loams have developed on greywacke in the east (McKelvey & Nicholls, 1959). In addition, there are localised high fertility soils associated with volcanic, alluvial, and colluvial deposits (Taylor & Sutherland, 1953).

The composition of Northland’s indigenous forest remnants shows important relationships with soil properties (Taylor & Sutherland, 1953). Angiosperm trees, *e.g.*, *Vitex lucens, Dysoxylum spectabile, Beilschmiedia* spp., give rise to rapidly decomposing litter leading to fertile, humus rich (mull) soils. Under coniferous trees, litter decomposes slowly, and soils are impoverished and acidic (mor soils). Measured rates of decomposition of litter in northern New Zealand forests (Enright & Ogden, 1987) generally support these observations in showing slower decomposition of conifer litter than angiosperm litter.

*Agathis australis* trees have a particularly strong leaching effect (Taylor & Dixon, 1968) and soils underlying *A. australis* forest are frequently podsolised (Taylor & Pohlen, 1959; Eckroyd, 1982). This species is evidently capable of competing successfully with angiosperm trees on low fertility soils. *A. australis* extends many fine, nodulated feeding rootlets into the mor litter layer which typically forms at the base of the tree. The trees may also be deep-rooted and capable of extracting nutrient from deep sources even though the shallow soils may be impoverished (Cox, 1973; Schouten, 1976, Lloyd, 1978). Deep rooting is also advantageous during droughts.

### 8.1.3 Climate

Northland has a mild, humid, and moderately windy climate, related to its northern location, low relief, proximity to the sea, and the strong influence of the subtropical high pressure belt (Moir *et al.*, 1986).

Rainfall shows much variability from month to month and from year to year (Fig.
8.2). There is a clearly defined winter rainfall maximum and usually at least one dry spell (>15 days with <1 mm rainfall) occurs between December and March. Soil moisture deficits occur on average 55 days between November and April. Rainfall increases from 1100 mm/yr in coastal areas to 2500 mm/yr in the high country (de Lisle, 1964; Fig. 8.3).

The surrounding ocean exerts a moderating influence on temperatures and few extremes are recorded. Mean annual temperature (MAT) range (Fig. 8.2) and diurnal temperature ranges are small compared with the national averages. MATs are higher in the far north (Ch. 11) and in eastern areas (15.5 - 16° C) and slightly lower in the west and south (14 - 15.5° C). Air temperatures decrease with increasing altitude in Northland at c. 0.6° C/100 m (Coulter, 1967). Therefore at altitudes of 500 m a.s.l. MAT should be close to 12° C, and range from 17° C in January to 10° C in July.

![Graph showing monthly rainfall and temperature variations](image)

**Fig. 8.2.** Mean and median monthly rainfall at Whangarei (Fig. 8.1a) and mean maximum and minimum monthly temperatures at Glenbervie Station near Whangarei; from Schouten, 1976.

Most areas receive c. 2000 hours of sunshine annually, 50% of the total possible. Air frosts are rare while shallow ground frosts may be frequent in sheltered inland areas. Frosts do not seriously affect plant life. The surface airflow over Northland is predominantly from the southwest (Tomlinson, 1975), especially in winter and spring. In summer and early
autumn, when the subtropical high pressure belt lies further south, easterly winds are equally frequent. Exposed coastal areas can be very windy with mean annual wind speeds among the highest in New Zealand. Occasionally Northland experiences gales and heavy rain associated with tropical depressions.

Fig. 8.3. Isohyets showing mean annual rainfall (mm), 1941-1970, from Moir et al., 1986.
8.2 NORTHLAND INDIGENOUS VEGETATION

8.2.1 Pre-European vegetation

On the basis of soil-vegetation relationships and indigenous forest remnants, Taylor & Sutherland (1953) reconstructed the pre-European vegetation cover of Northland (Fig. 8.4). Most of the region was covered by a mosaic of dense podocarp forest, with some areas dominated by *Agathis australis* or by angiosperm trees.

![Map showing pre-European vegetation of Northland](image)

**Fig. 8.4.** Pre-European vegetation of Northland inferred from soil evidence and forest remnants; after Taylor & Sutherland, 1953.
Coniferous forest evidently occupied ridge tops and steeper slopes. Angiosperm forest, with a *Beilschmiedia tarairi*-dominant, canopy would probably have occupied much of the more fertile lower slopes and gullies. The wetter flats were probably covered largely with *Dacrycarpus dacrydioides* dominated semi-swamp forest.

Early European naturalists (e.g., Colenso, 1844; Darwin, 1901; Banks & Solander (see Glenn, 1950)) described vast tracts of primary northern forests. However it seems that by the time of European settlement, *Leptospermum* and *Pteridium* scrub occupied much of the lowlands (Taylor & Sutherland, 1953). The occurrence of kauri gum (solidified *Agathis australis* resin) in widespread "gumlands" (mostly swampy areas) and in soils developed on west coast dunes (McKelvey & Nicholls, 1959; Hayward, 1978) indicates these areas formerly supported a forest cover with *Agathis australis* prominent. From soil profiles, at least some of the gumland areas may have had a long history of scrub-cover; others probably owe their origin to early Maori occupation (Taylor & Sutherland, 1953). Esler & Rumball (1975) described the vegetation of gumlands and the processes leading to their formation.

Schouten (1976) presented evidence for Holocene vegetation from the Puketurua catchment, 10 km west of this study site (Fig. 8.1a). There, gully infill deposits contained abundant *A. australis* gum and wood, some of which was charred, and frequently associated with charcoal. Numerous wood, leaf, and gum samples from these deposits were radiocarbon dated. The oldest evidence for fire at Puketurua was charcoal associated with *Phyllocladus trichomanoides* leaves, radiocarbon dated at 7710 ± 160 BP. However, burning evidently increased substantially after c. 1200 BP: A layer of charred leaves, twigs, and seeds, mostly *Leptospermum scoparium*, dated at 426 ± 54 BP, suggests that scrub covered at least part of the catchment at this time and illustrates the impact of frequent burning on the forest vegetation. Schouten estimated that by AD 1750 most of the Puketurua catchment was probably covered by *L. scoparium* scrub.

Fleming (1962, 1963, 1979) has argued that Pleistocene cooling in Northland was probably not sufficient to eliminate forest. He suggested however, that forest composition may have been different from the present, with more species from cooler areas (e.g., *Nothofagus*). Wardle (1963, 1988) and Clayton-Greene (1978) suggested that the Northland region may have acted as a refugium for warm-temperate plants during glacial stages (see also 1.4.5). Willett (1950) considered that stands of *N. truncata* in Northland are remnants of a formerly large, continuous area of beech forest which covered the northern part of New Zealand during Pleistocene glacial stages. As yet there have been too few palynological data to fully test these arguments (see below 8.3).

### 8.2.2 Modern vegetation

Today, in place of the former unbroken tracts of forest, there are scattered forested uplands separated by intervening cleared fertile lowlands. The indigenous forest remnants were classified as part of a nationwide forest survey (McKelvey & Nicholls, 1959); forest
categories recognised are for the most part consistent with those inferred from the soil-vegetation relationships of Taylor & Sutherland (1953; Fig. 8.4).

Forest remnants mostly occupy steep south-facing slopes at higher altitudes with infertile soils. Therefore they are unlikely to represent the full diversity of Northland’s original forest cover. Moreover, there is the possibility that our knowledge of the ecology of plant species, partially or entirely endemic to Northland, is biased towards these habitats. For example, the only unexploited stands of dense Agathis australis are on the more remote uplands and in the Waipoua Forest Reserve (Ch 3). Nearly all the trees occur on ridge crests, steep upper valley sides, or on undulating terrain with a rather high water table. Elsewhere A. australis occurs most consistently in small clumps or as widely spaced single trees on sharp knolls, steep ridges and spurs. Macrofossil evidence suggest A. australis stands were formerly more widespread in lowland areas, although the extent of these forests is unknown.

Remnant areas of lowland forest (< 600 m a.s.l.) consistently lacking A. australis are common. These essentially comprise scattered Metrosideros robusta and Dacrydium cupressinum emergent over a dense canopy of Dysoxylum spectabile, Beilschmiedia taraire, B. tawa, and Weinmannia silvicola. Other canopy species may include Elaeocarpus dentatus, Laurelia novae-zelandiae, Knightia excelsa, Prumnopitys ferruginea, Podocarpus totara, and Vitex lucens. Tree ferns, Cyathea spp., and Dicksonia spp., and the palm, Rhopalostylis sapida, are common subcanopy plants.

Nothofagus truncata is not common in Northland today, but may be locally prominent, usually in association with A. australis. From its present distribution, N. truncata would appear to favour edges of spurs periodically subject to stream erosion (J. Ogden, pers comm., 1990) Tall podocarp trees occur in all types of forests, the principal species being Dacrydium cupressinum, Prumnopitys ferruginea, Podocarpus totara, P. hallii, and Phyllocladus trichomanoides. Occasionally prominent are Halocarpus kirkii and Phyllocladus glaucus.

In areas of poor drainage and swamp margins, mature Dacrydium cupressinum and less commonly Dacrycarpus dacrydioides form a closed canopy, beneath which are scattered Syzygium maire, Laurelia novae-zelandiae, Beilschmiedia taraire, Ixerba brexioides, Ackama rosifolia, and D. cupressinum. A scattered shrub tier typically consists of Melicytus ramiflorus, M. macrophyllus, A. rosifolia, I. brexioides, Pseudopanax edgerleyi, P. crassifolius, Schefflera digitata, Coprosma grandifolia, Olearia rani, and tree ferns, while Freycinetia baueriana, Gahnia xanthocarpa, and Blechnum procerum form a moderately dense ground cover. These forests may have colonised swamps following a lowering of water table (McKelvey & Nicholls, 1959). Some low-lying areas of swampy terrain also contain minor remnants of dense Dacrycarpus dacrydioides forest. These are probably remnants of formerly much more widespread swamp forests which have been converted by drainage to farmland.

Forests within c.1 km of the coast are characterised by frequent Metrosideros
excelsa, some Myoporurn laeturn and Sophora microphylla, and local abundance of Corynocarpus laevigatus. These coastal forests may also contain Vitex lucens and Dysoxylum spectabile as well as Agathis australis and podocarps.

About two thirds of the area in indigenous vegetation is today occupied by scrub, some of which contains regenerating forest species. Leptospernum scoparium and Kunzea ericoides are the predominant scrub species, while Leucopogon fasciculatus, Senecio kirkii, Gleichenia spp., and Lycopodium spp. are locally prominent.

See Chapter 3 for a more detailed vegetation description of a Northland forest (Waipoua).

8.3 PREVIOUS QUATERNARY PALYNOLOGICAL INVESTIGATIONS IN NORTHLAND

8.3.1 Pleistocene

The earliest Northland investigations were undertaken by W.F. Harris in a reconnaissance survey aimed at establishing suitable palynological sites (see Moar, 1973). Of the many sites indicated, most remain uninvestigated. Exceptions are Hikurangi (Otakairangi) Swamp (this study) and the North Kaipara region (Fig. 8.1a), where lignites, paleosols, and lacustrine sediments associated with Quaternary dune-sands have yielded abundant macrofossils and palynofloras (Harris, 1953; Mildenhall, 1985; Murray & Grant-Mackie, 1989).

An early Quaternary pollen profile from North Kaipara Barrier (Murray & Grant-Mackie, 1989; Fig. 8.1a) indicates a transition from kauri-podocarp-hardwood forest to podocarp-angiosperm-beech forest. Mature kauri forests established during the Marahauan Substage (c. 1.6 million years ago), a warmer period, were evidently buried by migrating sand dunes during the subsequent Okehuan Substage (c. 1 million years BP). Conditions were wet during both substages and Murray & Grant-Mackie (1989) suggested a climatic cooling of c. 2°C based on the increase of Nothofagus (N. truncata) pollen during the Okehuan.

Mildenhall (1985) reported results from fourteen spot samples from various North Kaipara sites ranging in age from early Holocene to at least earliest Pleistocene. Ages were based on radiocarbon dating and palynology. Paleoclimatic interpretations were hampered by the lack of sequential spectra and by the overwhelming prominence of local swamp taxa in many of the samples. One sample associated with Libocedrus bidwillii wood, contains abundant Phyllocladus pollen with Halocarpus pollen common, while several other samples contain abundant Nothofagus menziesii pollen. The presence of extinct taxa indicates these spectra are mostly of Lower Quaternary (Hautawan) age. N. menziesii and L. bidwillii do not today occur north of 37° 30’ S and are found only at high altitudes in the northern parts of their ranges. Their presence in Northland in coastal situations implies a considerable cooling
of climate, but the *N. menziesii*-rich palynofloras also include taxa consistent with warm, frost-free temperate climates. Mildenhall concluded that local edaphic conditions or wind must have been the controlling environmental factors in these coastal dune swamps.

Of the remaining spot samples, one is of early Holocene age, based on a radiocarbon date NZ3871C (corrected for secular effect): 7050 ± 90 BP (7,800 - 8,000) conventional radiocarbon years). *Agathis australis* leaves were present and *Agathis* is the dominant tree pollen taxon. The pollen spectrum reflects a coastal swamp surrounded by fixed dunes supporting *A. australis* and *Leptospermum* (incl. *Kunzea ericoides*). It was suggested that the dune vegetation was periodically drowned by a rising water table or through dune migration. *Agathis* pollen is scarce or absent from most other samples, some of which contain abundant *Agathis* macrofossils. *Nothofagus fusca* type pollen is present in all 14 samples and abundant in six; *N. truncata* leaves occur at two localities.

Earlier, Harris (1953) demonstrated the value of obtaining a vertical sequence of pollen spectra from a ?Quaternary lignite from the same area (Fig. 8.1a). The profile, which was undated, indicates a marked transition from *Nothofagus fusca* type dominated spectra to podocarp dominated spectra (cf. Murray & Grant-Mackie, 1989). The work of Harris, Mildenhall, and Murray & Grant-Mackie indicates the potential of the North Kaipara area for constructing lengthy Quaternary pollen records, providing individual sections can be correlated and dated by independent (i.e. non-palynological) methods. The organic deposits are associated with as yet undated tephras and with terraces probably formed during interglacial sea level highs (Richardson, 1985). The pollen records to date suggest that podocarp-angiosperm forest persisted in the North Kaipara area (and by implication most of Northland) for much if not all of the Quaternary. Fluctuations in the abundance of *Nothofagus* and *Agathis* pollen may be related to interglacial/glacial cycles, although clarification of these relationships is also required.

### 8.3.2 Holocene

MacDonald (1984) analysed a 7 m pollen core from Oruariki Swamp, North Kaipara (Fig.8.1a). The base of the profile was radiocarbon dated at c. 8 ka. No other dates were reported. The basal samples are dominated by *Dacrydium cupressinum* pollen with *Nothofagus fusca* type (c. 20%) and *Metrosideros* pollen abundant. Following a 75 cm gap in the cored peat, a marked transition occurs to *Agathis* (up to 35%) and *Phyllocladus* dominated pollen spectra. *N. fusca* type pollen then declines to low levels and remains uncommon. The *Agathis* expansion at c. 5 m depth was not dated but occurred some time after 8 ka. *Agathis* pollen declines at c. 2 m, then rises again before a sharp decline around 1 m. Between 5 m and 1 m *Dacrydium* pollen steadily increases from 10% to 40%, while *Ascarina* pollen declines from 5% to trace amounts. Charcoal was noted in samples above 0.75 m along with rising *Pteridium* and Poaceae curves and the presence of 'European' pollen.
A pollen diagram from McEwen’s Bog (Kershaw & Strickland, 1988) covers a similar time interval, but has more dated samples. This site is situated close to the east coast, about 20 km southeast of Whangarei. Sediment accumulation commenced c. 6,500 years ago as sea level reached its present position. As at Oruariki Swamp, the record suggests that mixed conifer-angiosperm forest dominated the region until it was cleared during the European era. However, at McEwen’s Bog, Dacrydium pollen, although always dominant, declined relative to pollen of other tall podocarps and Nothofagus fusca type, especially after c. 4 ka.

Both sites show similar trends in Agathis pollen curves, despite the poor age control and greater Agathis abundance at Oruariki Swamp. The latter is probably due to differences in proximity to the nearest source trees. At McEwen’s Bog, Agathis pollen is present throughout the 6.5 ka sequence and peaked around 3 ka. Its abrupt decline near the top of both profiles coincides with the beginning of a phase of burning which evidently continued to the present.

Kershaw and Strickland (1988) suggested a change to a drier and cooler climate with increased seasonality after c. 4 ka, based on slower sediment accumulation and the rise of Nothofagus fusca type pollen at McEwen’s Bog. The subsequent development of a raised bog and increased peat growth may indicate an effectively wetter climate for the past few thousand years. These late Holocene climatic changes are similar to those proposed for southeastern Australia (Kershaw, 1982; Macphail & Hope, 1985).

Chester (1986) analysed pollen cores spanning the last 2-3 ka from the Bay of Islands (Fig. 8.1a) in an investigation aimed at dating the earliest evidence for human influence on the vegetation. Podocarp-angiosperm forest prevailed in the region until c. 1,000 years ago. Chester used an age of c. 900 yrs BP for the Kaharoa Ash, which was identified in one pollen profile, although others have used a younger age for this tephra (e.g., McGlone, 1983; Froggatt & Lowe, 1990; this study, Ch 6). Rapid and extensive deforestation is indicated by the dramatic decline in forest pollen, coinciding with strong increases in Pteridium spores and the pollen of seral scrub taxa. However Chester claims that earlier human activity is indicated by the beginning of a continuous charcoal record and an earlier Pteridium spore rise coinciding with an influx of silt. Her estimated age for this event (AD 550-600) was considerably earlier than estimates for human disturbance obtained elsewhere (McGlone, 1983) (see also Sutton, 1987).

Chester’s thesis exemplifies the problem of distinguishing human from other disturbances in pollen records. More objective criteria for dating archaeological events are also required. A single age estimate for the Kaharoa Ash should be resolved, and this employed consistently by all workers. Estimating the age of a disturbance event by linear interpolation between dated horizons is risky when the event itself is likely to have affected the sedimentation rate.
8.4 FIELD AND LABORATORY WORK

8.4.1 Otakirangi Swamp, locality and description

The pollen core was taken from near the centre of Otakirangi Swamp (GR Q06/179212; Fig.8.5-8), 15 km northwest of Whangarei, on the property of Alan and Christine Smith. Otakirangi Swamp is the most western of four peaty areas west of Hikurangi township, together referred to as Hikurangi Swamp (Fig.8.5). Hikurangi Swamp occupies a north-south trending fault-bounded depression between upstanding Waipapa basement rocks (8.1.1) to the east, and late Cretaceous - early Tertiary allochthonous sediments to the west (Thompson, 1961).

Fig. 8.5. Map of Hikurangi Swamp area showing swampland including Otakirangi Swamp.
Otakairangi Swamp occupies a 77 ha flat basin c. 100 m a.s.l., bounded to the north, south, and west by small hills (up to 250 m a.s.l.) of Waipapa greywackes and late Cretaceous carbonaceous sandstones. Drainage is to the southwest via the Wairua River, which has cut through an outcrop of Horeke Basalt. Eight km to the east of the coring site, the Miocene hypersthene dacite dome of Mt Hikurangi rises to 400 m a.s.l (Fig. 8.8). The subsurface stratigraphy of Hikurangi Swamp has been described from coal exploration drillholes (Isaac, 1984).

Otakairangi Swamp has been drained several times this century and is currently used for pastoral farming. It is prone to flooding during heavy rains, such as occurred during January, 1989 (Fig. 8.8) (see also Wells (1983)). Davoren (1978) classified the Hikurangi system as oligotrophic, high moor swamp. The uppermost peats consist primarily of moderately decomposed *Cladium* spp., and *Schoenus brevifolius*, *Empodisma minus*, and *Gleichenia dicarpa* as well as woody roots and fragments, probably of *Leptospermum*.
Fig. 8.7. Otakairangi Swamp, January 1988, looking southwest from Heaton Rd (see Fig. 8.6). X marks approximate position of pollen core site.

Fig. 8.8. Part of Hikurangi Swamp east of Otakairangi (see Fig. 8.5) flooded during heavy rainfall, January 1989. Photo NZ Herald
scoparium. Stumps of Dacrycarpus dacrydioides and Leptospermum scoparium (or Kunzea ericoides) are common at the present day surface (Davoren, 1978).

Depth probings by the author and previous mapping by Davoren (1978) revealed that the depth of peat is greatest in the eastern part of the basin (Fig. 8.6). The core site was 20 m south of a large drain running NW-SE across the swamp. The vegetation at the core site consists of Juncus pallidus and introduced pasture grasses and herbs, including Lotus pedunculata, Oenanthe pimpinellioides (Apiaceae); Festuca pratensis, Holcus lanata, Agrostis capillaris, (Poaceae); and Hypicar radicata (Asteraceae).

8.4.2 Stratigraphy and chronology of the pollen core

Six metres of sediment were extracted (Fig. 8.9). The basal 50 cm consists of stiff, pale blue clay and the uppermost 50 cm of dark, wet, fibrous peat. The remainder consists of fine, alternating bands of pale yellow clay and brown peat: from 50 - 250 cm and from 490 - 540 cm the clay bands are thicker than the peat bands, whereas the peat bands are thicker in the intervening section. Resistant layers within the banded clay/peat sections were encountered during coring. These may have been wood, although none was recovered. Well preserved large kahikatea (Dacrycarpus dacrydioides) evidently exhumed from the swamp sediments were observed elsewhere at the swamp.

No tephra layers were observed at this site, although the Kaharoa Ash had previously been recorded here (J.E. Cox, N.Z. Soil Survey, pers. comm., 1988). The chronology of the pollen core is thus based entirely on ten radiocarbon dated peat/clay samples. These consisted of 5 cm of vertical cored sediment, taken at c. 50 cm intervals between 50 - 475 cm (Fig. 8.9). As the date for the basal radiocarbon sample at c. 475 cm, 29,300 ± 1300 yr BP (NZ7547A), approaches the upper limit for conventional radiocarbon dating, no samples from the underlying sediments were submitted for dating. In the absence of any independent time markers, and given the susceptibility of organic sediments to contamination by younger carbon, these dates must be treated with caution, particularly those > 15,000 BP (see 2.4.2). The sample from 350 cm (NZ7630A: 30,800 +1500 -1300 yr BP), which seems from its date to be stratigraphically out of sequence (Fig. 8.9-10), is possibly evidence that contamination may have occurred at this site. However the possibility of "mix-up between samples" during processing cannot be discounted (W.H. Melhuish, Institute of Nuclear Sciences, pers. comm., 1989).

8.5 PALYNOOLOGY

8.5.1 Pollen sampling and the pollen sum

Fifty-seven pollen samples (Q06/f59(2A): i - Lvii) were taken, mostly at 10 cm intervals from 0 - 550 cm and at 575 and 600 cm (Fig. 8.9). Besides those taxa normally excluded from the pollen sum, Leptospermum, Syzygium, and Coprosma were also omitted. Pollen of these taxa exhibit highly variable abundances and were occasionally observed in
Fig. 8.9. Stratigraphy and radiocarbon chronology of Otakairangi pollen core Q06/59(2A); pollen samples numbered i-Lvii from top to bottom.
Fig. 8.10. Age-depth relationships for Otakairangi pollen core.
clusters or as composite grains. These are common swamp taxa and at times probably grew close to the coring site. Pollen preservation and abundance are generally good, except in the basal blue clay, where many palynomorphs are broken or degraded and low pollen concentrations were recorded.

8.5.2 Results (Fig. 8.11-12)

ZONE Ot1: 6.00 - 5.60 m

Description

*Myriophyllum* pollen characterises this zone; other aquatic pollen and spores present include *Callitriche* and *Isoetes*. Cyperaceae and *Polygonum* pollen is common. Algal spores are numerous. Asteraceae pollen is abundant, although most of these grains are poorly preserved, and recognised only by their distinctive echinate sculpturing. Other prominent herbaceous taxa are *Apiaceae*, *Ranunculaceae*, and *Tillaea*. Pollen of numerous tree taxa are present, but generally at lower percentages than in subsequent zones, e.g., *Agathis*, *Dacrydium*, *Dacrycarpus*, *Lagarostrobos*, *Libocedrus*, *Metrosideros*, *Nestegis*, *Phyllocladus*, *Podocarpus*, *Prumnopitys*. *Cyathea dealbata* spores are common. Non-aquatic pollen concentrations are lowest during this Zone.

Interpretation

A definite age for these sediments is lacking except that they are probably older than 30 ka. The site was a lake, fringed by sedges and numerous wetland herbs, of which *Polygonum* (*P.? decipiens*) was prominent. The source of the Asteraceae pollen is problematical, as this family includes numerous species of diverse habitats, including wetlands. Although Asteraceae has been included in the dryland pollen sum here, as with all other sites, it seems likely from the abundance of this pollen, that most was locally derived. Possibly this pollen represents plants growing on the fringes of the lake or at the margins of incoming streams. Fluvial transport to the site may be indicated by the abundance of *Cyathea* spores (Pocknall, 1980) and the generally poor preservation of pollen.

The abundance of locally growing herbaceous taxa makes it difficult to determine the extent of herbaceous species in the regional vegetation. Significantly, Poaceae pollen is scarce, yet this would be expected to be far more prominent if much of the region was without forest. Instead the prominence of lowland podocarp tree taxa in pollen percentages, and the virtual absence of *Nothofagus* pollen suggest the main regional vegetation type was warm-temperate forest. This interpretation is tentative however, because of low pollen concentrations, poor preservation, and the possibility of fluvial transportation and reworking of pollen.
ZONE Ot2: 5.60 - 4.70 m; > 30 ka

Description

*Myriophyllum* pollen declines initially then increases. Conversely, levels of Cyperaceae pollen and to a less extent of *Polygonum* pollen are higher in the first half of this zone. Asteraceae pollen declines abruptly to low levels, while pollen of numerous shrub taxa increase, notably *Leptospermum*, *Myrsine*, and *Coprosma*. Most tree pollen concentrations and percentages are higher during this zone, the predominant taxa being *Dacrydium* and *Libocedrus*.

Interpretation

Alternating clay-peat laminations and the changing abundance of aquatic pollen may indicate fluctuations in lake levels. Overall, aquatic plants were less prominent at this time and there were increases in herb, shrub and tree taxa tolerant of swampy substrates. These changes are consistent with the lake gradually shallowing as sediments accumulated and as plants colonised its shores. The lake may have become periodically dry.

The composition of the inferred regional vegetation varied little from that of Zone Ot1. Increases in *Dacrydium* and *Libocedrus* pollen partly reflect the decrease in Asteraceae pollen, but may also indicate the encroachment of these trees onto the swampy margins.

ZONE Ot3: 4.70 - 3.95 m; c30 - 21 ka

Description

Pollen of aquatic taxa and *Polygonum* decline and remain virtually absent for the remainder of the record. *Empodisma* pollen and *Gleichenia* spores appear for the first time and, together with Cyperaceae and *Leptospermum* percentages, exhibit highly variable percentages. *Leptospermum* pollen peaks alternate with Cyperaceae pollen peaks, whereas the *Gleichenia* and *Empodisma* spore and pollen peaks are in phase. Besides the shrub pollen taxa of the previous zone, *Dracophyllum* and *Ascarina* become prominent. *Dacrydium* remains the predominant tree pollen taxon, but also exhibits high variability. *Libocedrus* pollen is at lower levels than during Zone Ot2, while *Dacrycarpus* pollen increases. *Nothofagus fusca* type pollen rises to the 5% level, then declines. *Halocarpus* is recorded consistently for the first time. As in the two previous zones, charcoal levels are low.

Interpretation

Swamp developed over much of the basin, perhaps with localised shallow pools or wetter hollows. The alternating pollen/spore peaks between the predominant swamp taxa are similar to those described by Campbell *et al.* (1973) from Holocene peats of the eastern Bay of Plenty. They attributed alternating Restionaceae and Cyperaceae pollen peaks and variations in Restionaceae and *Leptospermum* macrofossil abundances to wetter (Restionaceae) and drier (Cyperaceae, *Leptospermum*) periods. The same plant-climate responses may have operated at Otakairangi. Overall, *Empodisma* pollen became more common during this zone and *Leptospermum* and Cyperaceae pollen less so, suggesting a
fluctuating but rising swamp water table. This is consistent with the rise of Ascarina pollen in suggesting increasing effective precipitation at this time.

ZONE Ot4: 3.95 - 2.55 m; c21 - 13.6 ka
Description
Empodisma pollen and Gleichenia spores are common, but less so than in the previous zone. Leptospermum is the predominant wetland pollen taxon. The Leptospermum pollen peaks continue to alternate with peaks of Cyperaceae, although towards the top of the zone Cyperaceae pollen falls to low levels. Charcoal concentrations are high for all but the middle sections of this zone. Only minor changes from the previous zone are evident in the tree pollen taxa: Halocarpus Libocedrus, Nothofagus fusca type, and Ascarina pollen levels and Cyathea dealbata spore levels are generally lower; Agathis, Elaeocarpus, Phyllocladus, and Prumnopitys taxifolia pollen levels are generally higher.
Interpretation
This Zone contains the earliest evidence for significant burning at this site. Fires evidently encouraged the expansion of Leptospermum populations on the swamp surface or around its margins. Both Leptospermum scoparium and Kunzea ericoides may have expanded as both species are common on swamps after fire. Lowering of the swamp water table is also implied by the change in the predominant local pollen taxon from Empodisma to Leptospermum.
Changes in the regional dryland vegetation may also suggest an overall drier climate than during the previous zone. In particular Agathis australis, Phyllocladus cf. P. trichomanoides and Prumnopitys taxifolia, which all expanded, are deep-rooted tall tree species preferring drier sites, whereas Ascarina lucida and tree ferns, which declined, are more susceptible to drought.

ZONE Ot5: 2.55 - 1.55 m; c 13.6 - 8 ka
Description
Extremely high charcoal concentrations occur in all but one sample. Empodisma pollen (especially late in the Zone) and Gleichenia spores (especially early in the Zone) rise to their highest sustained levels. Most Cyperaceae and all Leptospermum pollen levels are low. In the herbaceous and shrub taxa, Myrsine, Dracophyllum, and Asteraceae pollen increase and Poaceae pollen levels are the highest recorded in the entire sequence. Likewise Pteridium spores, otherwise rare or absent, are recorded more consistently here. In the tree taxa, pollen of Metrosideros, Ascarina and all gymnosperm taxa except Halocarpus are initially high, then fall to their lowest levels. Of these taxa, only Lagarostrobus fails to recover during subsequent zones. Conversely, Nothofagus fusca type and Halocarpus rise to their highest recorded levels, following a brief period of high Nestegis pollen levels. Pollen concentrations vary, but are generally high.
Interpretation

In the dryland vegetation, conifer-angiosperm forest evidently declined and gave way to forest and grassland communities in which Nothofagus (?N. truncata), Halocarpus and Poaceae were palynologically predominant, and which also contained a diverse shrub flora. In the swamp, much of the low moor vegetation characterised by Cyperaceae and Leptospermum/Kunzea was evidently succeeded by restiad peat bog communities. These important changes may have been associated with fire, because they occurred at a time when charcoal concentrations were highest.

Zone Ot6: 1.55 - 1.15 m; c8 - 4 ka

Description

Charcoal concentrations fall abruptly to low levels. Pollen taxa, which characterised the previous zone also decline sharply. Of these taxa, Halocarpus, Asteraceae, Dracophyllum, and Poaceae are rare in all subsequent spectra, while Nothofagus fusca type pollen falls. Leptospermum and Cyperaceae pollen increase steadily and Metrosideros and Dacrycarpus pollen curves show pronounced peaks, the latter associated with a Syzygium peak. Dacrydium pollen peaks initially, declines during the Metrosideros and Dacrycarpus peaks, and then increases again. Most of the other tree taxa which had declined during the previous zone also increase their pollen percentages. Pollen concentrations fall markedly during this zone.

Interpretation

The broad vegetation changes which had characterised Zone Ot5 were reversed during this Zone. The conifer-angiosperm forest which returned appears to have been similar to that of the pre-burning zones, but there were important differences. The expansion of Metrosideros vines, Ascarina lucida and tree ferns and the loss of Lagarastrobos colensoi suggest a milder, moister, and less frosty climate than that which had prevailed during Zone Ot4.

The brief Dacrydium cupressinum pollen expansion early in this Zone followed a period of high Empodisma and Gleichenia, and preceeded the Dacrycarpus pollen peak. This may reflect vegetation changes at parts of the swamp or swamp margins where drainage was improving. Lateral transitions from infertile, poorly drained restiad peat swamp, through a D. cupressinum belt to better drained Dacrycarpus dacrydioides swamp forest have been described in the modern vegetation at south Westland (Wardle, 1974; Dobson, 1979).

Zone Ot7: 1.15 - 0.10 m; c4 - 2 ka

Description

Empodisma pollen is virtually absent, and Gleichenia spores fall to their lowest levels since Zone Ot2. Charcoal concentrations are generally low. Cyperaceae and Coprosma pollen is common and that of Leptospermum abundant. Among the tree pollen
taxa, *Dacrydium* dominates, but the other tall podocarp taxa, *Prumnopitys* spp., and *Phyllocladus* also increase. *Agathis* pollen is consistently present, and increases towards the top of the sequence, as does *Libocedrus*. *Ascarina* is initially present but declines later in the sequence. *Nothofagus fusca* type pollen levels remain relatively low (<3%) throughout. The uppermost sample is distinctive: charcoal concentrations, *Gleichenia* and many other wetland taxa have high pollen and spore percentages, while *Leptospermum* values are low.

**Interpretation**

The expansion of *Leptospermum/Cyperaceae/Coprosma* swamp communities suggests a continued lowering of the swamp water table, perhaps due to higher net evapotranspiration. A drier overall climate at this time is also inferred from changes in the dryland taxa, in particular the expansion of the more drought-resistant *Agathis australis* and *Phyllocladus trichomanoides* and the loss of *Ascarina lucida*.

The record for the last 2000 years has largely been lost, almost certainly the result of burning and drainage of the swamp during the European era. Therefore the distinction of Polynesian and European eras cannot be made from these data. The uppermost spectrum, which is atypical for this zone, probably reflects human disturbance of the swamp vegetation and sediments.

### 8.5.3 *Nothofagus* pollen aperture counts

Aperture counts (see 2.3.8) were undertaken on *N. fusca* type pollen in an attempt to clarify the source species. A total of 276 grains were assessed from four samples (Q06/f59(2A): xviii - xxi) from the *N. fusca* type pollen-rich Zone Ot5 (Fig. 8.9). These data are compared with reference data for the four New Zealand *N. fusca* group taxa (Fig. 8.13).

The reference aperture counts (Hanks & Fairbrothers, 1976) are virtually indistinguishable for *N. truncata* and both varieties of *N. solandri*. These taxa have a single 7-aperture peak (61-66% of all grains). *N. fusca* is distinct from this group, with twin peaks for 6 and 7 apertures. The Otakairangi *N. fusca* type aperture count conforms with those of the single peak 7-aperture group, implying that *N. fusca* was not a major source species for the Zone Ot5 *N. fusca* type pollen.

Of the single peak 7-aperture group, evidence from modern distribution and ecology (Wardle, 1984) suggests that *N. solandri* var. *cliffortioides* is least compatible with the associated taxa in the Otakairangi spectra. Of the remaining candidates, *N. truncata* has a scattered distribution in Northland today, whereas *N. solandri* var. *solandri* is absent from mainland Northland. It is conceivable that both contributed to the abundant *N. fusca* type pollen in Zone Ot5. However, apart from this period, few changes to the regional vegetation are evident in the >30 ka record. Furthermore, there is no unequivocal evidence for species migration to or from Northland during this period. The most prominent source of *N. fusca* type pollen throughout the Otakairangi record is therefore likely to have been *N. truncata*. 
Fig. 8.11. (foldout) *Otakairangi* pollen percentage diagram, including summary diagram and stratigraphic plots (with taxa loadings) of the first two principal components. See Appendix 2 for explanation of 4-character pollen codes.

pollen sum = total dryland pollen excluding *Leptospermum*, *Syzygium* and *Coprosma*.

KEY TO RARE TAXA ABBREVIATIONS:

- dots (●) indicate <1% pollen sum
- NB *Ackama* (A) at depth 290 cm = 8%

A  Ackama
Ar  Aristotelia
As  Astelia
B  Beilschmiedia
C  Carmichaelia
Ch  Chenopodium
Co  Coriaria
D  Dodonaeas
Di  Dicksonia
Dy  Dyssoxylum
E  Entelea
F  Freycinetia
H  Histiopteris
He  Hedycarya
Ho  Hoheria
I  Isoetes
K  Knightia
L  Lycopodium varium
La  Laurelia
Lf  Lycopodium fastigiatum
Li  Liliaceae
Ly  Lygodium
M  Muehlenbeckia
Ma  Macropiper
Me  Melicytus
N  Nothofagus menziesii
P  Pseudowintera
Pa  Parsonsia
Pe  Pennantia
Ph  Parahebe
Pi  Pittosporum
Pl  Plagianthus
Po  Potamogeton
Pp  Paesia
Ps  Passiflora
Pt  Pteris
R  Ripogonum
Ra  Ranunculaceae
S  Scheflera
T  Tupeia
Tr  trilete fern spores
U  Urticaceae
V  Vitex
(blank page)
Fig. 8.13. Aperture counts for pollen of Nothofagus fusca type from modern pollen data of Hanks & Fairbrothers (1976) and from Zone Ot5, Otakairangi Swamp.

From the available Otakairangi evidence, N. truncata has probably been the only Nothofagus species of importance in Northland during the period represented. It expanded, evidently in association with fire, either during the late glacial or during the entire Last Glacial (see below, 8.6.3-4). This history of N. truncata is consistent with its scattered distribution in Northland today. It may possibly have survived in the region as an opportunistic species responding to periodic disturbances of the predominant conifer-angiosperm forest cover.

8.5.4 Principal components analysis

Of the 26 taxa which met the 5% criterion, nineteen taxa plus charcoal were included in the final analyses. An earlier analysis of the larger dataset produced low percentage variance explanations. This resulted from the large number of taxa in the dataset and the inclusion of several taxa, with ecologically different species. To offset these problems, the following taxa were omitted from the original 27: Libocedrus, Phyllocladus, Podocarpus, Coprosma, Dracophyllum, Myrsine, and Neomyrtus. Nevertheless the remaining pool of 19 taxa plus charcoal is larger than for any other analysis undertaken here.

Taxa scores on the first two components (Fig. 8.14a) cluster into three groups,
Fig. 8.14. Plots of first two Otakairangi principal components: (a; above) taxa loadings; (b; below) sample scores. See Appendix 2 for taxa abbreviations and text for explanation of Groups 1-3.
indicated by the strongest between-taxon correlations.

GROUP 1: high positive PC1 scores; these taxa are all common during Zones Ot1 & Ot6, the lake phase. Except for *Cyathea dealbata* spores, which may represent inwashed spores, they are all either wetland herbs or aquatics.

GROUP 2: positive PC2 scores; all taxa are prominent during Zone Ot5, the charcoal-rich Zone. The clustering of *Empodisma* and *Gleichenia* with charcoal indicates a strong link between burning and oligotrophic (high moor) swamp phases in the basin.

GROUP 3: negative PC1 scores, negative (or low positive) PC2 scores; *Leptospermum* apart, these are all podocarp-angiosperm forest taxa which are predominant throughout the profile, except Zone Ot5. *Leptospermum* falls into this group by virtue of its dissimilarity with Groups 1&2 rather than by its similarity with Group 3 taxa.

Spectra scores plotted for the first two components (Fig. 8.14b) do not cluster into groups comparable with the pollen zones as readily as at other sites. Zones Ot1-Ot4 are well represented along the PC2 axis reflecting decreasing influence of GROUP1 taxa and increasing influence of GROUP3 taxa. Spectra scores for Zones Ot5 & Ot6 are more diffuse along the PC1 axis reflecting increasing influence of GROUP2 taxa. These Zones are less discrete probably because of the influence of the local taxa *Empodisma* and *Gleichenia* which are also important, but less so, in other Zones. Zone Ot7 spectra are dominated by GROUP3 taxa, especially *Leptospermum*, and these cluster at the negative end of both axes.

Stratigraphic plots for the first two components (Fig. 8.11) also reflect these taxon groups and pollen zone comparisons. However the remaining principal components achieve only minor percentage variance explanations, and exhibit no consistent trends.

In comparison with other sites, these results reveal fewer interpretable taxonomic and biostratigraphic relationships. Percentage explained variance is lower for all principal components. These features are attributed to the following.

1. The greater time interval encompassed by the Otakairangi profile.
2. More taxa were included in the Otakairangi analyses, partly due to the greater time interval. The more taxa included, the more principal components are extracted and hence the smaller the individual contribution to explained variance.
3. A comparatively homogeneous suite of dryland pollen taxa which vary little throughout most of the profile. Lack of definition in the dryland taxa gives greater statistical weight to local taxa. The latter, by contrast, show considerable variation reflecting more complex relationships with soil drainage and fertility, and with fire.

8.6 DISCUSSION

Discussion in the following sections (8.6.1-3) proceeds with the assumption that the chronology of the Otakairangi pollen core is as indicated by the radiocarbon dates (Fig. 8.9-10), with the recognition that sample NZ7630A is probably stratigraphically out of place. On this basis, Zones Ot1-4 are last glacial or older and Zones Ot6-7 are postglacial (Holocene).
Zone Ot5, which is bounded by radiocarbon dates of 13,600 ± 350 and 7,820 ± 90, corresponds to the late glacial-to-earliest Holocene period.

This chronology is then reviewed and its validity reassessed in the light of the climatic interpretations and comparisons with other records discussed in the ensuing three sections.

<table>
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<th>ka</th>
<th>local pollen zone</th>
<th>NATURE OF SITE</th>
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<th>REGIONAL VEGETATION</th>
<th>EFFECTIVE PRECIPITATION</th>
<th>TEMPERATURE RELATIVE TO PRESENT</th>
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<td>aquatic/wetland herb communities</td>
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Fig. 8.15. Summary of the history of local and regional vegetation and climate inferred from the palynology of Otakairangi Swamp.

8.6.1 Regional vegetation during the last glacial

At Otakairangi the inferred regional vegetation of the last glacial was mixed conifer-angiosperm forest (Fig. 8.15). Although the problem of palynological under-representation
limits description of forest composition, the pollen spectra suggest a broad similarity to the pre-human Northland forests. This overall similarity (Zone Ot5 excepted) between Holocene and late Pleistocene spectra contrasts sharply with pollen records from higher latitude sites in New Zealand, where forest was very restricted in extent and grass-shrubland communities were widespread during the last glacial (McGlone, 1988). However, pollen spectra from the Far North radiocarbon dated to the last glacial (Ch. 11; Dodson et al., 1988) are consistent in indicating the survival of podocarp-angiosperm forest. Knowledge of the regional extent of forest in Northland requires further information from other sites dating to this time.

The Otakairangi pollen record indicates an unusually diverse assemblage of conifer trees, including *Dacrydium cupressinum, Prumnopitys taxifolia, P. ferruginea, Podocarpus* spp., *Dacrycarpus dacrydioides, Phyllocladus* spp., *Lagarostrobos colensoi, Agathis australis, Libocedrus plumosa* and *Halocarpus kirkii*. *Agathis* is palynologically less prominent than most of the other conifer taxa in these spectra, stands of *A. australis* trees undoubtedly occurred in the mixed conifer-angiosperm forests. However the size of the Otakairangi Swamp basin probably restricted the representation of the large, wingless and presumably less buoyant *Agathis* pollen grains.

*Metrosideros, Nestegis* and at times *Ascarina* were prominent but most angiosperm trees and shrubs were also probably under-represented, again suggesting some distance between the core site and dryland forests. Judging from modern pollen representation (Ch. 5), minor pollen percentages or even traces may undervalue the abundance of the numerous tree and shrub taxa characteristic of warm-temperate lowland forest. Taxa in this category, recorded in last glacial Otakairangi pollen spectra include *Ackama, Alectryon, Beilschmiedia, Dodonaea, Dysoxylum, Elaeocarpus, Griselinia, Hedycarya, Knightia, Macropiper, Melicytus, Pennantia, Phebalium, Pseudopanax, Rhopalostylis, Schefflera, Streblus, and Weinmannia*.

### 8.6.2 Climate during the last glacial

Climatic interpretations (Fig. 8.13) can only be tentative as most of the source species indicated have wide ecological ranges. Furthermore, not all the Otakairangi pollen taxa can be interpreted unambiguously, e.g., *Libocedrus, Phyllocladus, and Halocarpus*. It is possible that pollen of these taxa are from species with higher altitudinal and latitudinal distributions and which are absent from Northland today. Without macrofossil evidence therefore, the presence of *L. bidwillii, P. asplenifolius* var. *alpinus*, and *H. bidwillii* cannot be discounted. Nevertheless the conifer-angiosperm forest association and lack of significant grass-shrubland communities suggest that the northern, lowland species of these problematical genera are represented, *i.e.*, *L. plumosa, Phyllocladus trichomanoides, P. glaucus, H. kirkii*.

There is also some equivocal evidence for slightly cooler climate from the records for *Lagarostrobos, Quintinia, Sphagnum*, and *Poaceae*. Although never prominent at
Otakairangi, the pollen and spores of these taxa were more common during the late Pleistocene than during the Holocene. *Lagarostrobos colensoi* is a frost-tolerant tree (Sakai & Wardle, 1978), which is common today in lowland to montane western South Island swamp forests. In northern New Zealand it occurs at frosty sites, or on infertile swamp soils. *Quintinia* species occur in hilly forests in Northland today (Wardle et al., 1983), although they may also occur in lowland Northland forests (Allan, 1961). *Sphagnum* spp. become increasingly important at higher latitudes and at higher altitudes and are uncommon in northern New Zealand today (Dobson, 1979). Poaceae pollen dominated last glacial spectra from elsewhere in New Zealand, indicating substantial loss of forest and harsher climates (see 1.3.4). At Otakairangi however, the low (<5%) Poaceae pollen percentages do not suggest any significant loss of forest cover, nor are they likely to represent local sources growing in the swamp basin. Long distance dispersal from higher latitudes cannot be discounted.

These taxa are thus inconclusive indicators for cooler temperatures. At best their uncommon occurrence at Otakairangi suggests only a minor temperature depression, perhaps 1-2°C. On the other hand temperature depression could have been considerably greater, without markedly affecting the regional forest. There may be greater significance in the absence of key cool climate taxa, *e.g.*, *Nothofagus menziesii*, which were prominent at higher latitudes during the last glacial.

Minor changes in the dryland vegetation, if paralleled by developments in the swamp basin, are likely to reflect variations in effective precipitation rather than in temperature alone. The rise of *Ascarina* during Zone Ot3, which coincides with the expansion of restiad communities in the basin, suggests a change to a moister overall climate for the period 30-21 ka. The subsequent decline of *Ascarina* during Zone Ot4 was accompanied by burning, evidently localised in the swamp basin, the decline of restiad communities, and the expansion of *Leptospermum*. These changes may indicate a drier overall climate for the period 21-13 ka.

Few climatic interpretations can be made from the palynology of Zones Ot1-2, when the swamp basin was occupied by a lake. The regional vegetation evidently varied little from the subsequent zones while the distinctive local flora is attributed to the lacustrine environment. The presence of the lake itself may indicate a wetter climate or, more likely, it may have formed and persisted through geomorphic controls. Similarly, its subsequent shallowing and eventual disappearance may indicate a change to drier climates or, alternatively, the gradual infilling of the lake through hydroseral succession, independently of climate. Drainage of the lake, following river incisionment through a geomorphic barrier, is another non-climatic possibility.

### 8.6.4 The late glacial (Zone Ot5)

The most striking changes in dryland vegetation inferred from these data occurred
during the late glacial, assuming the radiocarbon dates are correct. The palynological changes at Otakairangi Swamp suggest a period of sustained disturbance during which the extent of conifer-angiosperm forest was substantially reduced. Many of the taxa which subsequently rose to prominence are light demanding, opportunist species capable of exploiting canopy gaps in damaged forests, *e.g.* *Nothofagus, Nestegis, Myrsine, Pteridium*, Poaceae and Asteraceae. Of these taxa, *Nothofagus (N. truncata)* was palynologically the most prominent. *Nothofagus* species can establish directly on new surfaces provided seed is available, and this gives them an advantage over many podocarp-angiosperm species in primary succession. (Cockayne, 1926; Holloway, 1954; Wardle, 1984). However *Nothofagus* are not well adapted for long distance dispersal, nor do they compete well where a dense vegetation cover is already present (Wardle, 1984).

Given the abundance of charcoal shards in the Zone Ot5 pollen spectra, fire seems to be the most likely disturbance mechanism which could account for these vegetation changes. It may be postulated that fires, previously intermittent and possibly confined to the swamp basin, now became more common and affected surrounding areas, evidently destroying large tracts of conifer-angiosperm forest. In the pollen assemblages the dominant conifer-angiosperm taxa gave way to *Nestegis* initially, then to *Nothofagus truncata, Halocarpus* and Poaceae. It is possible that these taxa represent distant pollen sources which merely were accentuated at this time by the reduction of local and extralocal pollen. More likely however, given their increased pollen concentrations at this time (Fig. 8.10), the *N. truncata* communities colonised fire affected areas near Otakairangi. That burning was repeated and possibly extensive is suggested by the consistently high levels of charcoal occurring throughout this zone. Whether the *N. truncata* communities were sustained by subsequent fires cannot be determined from these data. However the available evidence suggests that the return of conifer-angiosperm forest coincided with the cessation of repeated burning following several thousand years of *Nothofagus* dominance.

An alternative explanation is that the abundant charcoal shards and pollen grains from those taxa which characterise this Zone were eroded out of older soils and washed into the basin during floods. The swamp is prone to flooding today (8.4.1; Fig. 8.6b) and the laminated clay/peat stratigraphy of this section of the core may reflect a period of repeated inundation. However the pollen grains in this zone show few signs of deterioration, which might be expected to result from reworking and fluvial transportation (Cushing, 1967); in fact they are among the best preserved in the entire sequence. Furthermore, pollen concentrations are higher than in previous zones, whereas reworking might be expected to result in lower pollen concentrations. Therefore, on the available evidence here, I conclude that the charcoal and palynomorphs are likely to be *in situ*.

Neither the amount of area affected by fires, nor the extent to which *Nothofagus truncata* communities covered the Northland landscape can be determined from this single site. However, from the sparse evidence currently available there are indications that fires...
occurred elsewhere in Northland at this time. Two other late glacial sites are known from Northland, both from the far north. At Paranoa Swamp, North Cape (Dodson et al., 1988), the evidence is inconclusive for this time. The burning which damaged the vegetation at Trig Road (Ch. 11) also occurred during the late glacial-to-early Holocene. Charred *Phyllocladus trichomanoides* leaves from Puketura near Otakairangi (Fig 8.1a), radiocarbon dated as 7710 ± 160 yr BP are further evidence for early Holocene fires in mid-Northland (Schouten 1976). It is also interesting to note that *N. fusca* type pollen is abundant in early Holocene (c. 8 ka) spectra at the base of the Oruariki Swamp (MacDonald, 1984) pollen profile, but then falls to minor levels.

However, there are problems with the interpretation that Zone Ot5 spectra are late glacial. Although the severity and extent of burning suggest drier conditions, the evidence for fires coincides with the expansion of restiad peat bog communities and an initial surge in peat growth in the basin, which suggests wetter overall, and possibly cooler climate. A change in the seasonal distribution of rainfall, coupled with higher temperatures, resulting in drier and warmer summers but wet winters, might explain this apparent anomaly. Burning, although more frequent or extensive, would have been restricted to the driest time of year, while a high water table persisted for the remainder of the year. Nevertheless it is difficult to understand why *Nothofagus ?truncata* should be virtually absent during most of the last glacial, a period of cooler and probably drier climate, only to expand, dramatically, during the late glacial, when climate was warming. At higher latitudes elsewhere in New Zealand during this period shrub-grassland communities with scattered *Nothofagus* forest were replaced by expanding podocarp-angiosperm forest. At Otakairangi in mid-Northland, the reverse evidently occurred as conifer-angiosperm forest gave way to *Nothofagus* (*N. ?truncata*)-dominated forest and shrub-grassland communities.

In view of these problems, it is necessary to review the radiocarbon chronology of the Otakairangi pollen core, upon which correlation with other data is based.

### 8.6.4 The radiocarbon chronology reviewed

As noted above (8.4.2), NZ7630A is stratigraphically out of sequence with the other dates at this site, and is possibly evidence for carbon contamination. An older radiocarbon age may result from the introduction of water rich in dissolved carbonate, either through erosion in the catchment (e.g., Oldfield, 1978) or by water table movement (e.g., Polach, 1976). This phenomenon, described as "hard water error" by Deevey et al., (1954) (see also 2.4.2) occurs in areas of carbonate rocks and may be significant when samples to be dated are low in organic carbon e.g., lake and swamp sediments. On both these grounds, Otakairangi swamp sediments may be prone to hard water error, and furthermore, their stratigraphy and palynology indicate the swamp to have been periodically subject to water table movement and flooding.

Contamination of NZ7630A by old carbon would explain why it has an older
radiocarbon age than dated samples from underlying sediments, but it does not reconcile the conflict between Zone Ot5 and other New Zealand late glacial pollen spectra; nor does it account for the ecological problems which emerge if Zone Ot5 is assigned a late glacial age (see above 8.6.3)

Alternatively, it may be argued that contamination by younger carbon has affected all the Otakairangi dates of pre-Holocene age. If so, the Nothofagus grassland zone (Ot5) may represent a period of cooling corresponding to the last glacial; the preceding Zones, Ot1-4, would presumably correspond to the last interglacial. In addition to contamination by modern carbon, this hypothesis requires a considerable slowing of sedimentation rates, or post-depositional removal of sediments, as Zone Ot5 covers only about one vertical metre of sediment (Fig. 8.9).

Slower sedimentation rates or periods of non-deposition would not be unexpected at this Northland site during a cool, dry glacial period, particularly if substantial forested areas remained. High charcoal concentrations are interpreted as evidence for repeated burning at the swamp surface, which may have resulted in loss of sediment. Higher pollen, spore, and charcoal concentrations during Zone Ot5 (Fig. 8.10) are also indicative of either slow sedimentation rates, removal of sediment through burning, or both. The possibility of contamination by modern carbon through downwards percolation of organic acids, or root penetration by overlying woody vegetation cannot be discounted. The pollen spectra indicate swamp forest developed near the site during the early Holocene, and large Dacrycarpus dacrydioides logs have evidently been exhumed from the swamp sediments (8.4.2).

Thus the possibility that Nothofagus forest and shrub-grassland communities were the dominant vegetation in Northland during the last glacial, cannot be refuted from these data. Indeed this interpretation of the Zone Ot5 spectra may be more explicable in terms of modern plant ecology, and conforms with other paleoclimatic evidence (including palynology) from elsewhere in New Zealand. The alternative hypothesis, that Ot5 spectra are late glacial, may appear to be consistent with the few other Northland pollen spectra dated to this time (see above, 8.6.3). However, it is possible that these other records have been influenced by similar phenomena, i.e., slow- or non-deposition, or burning related removal of sediment during the last glacial, plus contamination by younger carbon. Certainly there is some evidence to suggest this has occurred at Trig Road (Ch. 11). A conclusion must await further evidence at more reliably dated last glacial pollen sites from Northland.

8.6.5 Holocene vegetation and climate (Zones Ot6-7)

Following the inferred period of burning, which probably continued into the early Holocene, Poaceae and Halocarpus pollen virtually disappeared from the Otakairangi record and Nothofagus ?truncata) pollen declined steadily to <5% levels. Dryland vegetation patterns during the early Holocene are partly obscured by the development of swamp forest in the basin, where it is suggested (above) that Dacrydium, Dacrycarpus, and Syzygium trees
became prominent. *Dacrydium* at least was probably also important in the surrounding forest, along with *Metrosideros* lianes and possibly *Beilschmiedia* spp. *Agathis* and *Ascarina* pollen, both absent from Zone Ot5, now re-entered the sequence.

That the period of burning at Otakairangi seems to have ended abruptly around 8 ka has implications for the climate of the early Holocene. At this time, a moist, warm climate evidently prevailed throughout New Zealand. As temperatures are unlikely to have been cooler in mid-Northland than during the late glacial (or last glacial), the cessation of burning at Otakairangi is consistent with higher rainfall during the early Holocene.

Late Holocene sedimentation rates (Fig 8.8) and pollen concentrations (Fig 8.10) varied markedly from those of the early Holocene. The five pollen spectra of the early Holocene Zone Ot6, covering 50 cm of vertical sediment, span c. 4 - 5,000 years, whereas the 12 spectra (120 cm) of the subsequent Zone Ot7 span a much shorter interval. However the Holocene chronology is based on just three radiocarbon dates and sedimentation rate variations are indicated. During the late Holocene, *Metrosideros* lianes were evidently less frequent, while the tall conifer trees *Agathis*, *Libocedrus*, *Prumnopitys*, *Podocarpus*, and *Phyllocladus*, were all more frequent than previously.

The Holocene section of the Otakairangi pollen record has many similarities to the more detailed pollen records obtained at Oruariki Swamp (MacDonald, 1984) and McEwen’s Bog (Kershaw & Strickland, 1988). All indicate a regional vegetation of mixed conifer-angiosperm forest; *Dacrydium*, *Phyllocladus*, and *Metrosideros* were the most prominent pollen taxa; *Agathis* pollen curves show similar trends.

*Agathis* pollen was absent during the late glacial and early Holocene at Otakairangi, when spectra were dominated by *Nothofagus* (7N. truncata) pollen. The Otakairangi Holocene *Agathis* record begins with sediments dated at 7,820 ± 90 yr BP (NZ7617). At Oruariki Swamp, *Agathis* is first recorded above the basal *Nothofagus* pollen-rich spectra, dated at c. 8,000 yr BP (MacDonald, 1984). At McEwen’s Bog, *Agathis* pollen is present throughout the 6.5 ka record. In addition, Mildenhall (1985) reported a spot sample from the North Kaipara Barrier containing abundant *Agathis australis* leaves and pollen with a corrected radiocarbon age of 7,050 ± 90 BP (7,800 - 8,000 conventional radiocarbon years; 8.3.2). From these records it may be inferred that a postglacial expansion of *A. australis* occurred in Northland around 7-8 ka. The Otakairangi profile provides a much longer Northland *A. australis* history than hitherto showing that *A. australis* was present for most of the >30 ka record. Its only significant period of absence was during the late glacial - early Holocene, when conifer-angiosperm species were evidently reduced by fire.

Following the postglacial expansion around 7-8 ka, *Agathis* pollen remained important and was evidently increasing towards the top of the Oruariki Swamp and McEwen’s Bog sequences, until set back by burning. This recent burning phase, which continued to the present, may have been entirely human-induced. It is missing from the Otakairangi profile. From this evidence it would appear that *A. australis* may have been
especially susceptible to burning in the past. During the human deforestation era, fires at or near Oruariki Swamp and McEwen’s Bog evidently damaged *A. australis* earlier and more severely than other trees. At Otakairangi Swamp, *Agathis* pollen levels show a marked decline during the charcoal rich Zone Ot5 spectra. The susceptibility of *A. australis* forest to burning was noted by early botanists (*e.g.* Colenso 1844, p.77; Cockayne, 1928, p.156).

The stratigraphic record of *Ascarina* at Northland sites is also of interest, because at other North Island pollen sites this taxon consistently shows a decline during the late Holocene from an early Holocene peak (McGlone & Moar, 1977). At Oruariki Swamp (MacDonald, 1984), *Ascarina* declines from c. 5% levels in the lower half of the sequence (early Holocene?) to trace amounts in the upper half (late Holocene?). However, at the two eastern Northland sites (Otakairangi Swamp and McEwen’s Bog (Kershaw & Strickland, 1984)), no clear trends are evident except that *Ascarina* pollen declines towards the top of both profiles. From this evidence, *Ascarina* pollen may be a less reliable marker of early Holocene strata in Northland than it is elsewhere in North Island. This is presumably because source plants were more sparsely distributed in Northland, as is the case today.

Mid to late Holocene climatic changes inferred from the Otakairangi pollen profile are broadly comparable to those proposed by Kershaw & Strickland (1988) (see above 8.3.2). A late Holocene *N.? truncata* increase, comparable to that at McEwen’s Bog, is barely evident at Otakairangi Swamp. Here however, steady increases in *Agathis*, *Phyllocladus*, and other tall podocarp taxa, and evidence for a lower water table, suggest a trend towards drier climates during the mid to late Holocene. At McEwen’s Bog, a subsequent rise in effective precipitation (perhaps due to further cooling) was inferred from the transition from semi-swamp forest to raised bog communities and faster accumulation of peat after c. 3.4 ka. At this time the Otakairangi swamp consisted of *Cyperaceae/Leptospermum* (low moor) communities, rather than raised bog. Nevertheless a surge in peat growth around 3 - 2 ka, comparable to that at McEwen’s Bog, is indicated by the uppermost two radiocarbon dates, and by the transition from laminated clay/peat to wet peat.
CHAPTER 9 TRIG ROAD, FAR NORTH

9.1 FAR NORTH PHYSICAL AND BIOLOGICAL SETTING

9.1.1 Geology, physiography and soils

Far northern New Zealand consists of two geologically distinct regions, hereafter referred to as the Far North. The Aupouri Peninsula is a long, narrow tombolo, predominantly of consolidated to semi-consolidated Pleistocene sands with a veneer of semi- and unconsolidated wind blown sands of mostly Holocene age (Fig 9.1; Kear & Hay, 1961; Hicks, 1975). It has provided a land connection since at least the late Pleistocene (Ricketts, 1975), between 'mainland' Northland, Mt. Camel, and the North Cape region, an outlier of Lower Miocene and Cretaceous sedimentary and igneous rocks (Kear and Hay, 1961). A series of terraces occurs within the Pleistocene sands (Ricketts, 1975), at heights which compare favourably with terrace altitudes at other coastal sections in northern New Zealand (Brothers, 1954; Chappell, 1975; Richardson, 1975) and may relate to interglacial high sea-level stands. Many of the terraces are capped by extensive peat deposits, some of which has been radiocarbon dated to the last glacial (Ricketts, 1979), with residual soil profiles suggesting they developed under forest cover (Hicks, 1975; Millener, 1981). Volcanic rocks have developed soils described as moderate to well-drained red brown clays, and poorly drained and podsolised loams and silty loams occur on sedimentary rocks (Sutherland et al., 1979).

![Three Kings Is. Map](image)

Fig. 9.1. Far North showing Quaternary geology and pollen sites.
9.1.2 Climate

The Far North climate is mild, humid and rather windy, owing to its low latitude, low elevation and extensive surrounding ocean. Mean annual temperatures of 15.5 - 16°C and sunshine hours exceeding 2120 / yr (Moir et al., 1986) are among the highest recorded for any New Zealand region. Rainfall is low to moderate, ranging from 1083 mm/yr at Cape Reinga to 1429 mm/yr at Kaitaia (Moir et al., 1986) and is strongly related to elevation. Winters are usually wetter than summers, when soil moisture deficits are common. Frosts are rare. Prevailing winds are south-westerly.

9.2 INDIGENOUS VEGETATION

9.2.1 Modern vegetation

Te Aupouri Peninsula

Seral coastal scrub communities occupy the unstable dunes of both coasts. Stable dunes support scrub dominated by Leptospermum scoparium and Kunzea ericoides. Typha angustifolia is common on the deeper, sand-free peat swamps, whereas sedge swamp communities occupy shallower and sandy peat, with Schoenus spp., and Cladium teretifolium prominent and, on drier margins, Gleichenia cincinata (Hicks, 1975). Forest is absent, except for isolated patches of kahikatea (Dacrycarpus dacrydioides) swamp forest in the south of the peninsula. In the hills of the same area, early European settlers described angiosperm-dominated forest containing stands of pure kauri (Agathis australis) and podocarps (Dick, 1950). Dunal scrub communities were also more extensive than at present, and apparently isolated remnants of pohutukawa (Metrosideros excelsa) and kohekohe (Dysoxylum spectabile) forest were reported.

North Cape

The present vegetation cover is mostly Leptospermum/Kunzea-dominated heathlands (McLean et al., 1985). Mitchell (1984) recognised five associations in the forest remnants of the region:
- three predominantly angiosperm associations with some coastal affinities including as common species Beilschmiedia tarairi, B.tawa, Dysoxylum spectabile, Vitex lucens, Sophora microphylla, Elaeocarpus dentatus, Cordyline australis, Corynocarpus laevigatus, Myrsine australis, Metrosideros excelsa, M. robusta, Rhopalostylis sapida, Schefflera digitata, Hoheria populnea, Cyathea dealbata, Knightia excelsa and Prumnopitys ferruginea;
- a late successional kanuka association consisting mainly of Podocarpus totara, Pseudopanax crassifolius and Kunzea ericoides;
- a kauri association consisting mainly of *Phyllocladus trichomanoides*, *Agathis australis*, *Dacrydium cupressinum*, *Libocedrus plumosa*, *Halocarpus kirkii*, *Lagarostrobos colensoi* and *Toronia toru*.

Mitchell (1984) noted that the kauri association occurs most frequently on ridges and gives way to angiosperm (*Beilschmiedia taraire*-dominant) associations in gullies.

### 9.2.2 Evidence for Quaternary vegetation

There seems little doubt that the present vegetation is fire induced (Dieffenbach, 1843; Gardner & Bartlett, 1980; Mitchell, 1984; Enright et al., 1988). From the burnt remains of large *Agathis australis*, Dieffenbach (1843) concluded that this species had recently been extensive in the area.

A pollen sequence from Paranoa Swamp, North Cape (Fig. 9.1), indicates persistent conifer-angiosperm forest for the last 17,000 years (Dodson et al., 1988). The authors expressed some uncertainty about the radiocarbon age estimate for the base of the sequence, as geomorphic evidence suggests a postglacial age for the site, and saline indicators and small input of *Nothofagus brassii* type pollen could suggest an estuarine unit contaminated by old carbon. A sediment change in the upper part of the record is dated at c. 6 ka and the remaining age estimates for this site are based on an assumed constant rate of sedimentation between these two dated horizons. Maximum diversity and complexity in the forest vegetation between 10.0 and 6.8 ka was interpreted as evidence for the warmest period in the record. *Nothofagus* pollen levels were never important, while *Dacrydium* and *Podocarpus* pollen and tree fern spores dominated throughout. *Agathis* pollen was initially absent, but levels increased from an estimated date of 11,500 yrs BP, then declined after 3000 yrs BP, perhaps associated with droughtiness. Shrubland also occurred throughout the record and appears to have been associated with natural fire.

A vertical sequence of peat lenses interbedded with organic-rich sands near Houhora township (Fig. 9.1) has yielded palynofloras ranging in radiocarbon age from >21,900 to 17,000 BP (Appendix 12; D.C. Mildenhall, pers comm., 1989). The six samples analysed all contain a similar palynoflora indicating derivation from an acid *Sphagnum* peat swamp surrounded by manuka (*Leptospermum*) flats, with podocarp forest in the background. Charcoal occurs in all samples suggesting periodic fires. *Agathis* pollen is absent, but otherwise the inferred vegetation is not unlike that which would be expected for late Holocene time, prior to the human era.

Other late Quaternary palynofloras have been obtained (by Harris in Leitch, 1966; Mildenhall, 1973a; 1974; in Ricketts, 1975; Pocknall in Millener, 1981), from spot samples taken at various Far North localities. Several distinct groups of assemblages emerge: podocarp-dominant (Mildenhall, 1973;1974); *Nothofagus* (including *N.menziesii*)-dominant (Leitch, 1966; Mildenhall, 1973a;1974; Millener, 1981) and *Leptospermum* or Restionaceae-
dominant (Mildenhall, 1973, 1974). Radiocarbon dates for peats associated with the palynofloras of Mildenhall (1974) indicate them to be mostly of late Otiran age. These peats contain abundant podocarp (especially Dacrydium cupressinum) pollen, with Nothofagus rare. The remaining palynofloras reported from far north spot samples have not been dated; however the diverse communities and broad climatic range indicated suggest they probably represent several stages within the Quaternary sequence. Nothofagus menziesii, which today commonly forms the tree-line throughout New Zealand south of c. 37° S, but is not found north of that latitude, has undoubtedly occurred in the Far North at times during the Quaternary.

In addition to forest remnants and palynological evidence, there is ample evidence that the North Cape region and the consolidated dunes of Te Aupouri Peninsula were forested during much of the Holocene. Peats of Holocene age, formed in interdune depressions, contain abundant logs of forest species, including a Agathis australis specimen from near Sweetwater, radiocarbon dated to 1860 ± 40 years ago (Hicks, 1975). Numerous other radiocarbon dates on faunal species usually associated with forest (land snails, avifauna, Sphenodon) also indicate that forest persisted up till pre-human times (Millener, 1981).

Despite a warm climate, the North Cape contains surprisingly few 'tropical' plants (Cheeseman, 1897) and no species is endemic to the North Cape Region (Gardner & Bartlett, 1980). With the exception of an unnamed species of Metrosideros (Gardner & Bartlett, 1980), most of the forest species found in the region today range throughout northern New Zealand and can grow under a variety of climates. Rare specimens of Lagostrobos colensoi, Podocarpus hallii, and Pseudowintera axillaris, which are more typical of higher latitudes and altitudes have been recorded at harsher sites (Gardner & Bartlett, 1980; Mitchell, 1984). In contrast, the flora of Three Kings Islands, geologically and (presumably) climatically similar to North Cape region and 15° latitude further north, is noted for its tropical affinities and strong endemic element (Gardner & Bartlett, 1980). Although Cheeseman (1897) attributed the lack of 'luxuriant' vegetation in the North Cape region to its arid climate, the essential distinction between these two areas would appear to be their links with the 'mainland' during the Quaternary. Whereas the North Cape region has been connected to 'mainland' Northland during at least three glacial stages and the entire present interglacial (Ricketts, 1975), the Three Kings Islands have remained isolated since their formation in pre-Pliocene time (Fleming, 1979). It has therefore been proposed that the North Cape flora (and that of mainland New Zealand in general - see Fleming, 1963) lost tropical and endemic species during Pleistocene glacial stages, through the direct effects of depressed temperatures and by competition from 'mainland' cool-climate species (Kelly, 1967; Gardner & Bartlett, 1980).

On the other hand, it has been suggested that the Northland region could have
provided refugia for forest during glacial events (Wardle, 1963; Clayton-Greene, 1978; see 1.4.5). The occurrence, at coastal localities, of subfossil wood from several lowland forest species (Leitch, 1966; Goldie, 1975; Hicks, 1975; Rickett, 1975; Millener, 1981), in particular Agathis australis, is interpreted as evidence for glacial forest inundated by postglacial sea-level rise.

9.3. FIELD AND LABORATORY WORK

9.3.1 Trig Road Swamp, locality and description

Pollen, plant macrofossil and radiocarbon samples were collected by Dr J.Ogden (AU Botany) from Trig Road swamp, a hollow formed in consolidated dunes of late Pleistocene age (Hicks, 1975), 6 km north-west of the township of Houhora (GR NZMS260 N03/169121; Fig. 9.1-4). The swamp hollow is c. 4 ha in area, and roughly oval in shape with a central drain running east-west down its long axis (Fig. 9.2). Little of the natural vegetation remains; manuka (Leptospermum scoparium) appeared to have been the principal woody species on the drained peat. The surrounding dunes are clothed with mature pines (Pinus radiata) and wattles (Acacia). Protruding Agathis australis logs indicate that the surface of the peat had been lowered by about 2 m. Fire scars on these logs attest to recent fires on the swamp.

Fig. 9.2. Trig Road site map
Fig. 9.3. Trig Road swamp (background) during excavation of Agathis australis (foreground) and other buried logs; photo J. Ogden.

Fig. 9.4. Typical plant macrofossil sample from Trig Road, including leaves and cones of Agathis australis.
At the time of sampling, the site was being excavated for *A. australis* timber. In total the contractors extracted 50-60 trees of >1 m diameter (Fig. 9.3). Several trees were c. 2.5 m diameter and at least 20 m to the height of the first branch. Nearly all the logs were lying with their heads towards the centre of the basin; heads were typically lower than roots. Cut ends of stockpiled logs were highly asymmetric, as is typical of trees growing on steep slopes. In parts the contractors had reached depths of > 6 m without reaching the bottom of the peat basin.

Although the excavations assisted with sample collection, it also prevented subsequent field sampling as the site was highly disturbed. Therefore all samples were collected on a single occasion in October 1986.

### 9.3.2 Stratigraphy and chronology of the pollen profile

Pollen samples (N03/f39 (i-xiv)) were taken at 10 cm intervals from the surface to a depth of c.140 cm (the water table) from the sides of a hole made during log excavation (Fig. 9.2;5). The sides were cut back to the undisturbed peat and sampled by pressing a glass vial into them. There was some evidence that fine roots from the surface vegetation penetrated the whole profile, but care was taken to avoid these. The vertical section included *Agathis australis* wood specimens at around 140 cm and 70 cm depth, a leaf litter horizon between 110 cm - 90 cm, and a 1 cm charcoal horizon at 27 cm (Fig. 9.5).

A total of nine radiocarbon dates were obtained. The four replicate pollen samples (see below, (5) - (8)) were small, covering a vertical interval of no more than 2 cm, and required dating by tandem accelerator mass spectrometry - indicated by the prefix NZA. The remaining dates - prefixed by NZ or SUA were obtained by proportional gas counting.

1. A 70-ring piece of *Agathis australis* wood taken from beneath the bark of a 2.6 m diameter log, unearthed by the logging contractors from an unknown, but considerable depth, was dated as 35,700 ± 500 yrs BP (SUA2746) (J.Ogden, pers. comm., 1988).

2. *Agathis australis* leaves were selectively picked from leaf litter samples MS1-3 and a composite subsample was dated as 34,070 + 760 - 840 yrs BP (NZ7632).

3. A peat sample from 142-147 cm, near the base of the pollen profile was dated as 22,300 ± 370 yrs BP (NZ7514).

4. The inner pith (containing the first 20 rings) of a small *Agathis australis* branch from 130-140 cm within the pollen profile was dated as 19,850 ± 400 yrs BP (NZ7633).

5. Duplicate of pollen sample N03/f39(xi), from 120 cm, was dated as 29,620 ± 660 yrs BP (NZA843).

6. Duplicate of pollen sample N03/f39(ix), from 90 cm (within the "leaf litter layer" of the pollen profile, was dated as 28,090 ± 660 yrs BP (NZA828).

7. Duplicate of pollen sample N03/f39(vi), from 60 cm, was dated as 23,500 ± 400 (NZA829)
(8) Duplicate of pollen sample N03/f39(i), from 10 cm, was dated as $3,870 \pm 120$ yrs BP (NZA453).

(9) Charcoal rich peat from 26-34 cm was dated as $10,370 \pm 100$ yrs BP (NZ7513).

The difference between (2) and (6) above suggests that the leaf litter samples do not constitute a single layer, as originally thought. Further discussion of the implications of these radiocarbon dates is deferred until after the pollen results are presented.

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**Fig. 9.5. Stratigraphy and chronology of Trig Road pollen profile.**

### 9.3.2 Plant macrofossil analyses

Plant macrofossil samples (Fig. 9.4) were collected from three locations c.60 m apart on a transect along the main drain (Fig. 9.2). It appeared that these samples came from a common horizon, although this was not certainly established. In the laboratory, these samples were examined in a semi-quantitative manner by a team of sorters working under Dr Ogden, with results listed in Table 9.1.
Table 9.1. Results of Trig Road plant macrofossil analysis; J. Ogden, pers. comm., 1989.

All three plant macrofossil samples were dominated by Agathis australis leaves, cones and gum. Other prominent species were Lagarostrobus colensoi, Dacrydium cupressinum, Phyllocladus glaucus, Leucopogon fasciculatus, Dracophyllum sinclairii, and D. lessonianum. Although the macrofossil assemblage is likely to be biased in favour of harder floral parts (e.g., harder conifer leaves are abundant; softer angiosperm leaves are rare), it provides secure evidence for species growing very close to the site.

9.4 PALYNOLOGY

9.4.1 Pollen sampling and the pollen sum

The pollen counts were converted to percentages using a sum of all dryland pollen taxa excluding Leptospermum and Restionaceae, both of which at times are over-represented. In some samples from both sites, Leptospermum pollen occurs in clumps and
this, along with the sharp fluctuations in its frequency, suggests an on-site presence.

Four additional samples from Trig Road were pollen-analysed, two each from litter samples MS1 and MS2. Each sample consisted of several sub-samples of sediment matrix, taken from different portions of the litter sample. Samples were processed and analysed in the usual way (2.3.4), except that Lycopodiwn marker spores were not added. As the counts for each pair of samples were similar, these paired counts were combined and percentages derived from the combined totals.

9.4.2 Results

Trig Road pollen profile

The pollen spectra (Fig. 9.6-7) are subdivided into four zones.

ZONE Tr1: >105 cm. Pollen spectra are dominated by Dacrydium and Weinmannia; other common taxa are Agathis, Leptospermum, Phyllocladus, Metrosideros. Numerous other forest tree and shrub taxa are present. This suggests diverse conifer-angiosperm forest grew on the dunes surrounding the site, perhaps with a shrubby fringe of Leptospermum/Kunzea which may have extended close to the core site.

ZONE Tr2: 105 - 65 cm. Pollen spectra are of a similar composition to the previous zone, except that pollen concentrations are lower and Agathis pollen is more common. Sharp fluctuations in the pollen curves for Leptospermum, Agathis (both of which occur in clumps) and for Weinmannia, together with the A. australis dominated leaf litter layer, suggest that these taxa were now growing close to the core position.

ZONE Tr3: 65-35 cm. Agathis percentages and total pollen concentrations increase while Weinmannia decreases during this Zone. Evidently A. australis became increasingly important in the mixed conifer-angiosperm forest on surrounding dunes; increasing levels of Empodisma, Cyperaceae, Leptospermum pollen and Gleichenia spores indicate the beginnings of oligotrophic swamp development in the basin.

ZONE Tr4: <35 cm. These uppermost spectra record the expansion of plants indicative of oligotrophic peat bogs (Empodisma, Gleichenia, Leptospermum, Cyperaceae) or of open water shallow pools (Myriophyllum). Increases in other shrubby taxa, including Dracophyllum, Astelia, and Leucopogon may also indicate increases in the overall extent and diversity of swamp vegetation. Agathis pollen levels decline sharply and almost disappear, while Phyllocladus and Nestegis increase and Ascarina pollen is recorded consistently. These assemblages are rich in microscopic charcoal and pollen concentrations are relatively
Fig. 9.6. (foldout) Trig Road pollen percentage diagram, including summary diagram and stratigraphic plot (with taxa loadings) of the first principal component. See Appendix 2 for explanation of 4-character pollen codes.

pollen sum = total dryland pollen excluding *Leptospermum*

KEY TO RARE TAXA ABBREVIATIONS:

dots (●) indicate <1% pollen sum

+ noted in scanning

A Asteraceae
Ac Ackama
Ar Aristotelia
Ap Apiaceae
B Blechnum
C Cyathea smithii
Ca Callitriche
Ch Chenopodium
Co Cordyline
Cr Coriaria
Cs Casuarina
D Dodonaea
G Griselinia
Ga Gaultheria
H Hoheria
He Hedycarya
Hy Hymenophyllum
I Ileostylis
K Knightia
L Lygodium
La Laurelia
M monolete fern spores
Mu Muehlenbeckia
Me Melicytus
N Nothofagus fusca
P Poaceae
Pa Parsonsia
Pe Pennantia
Pi Pittosporum
Po Potamogeton
Pt Pteridium
R Rubus
Rh Rhopalostylis
S Streblus
Sc Schefflera
Sp Sporadanthus
Sy Syzygium
T Tupeia
To Toronia
Tr trilete fern spores
high. *A. australis* evidently disappeared from the local forest vegetation, which also appears to have more diverse angiosperm elements than before.

The vegetation sequence at Trig Road and its chronology are discussed further below (9.5.2-3).

**Palynology of Trig Road plant macrofossil samples** (Table 9.2)

The plant macrofossil samples yielded similar pollen spectra to Zones Tr1-3 above (Table 9.2) MS2 samples are dominated by *Agathis* with *Dacrydium, Prumnopitys ferruginea*, (and *Leptospermum*) also abundant. Other important taxa include *Phyllocladus, Podocarpus* and *Prumnopitys taxifolia*. This assemblage indicates kauri-podocarp forest, with the canopy consisting largely of the above coniferous taxa. Numerous dicotylous taxa (including *Metrosideros, Nestegis, Weinmannia, Ackama, Ixerba*) are present, but contribute less to the pollen rain, perhaps due to a dense understorey. Taxa typical of peat bogs were present (*Empodisma, Gleichenia, Sphagnum*) together with others usually associated with wetlands (*Leptospermum, Syzygium, Lagarostrobos, Myriophyllum, Cyperaceae*).

<table>
<thead>
<tr>
<th>TAXON</th>
<th>MS2 P%</th>
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<th>MS3 P%</th>
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<td>22.2</td>
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<td>c</td>
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<th>M</th>
<th>MS3 P%</th>
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<td><em>Torenia</em></td>
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<td><em>Sphagnum</em></td>
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Table 9.2 Palynology of Trig Road plant macrofossil samples. Symbols are as follows; P% pollen percentage; t pollen/spores present in traces (<1%); - pollen or macrofossils absent; M estimated macrofossil abundance: + present; c common; a abundant. Species names in brackets were identified from macrofossils. Macrofossil data from J. Ogden, pers. comm., 1989).
MS3 samples are dominated by *Leptospermum*, with *Agathis*, *Dacrydium* and *Phyllocladus* abundant. These assemblages are similar to those of MS2, in reflecting kauri-podocarp forest, with dicotylous understorey. Differences between the two do not necessarily imply that MS2 and MS3 are of substantially different ages. *Quintinia* and *Phyllocladus* are more common in MS3, and *Prumnopitys ferruginea* less common, possibly due to the relative proximity of each sample to stands of these trees. Wetland taxa (e.g. *I-agarostrobos*, *Syzygium*, *Empodisma*) are scarce or absent in MS3, perhaps because this sample occurred in a drier part of the basin.

9.4.3 Principal Components Analysis

Thirteen taxa met the 5% criteria. PC1, which accounts for 44% of total variance, separates Tr1 samples from the other pollen zones (Fig. 9.6; Fig. 9.8b). PC1 has high positive scores for the postglacial peat swamp taxa (*Empodisma*, *Gleichenia*, *Leptospermum*) and those dryland taxa which also expand significantly at this time (*Phyllocladus*, *Nestegis*) (Fig. 9.6; Fig. 9.8a). PC2, which accounts for 23% of remaining variance has a high negative loading for *Agathis* and thus distinguishes samples where this pollen is prominent. Few other consistent stratigraphic or ecologic relationships emerge, probably due to the small sample size (14 spectra). As a result, with the exception of Tr1 samples, distinctions between the other pollen zones (Fig. 9.8b) are not as strong as at other sites where more spectra have been analysed.

9.5 DISCUSSION

9.5.1 Comparison of Trig Road plant macrofossil and pollen assemblages

Although both plant macrofossil and pollen assemblages are expected to be biased in favour of certain plants in different ways (e.g., softer angiosperm leaves may be under-represented in macrofossil assemblages; tall, anemophilous trees are generally well- to- over represented in pollen assemblages), the two types of assemblages can nevertheless be usefully compared.

Most species identified as macrofossils are represented in the pollen assemblages (Table 9.2), the exceptions being *Pittosporum tenuifolium* and *Lepidothamnus intermedius*, which are typically under represented in pollen assemblages (Macphail & McQueen, 1983). Records of fossil *Lepidothamnus* pollen are rare (Pocknall, 1981a) and at least some grains of this genus may have been recorded as "podocarpoid" (Fig. 9.6). Of those taxa with abundant macrofossils, only *Lagarostrobus* is not recorded as common in the pollen assemblages.

Of the common pollen taxa, all but *Prumnopitys taxifolia* and *Quintinia* are recorded as macrofossils. The former, a tall, often emergent conifer may not have been growing close to the site, but was probably common extra-locally and thus contributing to the regional
Fig. 9.8. Plots of first two Trig Road principal components showing (a) taxa loadings, (b) sample scores
pollen rain.

9.5.2 The Vegetation Sequence at Trig Road

The basal pollen samples indicate a forest canopy which included common *Dacrydium cupressinum, Prumnopitys* spp., *Podocarpus* spp., *Agathis australis, Weinmannia, Elaeocarpus* and *Metrosideros*. Shrubby taxa included *Dracophyllum, Myrsine, Astelia, Neomyrtus/Lophomyrtus, Leucopogon fasciculatus, Leptospermum/Kunzea*, and *Coprosma*. Many of these taxa can tolerate waterlogged conditions, which, together with the generally good pollen preservation, the peaty sediment, and the occurrence of *Cyperaceae* pollen, suggests the site at this time may have been a swampy interdune hollow enclosed by forest.

The lower half of the sequence (Zones Tr1-2; Fig 9.6), shows few changes except for fluctuating percentages of *Agathis* and *Weinmannia*. Both are interpreted as growing locally. In the Waipoua modern pollen study (Ch 3), relatively high percentages (>10%) of both taxa were recorded where trees were growing nearby and similar observations for *Weinmannia* have been made elsewhere (Pocknall, 1978; McGlone, 1982). This may explain why *Agathis* and *Weinmannia* are common in the lower Trig Road palynofloras, but rare or absent from approximately coeval assemblages recorded from other Far North localities, including Houhora Tavern.

Poor pollen dispersal and low pollen production may also account for the comparative infrequency of *Agathis* in Northland pollen spectra when *Agathis* macrofossils (leaves, wood, gum) are recorded in abundance throughout the region. However, there is also evidence in the Trig Road pollen assemblages to support the contention (Mildenhall, in Richardson, 1985) that *Agathis* pollen does not preserve as well as other pollen types. Fertilisation by an *Agathis* pollen grain can only take place by random disruption of the exine, there being no special aperture(s) or area of weak exine. Therefore, unlike most other pollen grains, where pollen tube development or the uptake of moisture is confined to special areas, *Agathis* must absorb moisture over the whole surface and burst at random, causing ill-defined rupture fractures, presumably following irregular endocrackes (D.C. Mildenhall, pers. comm., 1989). This can be demonstrated by comparing fresh *Agathis* pollen, where a large percentage of grains remain intact, with fossilised material in which ruptured grains are more common.

The peats from 105 cm to 75 cm contain macrofloral remains, consisting of fragmented leaves, cones, seeds, flowers, and small branchlets. The leaves and cones are predominantly *Agathis australis* (kauri gum is also common), but several other species are probably also represented. In the field this leaf litter horizon and samples MS1-3 appeared to be lateral equivalents from a single leaf litter layer extending throughout the site. The common features were their composition (determined in the field) and general appearance, and their consistent occurrence beneath *?A. australis* wood, at an apparently similar yet
uncertain depth. However, the radiocarbon dates suggest that the leaf litter layer in the pollen profile is not the same age as the other plant macrofossil samples.

Nevertheless, the occurrences as plant macrofossils of *Weinmannia silvicola*, *Libocedrus plumosa*, *Phyllocladus glaucus* and *Podocarpus totara* in MS1, MS2 and MS3, do assist with the interpretation of the pollen record. These genera include palynologically indistinguishable species of cooler climate affinities and more southern distributions (*W. racemosa*, *L. bidwillii*, *Phyllocladus aspleniifolius*, *Podocarpus hallii*). The occurrence at Trig Road of these latter species, which from the pollen evidence alone cannot be entirely discounted, would have implied considerable expansions of their present ranges. More plausibly, the northern or lowland species of these genera (*W. silvicola*, *L. plumosa*, *Phyllocladus aspleniifolius* or *P. trichomanoides*, *Podocarpus totara*) are represented in the Trig Road pollen spectra. These species all occur in the Far North today and the plant macrofossils indicate their presence at Trig Road during the last glacial. It is possible that the source species for these taxa changed during the c. 30 ka pollen record. However this is considered unlikely because the environmental changes implied by such considerable range expansions would presumably have been manifested in other ways in the pollen record at Trig Road or at other Far North sites.

Pollen samples (N03/f39(viii - x)) from within the leaf litter horizon contain more *Agathis* than do the underlying samples, as is to be expected from the abundant *Agathis* male cone fragments in the leaf litter layer (Fig. 9.4). Otherwise they vary little in composition from the underlying assemblages, but show a ten-fold reduction in pollen concentrations (grains/cm³), probably due to the increased sediment bulk of the leaf litter (Fig. 9.6-7). The origin of the leaf litter layer is uncertain. The radiocarbon dates on *A. australis* wood (SUA2746, NZ7514; see above, 9.3.2) confirm field observations that logs occur throughout the swamp apparently at different horizons, indicating that they are not due to a single catastrophic event. It seems more likely that the swampy basin persisted for some time as a graveyard for tall trees occupying the slopes of the surrounding dunal ridges. As noted previously all leaf litter samples were observed directly beneath (?*A. australis*) wood. Leaf litter buried by fallen trees in a swampy environment would thus be relatively insulated from biological attack and weathering processes.

Restionaceae pollen (mostly *Empodisma minus* but including *Leptocarpus similis*) is consistently recorded first at 90 cm (N03/f39(ix)), within the leaf litter layer, and together with *Gleichenia* and *Leptospermum*, increased dramatically above 40 cm (N03/f39(iv)). This is interpreted as encroachment of oligotrophic peat swamp (Dobson, 1979) on to the swampy basin, gradually at first and later at an accelerated rate. The expansion of peat followed the deposition of the leaf litter layer and the substantial macrofloral debris may have affected the swamp drainage, perhaps by damming outlets. Another possible explanation for peat swamp development is a rising water table due to sea-level rise (and possibly increasing
precipitation) at the end of the last glacial.

During the initial peat encroachment, *Weinmannia* declined and then disappeared from the record, while *Agathis* apparently expanded. Thereafter *Agathis* declined sharply as peat encroachment accelerated, and fires, evidenced by higher levels of microscopic charcoal, became more frequent. A local fire (or fires) resulted in the charcoal layer at 27 cm, which occurs within the section of peat dated to 10,370 ± 100 (NZ7513; see 9.3.2). It is not clear whether fire was the sole cause of the *Agathis* decline or whether these trees were already undergoing decline due to peat encroachment and a rising water table. Other trees survived and some (e.g., *Phyllocladus, Nestegis*) apparently prospered following the *Agathis* decline. That the pollen input of these and other tree species was not adversely affected by either peat expansion or local burning, suggests that, unlike *Weinmannia* and *Agathis*, their pollen derivation included non-local sources.

9.5.3 The chronology of the Trig Road pollen profile

The radiocarbon chronology of the Trig Road pollen profile (Fig. 9.5-6) is problematical because the chronological order of the seven dates does not correspond to the vertical sequence of radiocarbon samples. The dated samples NZA843, NZA828, NZA829 are older than the stratigraphically lower dated samples NZ7514, NZ7633. It is probably coincidental that the four TAMS dates from the pollen profile are in stratigraphical and chronological order, as are the three gas proportional counted dates; the inverted chronology results from the merging of these two sets of dates. Some explanations for this discrepancy are considered below. Massive mixing of the peats during excavations at the site cannot be discounted, but seems unlikely as, in view of this possibility, extreme care was taken to sample apparently undisturbed material. The preservation of discrete charcoal and leaf litter layers (Fig. 9.5), as well as palynological distinctions between upper and lower sections of the peat profile (Fig. 9.6) also argue against mixing on a large scale. Contamination by modern carbon may have occurred through downwards percolation of organic acids or by roots penetrating older substrata. Erroneously young ages, perhaps resulting from these mechanisms have been reported (see 2.4.2-3). Evidence for downwards root penetration was observed at Trig Road and the pollen record (below) indicates that woody vegetation has occurred at the swamp surface in the past. However, contamination by modern carbon would not by itself explain the Trig Road anomaly, where the two lowermost dates, one on *Agathis australis* wood (NZ7633), the other on peat immediately below the wood (NZ7514), are younger than the three overlying dated samples. The *A. australis* wood sample was cut from a larger piece whilst in situ and was probably from a tree which fell into the swamp, and which may then have subsided through the soft peaty substrata to its observed position. If so, the immediately underlying peat (NZ7514) may have been contaminated by younger carbon leached from the wood. This seems to be the most plausible explanation for the inverted
sequence of dates at this site and would indicate that the two lowermost radiocarbon dates are not reliable age estimates for the base of the Trig Road pollen profile. Furthermore, if the radiocarbon dates are accepted, they suggest a substantial hiatus around the charcoal horizon, dated as 10,370 ± 100 yrs BP (NZ7513), as peat from 30 cm below this was dated as 23,500 ± 400 yrs BP (NZA829). This section of the pollen profile also records the most striking palynological changes of the entire record: the loss of *Weinmannia* and *Agathis*; the expansion of peat swamp vegetation; and a dramatic increase in microscopic charcoal. The dates and pollen evidence suggest strongly that this section of the pollen profile (between 60-30 cm) was subject to erosion by burning. Subsequent periods of peat erosion (or non-accumulation) probably occurred as charcoal and pollen concentrations remain high and the apparent sedimentation rate is low for the uppermost 30 cm as well. In view of the doubts expressed above, and the known problems concerning the accuracy of radiocarbon dates > c. 20 ka (e.g., Polach, 1976), I cannot be sure that any of the Trig Road radiocarbon dates of last glacial age are correct. It is possible that contamination by modern carbon has seriously affected all these dates. There is strong evidence for either non-deposition or sediment removal, or both, in the uppermost 60 cm. Vegetation, some of it woody *Leptospermum* / *Kunzea*, grew close to the core site during postglacial time, and downwards root penetration through the peats was observed in the field. Harkness (1975) has shown that 5% contamination by modern carbon is sufficient to give an apparent age of 24,000 BP to a sample of last interglacial age (see 2.4.2; Table 2.2). Therefore, it may be argued that the lower part of the Trig Road profile (Zones Tr1-3) was deposited during the last interglacial. If this were so, the significant burning indicated by the charcoal horizon may have destroyed much or all of the record for the last glacial, so that the period of hiatus is much longer than the c 13 ka suggested by dates NZ7513 and NZA829. An interglacial age for the lower Trig Road peats would certainly not conflict with the pollen record obtained from them, and might help reconcile the differences between that site and other pollen sites from the far north (see below). However, the evidence for such an interpretation is, at best, circumstantial.

9.5.4 The vegetation of the Far North during the last glacial

Assuming the radiocarbon dates (Fig. 9.5-6), are not substantially incorrect - except for NZ7514 and NZ7633, which are stratigraphically out of position - the basal Trig Road pollen assemblages date from the latter part of the last glacial, yet they record a mixed conifer-angiosperm forest, comparable to postglacial palynofloras from throughout lowland northern New Zealand (e.g. McGlone, Nelson, & Todd, 1984; Kershaw and Strickland, 1988; Newnham et al., 1989). The warm-temperate, lowland character of these assemblages, together with the absence of *Nothofagus*, *Halocarpus* and Poaceae pollen, sets them apart from other contemporaneous New Zealand pollen assemblages (see 1.3.4).
However a number of pollen taxa present in the basal assemblages can be confidently identified only to genus level and these genera (e.g., *Libocedrus*, *Weinmannia*, *Metrosideros*, *Phyllocladus*, *Podocarpus*, *Pseudopanax*, *Dracophyllum*, *Myrsine*, *Asteria*, *Neomyrtus*-type) include species of diverse or wide-ranging ecologies and distributions. This problem is common to all New Zealand Quaternary pollen assemblages (see Macphail and McQueen, 1983), but is particularly acute in the late Pleistocene of Northland, for which paleobotanical and paleoclimatic evidence is scarce, and where several vicariant species occur (e.g., *Weinmannia silvicola* / *W. racemosa*, *Libocedrus plumosa* / *L.bidwillii*). The Trig Road basal palynoflora suggests a warm-temperate climate, because it lacks diagnostic cool-climate taxa, and contains several unequivocally warm or lowland taxa, including *Metrosideros robusta* type (*M.rousta* or *M.excelsa*) and abundant *Dacrydium cupressinum*. This interpretation is supported by the Trig Road macrofloras.

The occurrence of lowland conifer-angiosperm forest on Te Aupouri Peninsula during the last glacial is consistent with the few paleobotanical data from the Far North for this time. A number of Far North sites contain preserved wood of lowland forest species (notably *Agathis*), radiocarbon-dated to the last glacial (Leitch, 1966; Hicks, 1975; Ricketts, 1975; Goldie, 1975; Millener, 1981;), although the reliability of dates which approach the upper limits of radiocarbon dating may be questioned (cf. Moar, 1984), including dates on wood (Bussell, 1988).

Palynological evidence is fragmentary and generally poorly dated. The Paranoa Swamp pollen profile (9.2.2), dating from c.17,000 BP shows conifer-angiosperm forest, initially with some possible cooler elements, but with *Nothofagus* always rare (Dodson et al., 1988). The Houhora Tavern Section pollen spectra (Appendix 12) are consistent with those of the basal Trig Road assemblages (Fig. 9.6) in indicating podocarp forest near the site, but vary in that they contain *Nothofagus ?N. truncata* pollen (rare at Trig Road) and lack *Agathis* pollen (common at Trig Road). The abundant micro- and macro-fossil evidence for *Agathis* at Trig Road during (evidently) the last glacial is all the more striking when compared with the absence of *Agathis* pollen from apparently coeval spectra at Houhora Tavern Section and Paranoa Swamp (Dodson et al., 1988).

*N.menziesii* was not found at either Trig Road (Fig. 9.6) or at Houhora Tavern Section (Appendix 12), and has not been recorded in macrofloral lists, with associated radiocarbon dates, from other sites (see 9.2.2). It seems likely therefore that the *N.menziesii*-rich palynofloras of Leitch (1966, 1970) and of Ricketts (1975) (9.2.2) date from an earlier glacial, with cooler or harsher climates than the last glacial. Traces of *N.menziesii* pollen recorded at Paranoa Swamp at c 17,000 BP (Dodson et al., 1988) may indicate isolated *N.menziesii* sources in the eastern North Cape around this time; the morphology and fragility of the pollen make it an unlikely candidate for reworking. In contrast, pollen of the *N. brassi* group, which is also recorded at Paranoa Swamp, is assumed to have been reworked, when
found in New Zealand pollen assemblages younger than Hautawan (lower Quaternary). In the Far North however, there are two other possible sources, besides reworking, for late Pleistocene *N.brassii* pollen: long distance dispersal from the north (presumably New Caledonia) or survival in the North Cape region at least until the late Pleistocene. The persistence of forests of warm-temperate character together with the scarcity of fossil evidence for cool-temperate plants, suggests that the last glacial climate of the Far North was less severe than in the remainder of the country. The abundant charcoal remains at Houhora Tavern Section and Paranoa Swamp (Dodson *et al.*, 1988) may indicate a relatively dry climate, strong winds are likely to have been more frequent (Thiede, 1979) and temperatures were almost certainly cooler (CLIMAP, 1981). Indeed, the extent of changes in these climatic parameters, relative to present values, may have approached those similar to that experienced elsewhere in New Zealand. However, these differences in climate were not sufficient to seriously affect the survival of lowland conifer-angiosperm forest in the Far North.