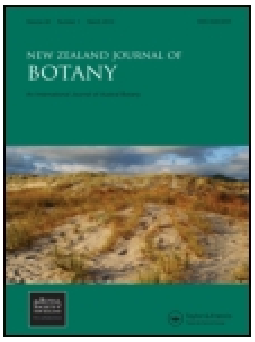


New Zealand Journal of Botany

ISSN: 0028-825X (Print) 1175-8643 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzb20

Mid and late Holocene pollen diagrams and Polynesian deforestation, Wanganui district, New Zealand

M. Royd Bussell

New Zealand Journal of Botany, 1988, Vol. 26: 431–451
0028–825X/88/2603–0431$2.50/0

Mid and late Holocene pollen diagrams and Polynesian deforestation, Wanganui district, New Zealand

M. ROYD BUSSELL
Department of Biogeography & Geomorphology
Research School of Pacific Studies
The Australian National University
G.P.O. Box 4, A.C.T. 2600
Australia

Abstract Two sites near Waverley, western North Island, provide a mid to late Holocene vegetational, climatic, and fire history for the area. A mid Holocene flora at Waverley Beach includes a local fossil *Podocarpus totara* forest preserved as *in situ* stumps exposed in Hauriri Terrace cover beds. Fossil pollen suggests the presence of surrounding podocarp-hardwood forest dominated by *Beilschmiedia tawa*(?) and *Dacrydium cupressinum* but with common *Ascarina lucida* and *Dodonaea viscosa* in the understorey, suggesting a maritime, moist, warm-temperate climate was present. At Waverley Beach, the local, dense forest phase of *Podocarpus totara* appears to have been eliminated by water table elevation following the post-glacial rise in sea level up to 6500 BP. The decline in abundance of *Ascarina* and *Dodonaea* pollen from the mid to late Holocene is suggestive of a milder climate during that period. Around Lake Waiau swamp, pre-clearance podocarp-hardwood forest was probably dominated by *B. tawa*(?), *D. cupressinum*, *Prumnopitys taxifolia*, *Metrosideros*, and *Knightia excelsa*.

Deforestation by Polynesian burning is recorded at 1 m depth in Lake Waiau swamp by the abrupt decline in arboreal pollen values. This event is poorly constrained by radiocarbon dating, and at present an age range of *c*. 685 CAL BP–210 BP is suggested. The scatter in radiocarbon ages for the Lake Waiau swamp peat provides a warning against the simple interpretation of ages of similar material, where few dates have been obtained. Fire activity at both sites is indicated by measurement of microscopic charcoal particle area. Pre-Polynesian fires may have been significant in affecting the vegetation composition.

The chronology for dune-sand deposition does not correspond with previously described periods of dune formation. At Waverley Beach, dune-sand was deposited soon after 6600 BP and stopped prior to *c*. 5750 BP. A second period of dune-sand deposition occurred after 5700 BP. At Lake Waiau, dune movement blocked off Waiau Stream before *c*. 3500 BP; aeolian transport of sand continued for a short time after the lake was first formed.

Received 3 August 1987; accepted 8 March 1988

Keywords Wanganui; palynology; Holocene; pollen analysis; Aranuian; Polynesians; Maori; deforestation; marine terraces; swamps; bogs; peat; lignite; charcoal; fires; sea level; dune activity; fossil forest; radiocarbon dates

INTRODUCTION

The present studies from two sites, Lake Waiau swamp and Waverley Beach, near Waverley, Wanganui district, western North Island, provide the first Holocene pollen diagrams from this area. The sites lie in the younger cover beds of an extensive flight of late Quaternary marine terraces that dominate the geography of the south Taranaki-Wanganui coastal area (Fleming 1953; Dickson et al. 1974; Pillans 1983).

Physiography and geology

The surfaces of the south Taranaki-Wanganui marine terraces provide a gentle, tilted landscape from the cliffed coast to *c*. 15 km inland. Late Quaternary uplift has involved shore-normal tilting, but slight doming is evident in shore-parallel deformation trends. The doming centres on Waverley, where maximum uplift is calculated at *c*. 0.6 mm yr^{-1} (Pillans 1983). Sand dunes are common along the entire coast and they become extensive inland in the area south-east of Wanganui. There are few active dunes, and fixed dunes are of parabolic or chaotic form (Fleming 1953).

The dunes have migrated across the coastal lowland impounding streams to form numerous small lakes and swampy areas. Drainage of much of the area for farmland has altered the original landscape (Fleming 1953). In the hinterland the older sediments of South Wanganui Basin (Anderton 1981), comprising over 4000 m of Plio-Pleistocene sediments, have been deeply dissected. Land altitude progressively increases inland.

To the north-west, Mt Egmont (2518 m) is a late Quaternary, andesitic stratovolcano of classic form, and it is the youngest in a chain of volcanoes that trend north-north-west (Neall et al. 1986). Although there has been substantial Holocene activity originating from Mt Egmont, this has mainly been in the form of locally deposited volcanoclastics—principally lahars and ash showers—and vegetation in the Wanganui district was most likely unaffected. Of the Holocene volcanic activity occurring in the Taupo Volcanic Centre (Topping 1973; Topping & Kohn 1973; Pullar et al. 1973), only the voluminous Taupo Pumice eruption of *c.* 1800 BP (Healy 1964) is recorded as having had any substantial effect on the Waverley–Wanganui district, and then mainly in the Wanganui Valley where large volumes of pumice were transported down the valley to be aggraded as alluvial terraces near the river mouth (Fleming 1953).

The late Quaternary history of South Wanganui Basin has involved marine transgression onto the rising coast during each phase of warm climate, which resulted in the cutting of marine platforms (wave cut surfaces) and coastal cliffs, with each successive platform and cliff being cut at a lower level in the landscape. On withdrawal of the sea during cooling climates, terrestrial sediment was deposited onto the exposed marine platforms to form the terrace cover beds. These sediments comprise dune-sand, alluvium, tephra, laharic debris (in the north-west), lacustrine deposits, peat (now soft lignite), and loess.

Vegetation and climate

Except for small pockets, there is little remaining of the coastal-lowland forests that once covered the Wanganui district. Present land usage is principally for dairy farming, and rich pasture occupies the freely draining, fertile, yellow-brown earth soils of the terraces.

Pre-clearance vegetation can be reconstructed through comparison with nearby areas and analysis of vegetation remnants. Vegetation at the coast probably supported sandbinder communities on dunes; principally *Spinifex hirsutus*, *Desmoschoenus spiralis*, and *Scirpus nodosus*.

Further inland, coastal to semi-coastal forest most likely comprised a low canopy of *Dysoxylum spectabile*, *Rhopalostylis sapida*, *Corynocarpus laevigatus*, *Beilschmiedia tawa*, *Elaeocarpus dentatus*, *Alectryon excelsus*, and *Hedycarya arborea*. The understorey may have comprised *Dodonaea viscosa*, *Myoporum laetum*, *Melicytus ramiflorus*, *Macropiper excelsum*, *Geniostoma rupestre* var. *ligustrifolium*, *Cyathea medullaris*, *C. dealbata*, and *Streblus heterophyllus* (cf. Esler 1978; Clarkson 1981, 1985). Because of the mild, maritime climate of inland Wanganui, many species normally associated with coastal habitats extend well inland (Wanganui River Reserves 1982).

Lowland podocarp-hardwood forest would have formed the most extensive tracts of the Wanganui-Waverley area. The canopy was probably dominated by *Beilschmiedia tawa*, with emergent *Metrosideros robusta* and the podocarps *Dacrydium cupressinum*, *Prumnopitys taxifolia*, *P. ferruginea*, *Podocarpus totara*, and *Dacrycarpus dacrydioides*. Additional important canopy hardwoods were *Nestegis cunninghamii*, *N. lanceolata*, *Alectryon excelsus*, *Hedycarya arborea*, *Elaeocarpus dentatus*, and *Laurelia novaezelandiae*. In the understorey, *Coprosma* spp., *Melicytus ramiflorus*, *Pseudowintera* spp., *Hoheria sexstylosa*, *Geniostoma rupestre* var. *ligustrifolium*, *Metrosideros* lianes, *Cyathea dealbata*, and *C. medullaris* were probably common. Ferns and mosses would probably have formed a luxuriant ground cover. The small tree, *Ascarina lucida*, is not known from present day vegetation remnants and its pre-clearance distribution is unknown (see below).

Inland, behind the oldest marine terrace remnants, *Nothofagus solandri* var. *solandri* forms distinct ridgeline forests (above *c.* 450 m) on the poorer soils. The associated canopy trees are *Weinmannia racemosa* (which altitudinally replaces *B. tawa*), *Podocarpus hallii* (which altitudinally replaces *P. totara*), *B. tawa*, and the understorey shrubs *Leucopogon fasciculatus*, *Cyathodes juniperina*, and species of *Coprosma*, *Helichrysum*, and *Gaultheria* are present.

Clarkson (1985) described altitudinal succession in the Kaitake Range (north-western Egmont National Park) and vegetation communities for central-western North Island have been described by Bussell (1988). On Mt Egmont, where *Nothofagus* is absent, montane podocarp-hardwood forest forms the timberline at *c.* 1050 m, above which subalpine shrubland, grassland, herbfield, and mossfield is successively developed with increasing altitude.

At the time of European settlement (*c.* 1840 AD) the coastal region was already cleared of vegetation by the Maori, along a strip about 5 km wide running along the coast between Hawera and Wanganui (Wendelken 1976). Early reports described this area as fern and scrub covered (Dieffenbach 1843). The town of Waverley was established in 1868 AD and large areas of the Wanganui hinterland were cleared of forest for farmland from 1880–1910 AD (Downes 1915; Fleming 1953).

The climate of the Wanganui region is mild (maritime, warm-temperate) with few extremes. Annual rainfall is 900–1250 mm and is evenly distributed through the year. West to north-west winds prevail with relatively frequent gales (Robertson 1957; Maunder & Browne 1972). Occasional summer drought may be severe enough to cause tree death (Atkinson & Greenwood 1972).

METHODS

Two geographically similar sites were selected to determine the mid and late Holocene vegetation history for the Waverley district. At Lake Waiau swamp (Fig. 1), a 5 m core was obtained for pollen analysis after a transect across the swamp had been made to determine the cross-sectional profile and stratigraphy. Cores were taken using a "D section" corer (Jowsey 1966) and a Hiller borer for the lowermost samples. At Waverley Beach (Fig. 1), samples were collected at regular intervals from the cliff exposure at the back of the beach. At both sites, samples were prepared from 20 cm intervals, which was adequate because of the rapid depositional rate. Samples of 1 cm^3 were successively treated with KOH, HF, bleach (Schultze solution), and acetolysis mixture (Faegri & Iversen 1975). Counting was normally continued until a sum of >250 was obtained. This sum comprised native dry land pollen (no spores). On completion of the count a scan was made for additional taxa which were noted as present (but not included in the sum). At Lake Waiau swamp, low pollen sums for the uppermost samples were obtained; interpretation of these samples was made with caution. Charcoal area was measured following the method described by Clark (1982).

Bulk density, percentage loss on ignition, and elemental analyses were determined for successive peat samples taken at 25 cm intervals from the Lake Waiau swamp core to determine the change in properties of the peat with depth.

Six peat samples from Lake Waiau swamp and three wood samples from Waverley Beach were submitted to the A.N.U. Radiocarbon Dating Laboratory. Methods of pretreatment and dating by liquid scintillation spectrometry are described in full by Gupta & Polach (1985). All calculations are based on a ^{14}C half life of 5568 years. The ages are reported as conventional years BP with one standard deviation error terms, or as percent modern (%M). Dates from these samples are corrected for measured $\delta^{13}C$; dates from the Waverley Beach wood samples are corrected using a best estimate of -22.0 ± 2.0 permil $\delta^{13}C$ (Stuiver & Polach 1977). For peat samples from Lake Waiau swamp, calibrated ages are computer-calculated using the dendrochronological calibration curves of Stuiver & Pearson (1986) and Pearson & Stuiver (1986); these ages are reported in years CAL BP. All results and calibrated ages are shown in Table 1.

Plant names used in the text follow Allan (1961), Moore & Edgar (1976), and the ammendments of Connor & Edgar (1987) and Brownsey et al. (1985).

LAKE WAIAU SWAMP

Lake Waiau (grid ref. 39°47′S, 174°40′E) is one of a series of small, freshwater lakes in the Wanganui district and was formed by the impoundment of Waiau Stream by dune-sand. The swamp at the northern end of the lake (Fig. 1) appears to have developed from the time of lake formation and prograded southward with time. The swamp has a small, local catchment of *c*. 6.6 km^2. Waiau Stream is not deeply incised and flows mostly through sand-dune and loess cover bed material of the Rapanui Terrace (Fleming 1953).

Phormium tenax is the physiognomic swamp dominant. Other common components include *Carex* spp., *Ulex europaeus* (exotic), *Cordyline australis, Typha orientalis, Cortaderia toetoe, Coprosma robusta, Blechnum capense* ("blackspot" form), and *Pteridium esculentum.* A full species list is shown in Table 2. A drainage channel has been dug on the swamp margin but water still flows over much of the swamp surface.

Encroachment of the swamp vegetation into Lake Waiau from the north has resulted in the development of a hydrologic zonation of changing vegetation with increasing distance from the lake. *Typha* and *Baumea* occur at the lake margin and are followed by the dominant *Phormium-Carex* community further back. Scattered *Cordyline* then becomes physiognomically important. A similar sequence of swamp vegetation change was described at Pukepuke Lagoon in the Manawatu district by Ogden & Caithness (1982). They

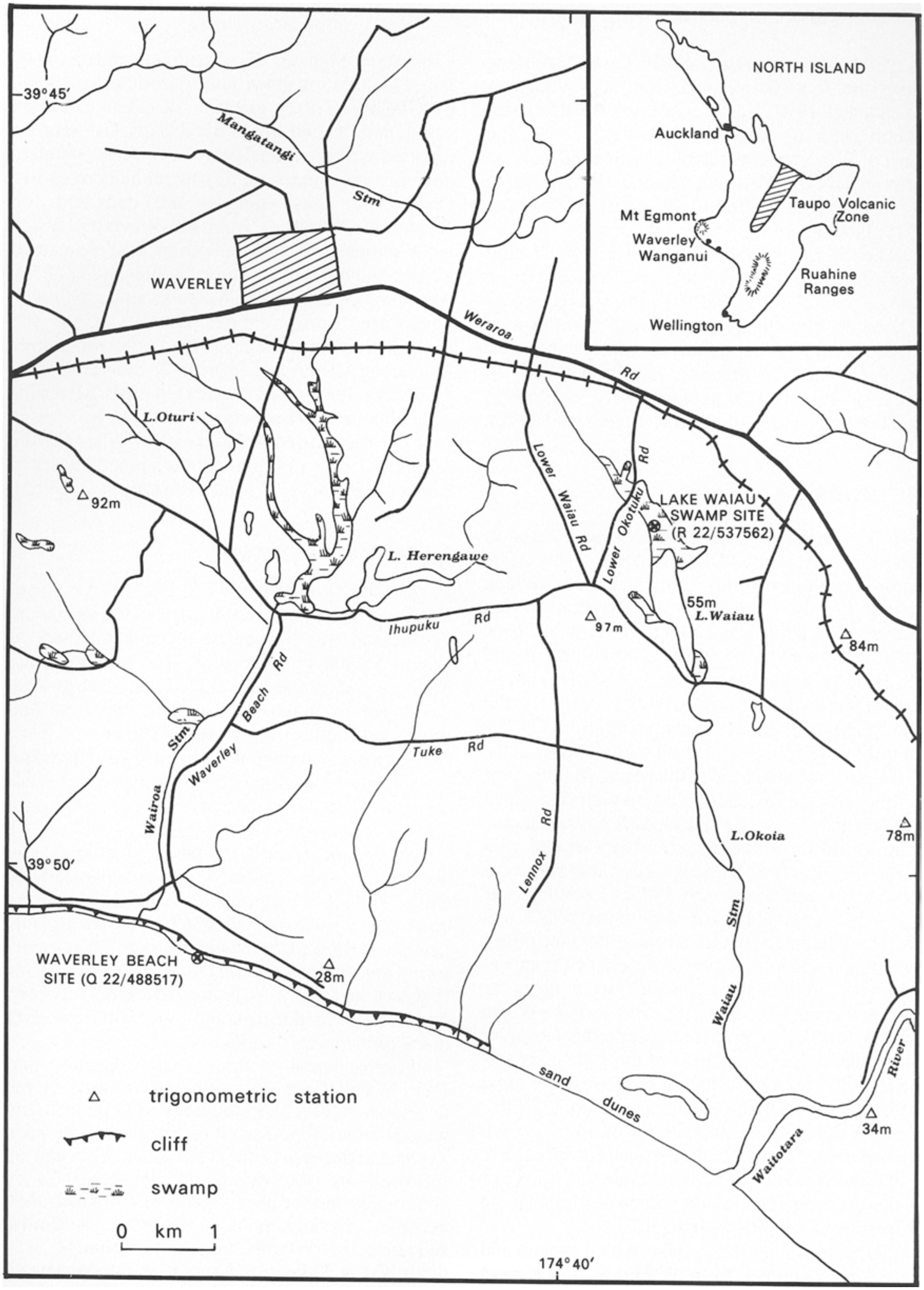


Fig. 1 The coastal Waverley district, showing the location of the Lake Waiau swamp and Waverley Beach pollen sites.

Table 1 Radiocarbon age determinations for samples from the Lake Waiau and Waverley Beach sites. Calibrated ages were computer-calculated. BP = before present (1950), %M = percentage of modern radioactivity of the sample. ^{14}C half life used = 5568 yr.

Sample number	Site	Conventional age (BP or %M)	δ^{13}C values (permil)	Calibrated age to 2σ (CAL AD/BC)	Calibrated age to 2σ (CAL BP)
ANU 4843	LW (1m)	97.9±1.2 %M	–30.5±0.4	1620–1955 CAL AD	330–0
ANU 6343	LW (1–1.1m)	610±80 BP	–24.0±0.2*	1265–1436 CAL AD	685–514
ANU 4842	LW (2m)	860±90 BP	–30.9±0.4	1011–1280 CAL AD	939–670
ANU 6351	LW (2–2.1m)	1420±100 BP	–24.0±0.2*	410–820 CAL AD	1540–1130
ANU 4841	LW (3m)	2920±160 BP	–33.7±0.4	1470–810 CAL BC	3419–2759
ANU 4847	LW (4m)	2710±290 BP	–29.5±0.4	1270–410 CAL BC	3219–2359
ANU 5215	WB (2.9m) (upper)	5750±90 BP	–22.0±2.0*	–	–
ANU 5214	WB (6.5m) (middle)	6570±90 BP	–22.0±2.0*	–	–
ANU 5213	WB (8.5m) (lower)	7000±100 BP	–22.0±2.0*	–	–

LW = Lake Waiau. WB = Waverley Beach.
*Estimated on the basis of average δ^{13}C values of peat or wood relative to PDB standard (Stuiver & Polach 1977); other δ^{13}C values were measured.

considered that future succession would lead to the development of semi-swamp forest dominated by *Dacrycarpus dacrydioides*, remnant examples of which occur in the Wanganui region today.

Stratigraphy

Stratigraphy established from the cored transect (Fig. 2) indicates the infilled valley is slightly asymmetrical in cross-section and steep-sided. Dune-sand underlies organic mud which in turn underlies muddy peat, with fibrous peat near the surface. Stratigraphic horizons are not distinctive, consisting of subtle colour changes superimposed on a trend of increasing fibrousness of the peat toward the surface. At the base of core 5 (Fig. 2), light grey, sandy mud may indicate a former alluvial channel.

A 5 m core was extracted for palynological investigation from a site west of the swamp centre (Fig. 1) at grid ref. R22/537562 (NZMS 270). The core was logged (Fig. 3a) and other analyses performed on samples from it reveal further detail (Fig. 3a, 3b). Bulk density of the sediment changes little in the upper 2.25 m, where it averages 0.1 g cm^{-3} then increases steadily to >1 g cm^{-3} at the base (5 m). The loss on ignition (l.o.i.) curve shows increase from the top of the core to 1 m depth (85% weight loss), followed by decline and recovery to 2.0 m, then rapid decline to 2.5 m, little change to 3.75 m, then continued gradual decline to the base. These trends strongly parallel the curves of elemental carbon, nitrogen and hydrogen, showing that l.o.i. essentially reflects organic content in this core. Carbon shows a maximum of 44% while nitrogen and hydrogen show maximum values of 2.6% and 4.9%, respectively. Hydrogen values fluctuate rather more in the upper 2 m than nitrogen and hydrogen. On the basis of these curves four lithozones are designated (Fig. 3b):

Lithozone A (5.0–3.9 m): Characterised by high bulk density (0.7–1.1 g cm^{-3}) and low content of organic constituents (l.o.i. 15% of bulk). The zone corresponds to the lower litho-stratigraphic unit of light grey, sandy mud (see Fig. 3a).

Lithozone B (3.9–2.5 m): Characterised by fairly uniform bulk density of *c.* 0.2 g cm^{-3}, and moderate organic content (l.o.i. about 25%).

Lithozone C (2.5–2.0 m): This is a transition zone where bulk density declines to <0.1 g cm^{-3} and organic content increases substantially (l.o.i. rises to 70%). There is no apparent colour change in the peat boundary that corresponds to the zone B–C transition.

Lithozone D (2.0–0 m): Characterised by low bulk density (*c.* 0.1%) throughout. Maximum values are obtained for all the elements analysed but they fluctuate markedly. All the elements analysed show a strong decline in abundance in the upper 0.5 m.

A search was made for glass shards of tephra derived from the Taupo Pumice eruption of 1800 BP. Organics were removed from samples at 5 cm intervals between 2–3 m using hydrogen peroxide. No concentration of shards was discovered.

Table 2 Flora of Lake Waiau swamp, showing species abundance and local ecology.

Ferns	Abundance	Local ecology
Asplenium flaccidum	o	epiphytic
Athyrium australe	o	swamp surface, damp
Blechnum capense ("blackspot")	c	swamp surface, damp
Histiopteris incisa	o	swamp surface, damp
Hypolepis ambigua	o	swamp surface, damp
Lastreopsis sp.	o	swamp surface, damp
Phymatosorus diversifolius	o	climbing on *Cordyline*
Pteridium esculentum	c	swamp surface, damp
Pteris macilenta	o	swamp surface, damp
Flowering plants		
Baumea articulata	c	lake margin, wet
B. teretifolia	c	swamp surface, wet
Bidens sp.*	o	swamp surface, wet
Carex coriacea	c	swamp surface, wet
C. geminata	c	swamp surface, wet
C. virgata	c	swamp margin & farmland
*Cirsium vulgare**	o	swamp surface, damp
Coprosma robusta	a	swamp surface, wet
C. tenuicaulis	c	swamp surface, damp
Cordyline australis	c	swamp surface, damp
Cortaderia toetoe	a	swamp surface, damp
Erechtites minima	o	swamp surface, damp
*Erigeron canadensis**	o	swamp margin
*Epilobium ciliatum**	o	swamp surface, damp
Galium sp.*	o	swamp margin
Geniostoma rupestre var. *crassa*	c	swamp surface, damp
*Holcus lanatus**	o	swamp margin
*Juncus australis**	c	swamp margin & farmland
Lemna minor	c	free-floating
*Lotus corniculatus**	c	swamp margin
Melicytus ramiflorus	c	swamp surface, damp
Muehlenbeckia complexa	c	liane in swamp plants
*Nasturtium microphyllum**	c	running water in trench
Phormium tenax	d	swamp surface, wet
*Phytolacca octandra**	o	swamp margin
Polygonum decipiens	c	swamp margin
P. sp.	o	swamp margin
*Ranunculus repens**	c	swamp margin
Senecio minima	o	swamp margin
Solanum aviculare	c	swamp surface, damp
S. nodiflorum	o	swamp surface, damp
Typha orientalis	c	swamp surface, damp
*Ulex europaeus**	a	swamp surface, damp

* = exotic.
d = dominant throughout swamp.
a = abundant throughout swamp.
c = common (occurs locally in swamp).
o = occasional (rare occurrences in swamp).

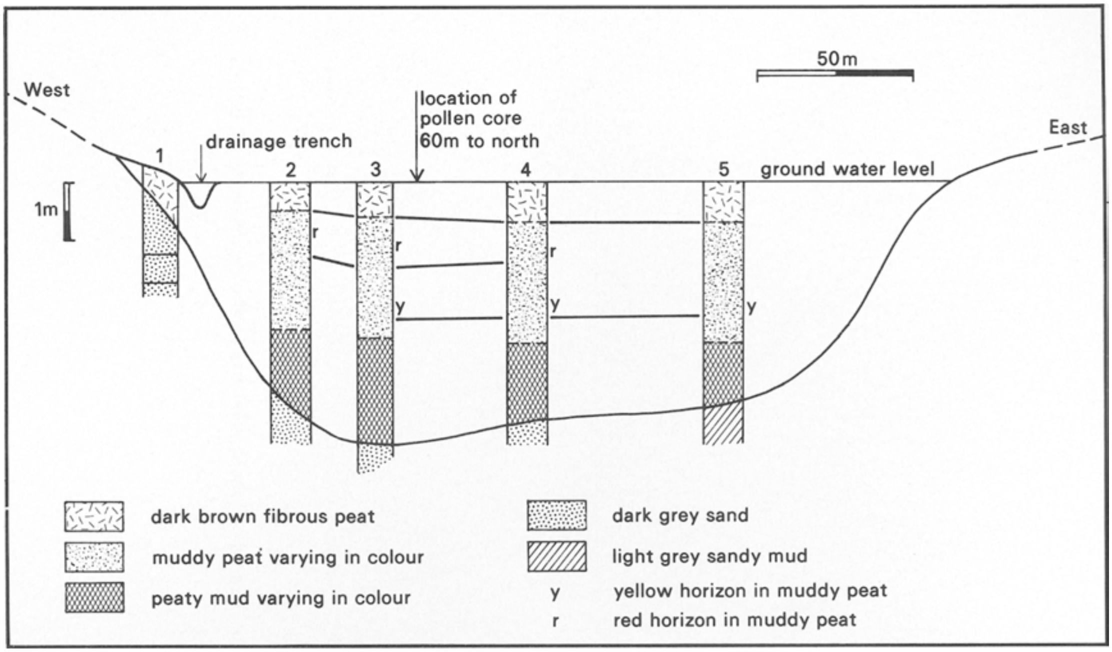


Fig. 2 Cross-section of deposits in Lake Waiau swamp.

Initially four samples of peat were taken at one metre intervals for radiocarbon dating (Fig. 3a). Two further samples were later dated from immediately below the 1 m and 2 m samples in order to tighten the chronology of the site. The age-depth curve (Fig. 3a) has been drawn using computer-calculated calendar ages derived from the dendrochronological calibration curves of Stuiver & Pearson (1986) and Pearson & Stuiver (1986). The best-fit age-depth line is drawn by taking the middle value between the maximum and minimum ages for dates.

The uppermost date at 1 m (ANU 4843) had a 97±1.2% modern age, but the later sample from immediately below it (1.0–1.1 m) yielded an age of 610±80 BP (ANU 6343). The first sample from 2 m was 860±90 BP (ANU 4842), but the later sample, again immediately below (2.0–2.1 m), had an age of 1420±100 BP (ANU 6351). The $\delta^{13}C$ values that were measured for four peat samples were in the range of –30 permil, suggesting that chemical reworking may have occurred. This is most likely to be a result of the *in situ* degradation of the organic material and is not thought to affect dating of these samples (J. Head pers. comm.). Low organic content in samples from lower down in the core meant that the age error determinations were large for these samples, but this does not affect the interpretations made below.

Pollen diagram (Fig. 4)

Pollen in the lowermost 1.2 m (lithozone A) was too corroded and sparse to count but well preserved pollen was obtained from the uppermost 3.8 m.

Local pollen zones:

Zone 1 (3.8–1.1 m): Characterised by dominance of pollen from *Dacrydium cupressinum* and *Prumnopitys taxifolia*, while *Podocarpus*, *Metrosideros*, *Knightia excelsa*, and *Nestegis* pollen is common. Ferns spores are abundant, with *Cyathea dealbata* and *C. smithii* types dominant. Pollen from a variety of small tree, shrub, and herb taxa are common but none are prolific. Local swamp pollen is derived from Cyperaceae and *Typha orientalis*, and aquatic contributions are made from the colonial algae *Pediastrum* and *Botryococcus*. Other unidentified algal cysts are present. Trends in zone 1 include a decline in the abundance of *P. taxifolia* and *K. excelsa* pollen; the latter has maximum of 24% in the lowermost sample. *Metrosideros* pollen percentages fluctuate and generally increase while *Nestegis* pollen increases at the base. Charcoal is common only in the lowermost two samples. Subzone 1b (2.3–1.1 m) is distinguished from 1a on the basis of increased values for swamp taxa, namely Cyperaceae and *Typha*. Other changes that occur in this subzone

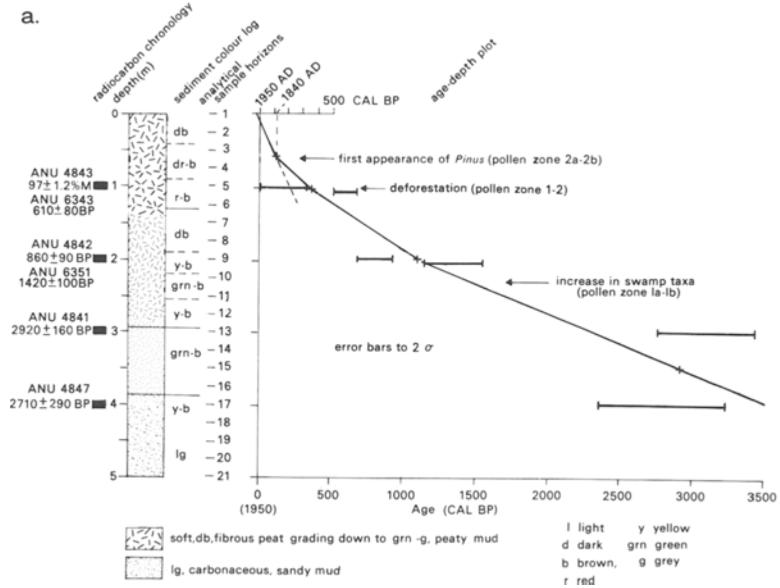


Fig. 3a Stratigraphy of the Lake Waiau swamp core and the age-depth curve.

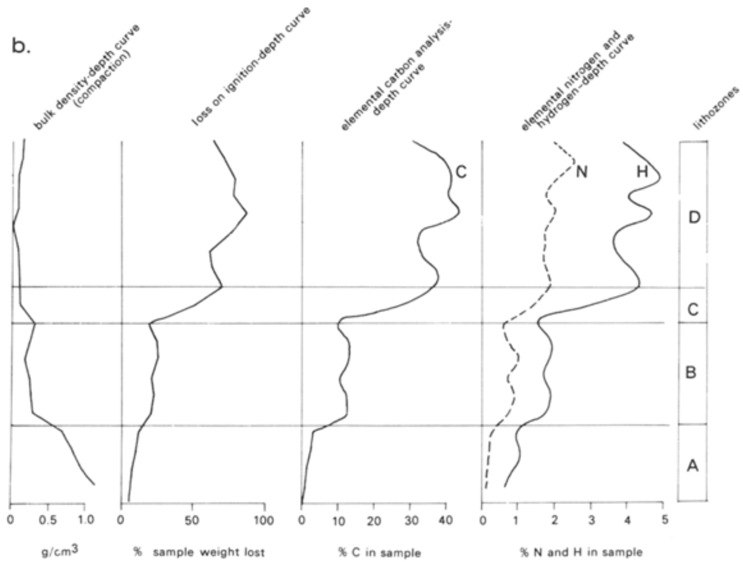


Fig. 3b Record of geochemical analyses of successive core samples.

include increases in pollen of *Leptospermum/Kunzea, Metrosideros*, and monolete fern spores. There is also a decline and recovery of *Prumnopitys taxifolia* values. Colonial algae are less frequent than in zone 1a.

Zone 2 (1.1–0 m): Characterised by the sudden decrease in arboreal pollen values and the emergence of shrub-grass-fernland derived pollen. *D. cupressinum* values, in particular, decrease and many other tree taxa that were previously common are no longer seen. *Leptospermum/Kunzea* pollen has a 54% maximum at 1.0 m and then shows marked fluctuations. Spores of *Pteridium esculentum* become dominant together with Poaceae, which increases upwards. *Blechnum* and Anthocerotaceae spores become more common than previously. Charcoal area values increase dramatically with a maximum of 25 $cm^2 cm^{-3}$ at 0.2 m depth. Zone 2b is distinguished from 2a by having higher values for Asteraceae (both Tubuliflorae and *Taraxacum* type), Poaceae, and charcoal particles, and the incoming of exotic *Pinus* pollen. *Typha* pollen is absent from the base of zone 2, then becomes abundant and shows an upward decrease.

Surface sample representation of the modern swamp flora

A comparison of the modern surface sample pollen spectrum (R22/f131–1)* (Fig. 4) with the modern swamp flora (Table 2) shows some major discrepancies in representation. The low influx of externally derived pollen has most likely resulted in inflated percentages for the local taxa. The swamp physiognomic dominant, *Phormium tenax*, is only represented by 8% of the pollen (this is the highest percentage recorded at the site). Under-representation of *Phormium* has been recorded by previous workers (McGlone 1982). Cyperaceae contributes 29% of the pollen, presumably derived from several species of *Baumea* and *Carex*; this is a reasonable representation. *Pteridium esculentum*, although common in the swamp itself, is very over-represented at 74%; incorporation of whole pinnules in the sediment from the local growth of this fern may be responsible. *Blechnum capense* ("blackspot" form) is common in the swamp and is recorded at 8%. *Cordyline australis* is a physiognomically important tree element which is severely under-represented. *Typha orientalis* is common in the flora but its distribution at present is patchy—it prefers shallow water of the lake margin. The 2% *Typha* recorded is most likely a representation of sparse *Typha* in the middle reaches of the swamp where the core was taken, and where running water was present. *Cortaderia* (native Poaceae), a common swamp element, was not palynologically distinguished from other grass taxa. *Coprosma robusta* and *C. tenuicaulis* are common shrubs in the swamp but, surprisingly, their pollen is not recorded in the surface sample. Normally *Coprosma* is well representd but representation may vary depending on which species are involved (Moar 1970; Dodson 1976; Pocknall 1978, 1982; McGlone 1982; Bussell 1988). Other shrubs such as *Melicytus ramiflorus, Solanum* spp., and *Geniostoma rupestre* var. *ligustrifolium* are common in the swamp but are not recorded in the pollen spectra. Most of the exotic taxa listed in Table 2, except *Ulex europaeus* (gorse), occur at the swamp margins in contact with the surrounding farmland. *U. europaeus* pollen is not recorded, although the shrub is abundant throughout the swamp.

*NZ fossil record form number.

Interpretation

Local site conditions: The sand dune activity that initiated the formation of Lake Waiau before c. 3500 BP probably continued for some time following establishment of the lake, as shown by the lacustrine sandy mud unit from 5.0–3.9 m (lithozone A, Fig. 3a). The basin appears to have been rapidly filled within about 3500 years. Sedimentation appears to have progressively increased toward the top of the core (Fig. 3a). This has been partly a function of changing site conditions but compaction effects below 2 m are likely to have been fairly significant, judging from the bulk density curve (Fig. 3b).

Considerable quantities of the freshwater colonial algae *Pediastrum* and some *Botryococcus* in pollen zone 1a suggest lacustrine conditions at the site when the deposition of organic mud in lithozone B occurred, suggesting that the dunes had stabilised by that time. Some swamp developed at the lake margins and further up Waiau Stream to the north-west. Later, with shallowing of the lake basin, sedge-flax (*Phormium tenax*) communities, with margins of *Typha orientalis*, appear to have encroached into the lake (cf. Cockayne 1967). True swamp conditions were established at the site during the transition lithozone C, as indicated by major increase of organic constituents, the decline in open water taxa such as *Pediastrum* and *Botryococcus*, and the increase of the swamp taxa Cyperaceae and *Typha* at 2.2 m depth. However, the abundance of *Phormium* in the swamp is difficult to establish since its pollen seems to be severely under-represented (see above).

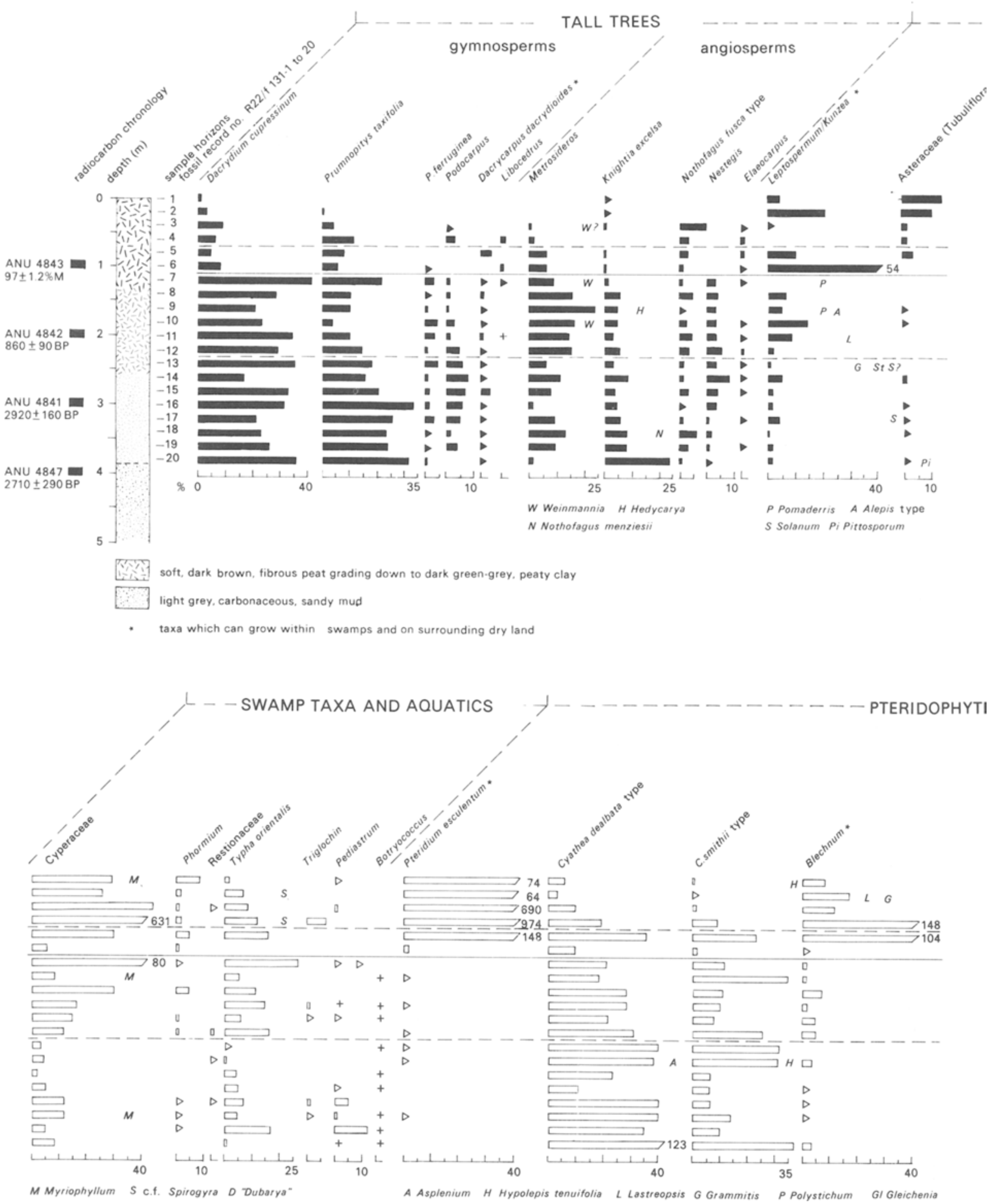
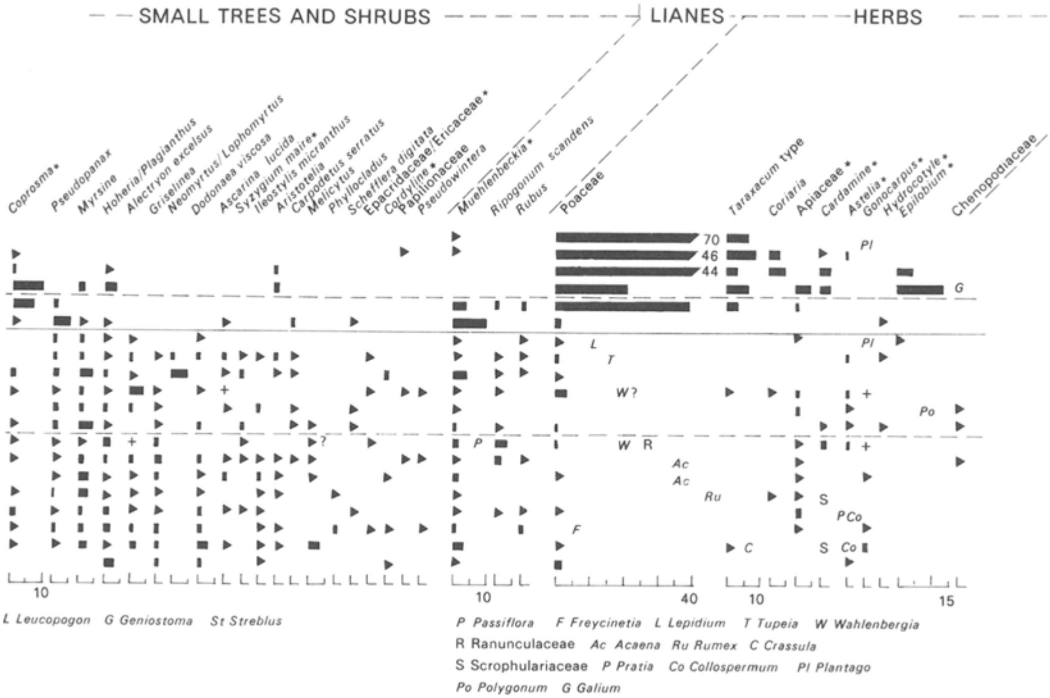
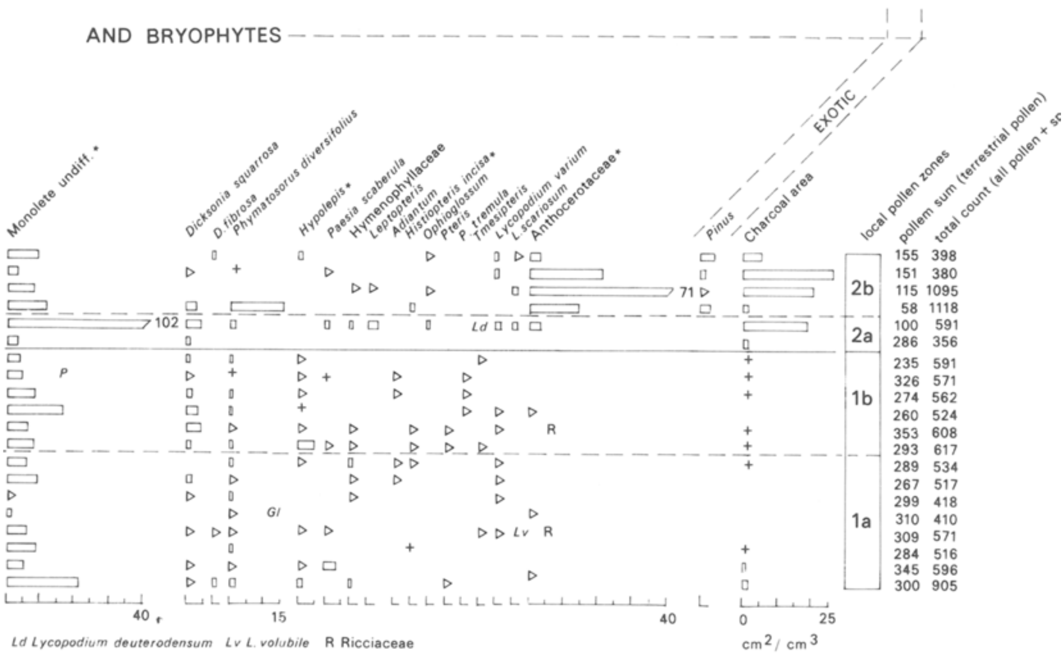


Fig. 4 Pollen diagram, Lake Waiau swamp.
▷ = less than 1%; + = taxon recorded after formal count. Pollen sum based on total dry land, native taxa,





excluding Pteridophyte spores. Blacked in histograms shown for taxa included in the pollen sum.

Low values of Cyperaceae and the absence of *Typha* at 1.0 m suggest that the swamp vegetation may also have been burnt or possibly cut by humans when the surrounding district was deforested. However, the swamp vegetation appears to have re-established and *Blechnum* (*B. capense* "blackspot" form) started to become more abundant. *Typha* and *Blechnum* decline through the upper 80 cm, suggesting further shallowing at the site as peat built up. In the uppermost sample, higher values for *Phormium* may be related to increased, human-induced drainage of the swamp when *Phormium* and sedges replaced *Typha*.

Comparison of Fig. 3 and 4, and the above considerations, indicate correspondence of lithozone A–B boundary with the base of pollen zone 1 when local conditions (establishment of the lake and cessation of aeolian sand movement) became suitable for the accumulation and preservation of pollen. The transition from a lacustrine to a swamp environment is represented by lithozone C and is suggested to have caused changes in local pollen representation between subzones 1a and 1b.

Surrounding vegetation history

Prior to deforestation, lowland podocarp-hardwood forest of the Waverley district most likely had a *Beilschmiedia tawa* dominated canopy, the pollen of which is not recorded (Macphail 1980; Bussell 1988). However, the presence of other pollen shows that *Dacrydium cupressinum*, *Prumnopitys taxifolia*, and *Metrosideros* were common, while *Podocarpus totara*, *Dacrycarpus dacrydioides*, and *Prumnopitys ferruginea* were also present. These trees were probably emergent above a *B. tawa*-dominated canopy which also comprised *Knightia excelsa*, *Nestegis* spp., and *Elaeocarpus dentatus*. Understory trees and shrubs included *Pseudopanax* spp., *Hoheria/Plagianthus* (*H. sexstylosa*?), *Coprosma* spp., *Alectryon excelsus*, *Griselinia* spp., *Ascarina lucida*, *Aristotelia serrata*, *Carpodetus serratus*, *Melicytus* spp., *Schefflera digitata*, *Pseudowintera* spp., *Cyathea dealbata*- and *C. smithii-types*, and *Dicksonia squarrosa*. Numerous forest-floor ferns were present. *Dodonaea viscosa* may have been growing in low forest or scrub nearer the coast.

The common occurrence of *K. excelsa* is different from present day undisturbed, lowland forest stands but it is common, particularly on ridges, following forest clearance by fire (McKelvey 1963; P. Wardle et al. 1983). The presence of 24% *K. excelsa* at the base of zone 1 suggests forest disturbance and that this tree was common. The contemporaneous charcoal abundance at the same level may indicate that pre-Polynesian fire and the high *Knightia* levels are associated.

Changes in non-swamp taxa that occur in subzone 1b, such as the increases in *Metrosideros*, *Leptospermum/Kunzea*, and monolete ferns, and the decrease and recovery of *Prumnopitys taxifolia*, cannot easily be attributed to a cause. Some fluctuations may be related to changes in pollen deposition caused by the transition from lacustrine to swamp conditions mentioned above.

Deforestation of the catchment is evidenced by the major decline in the representation of arboreal taxa and a coeval dramatic increase in charcoal area values. This event was presumably due to fires lit by Polynesians. High levels of *Leptospermum/Kunzea* pollen indicate that shrubland developed on at least some cleared areas following deforestation but later the landscape was dominantly fernland of *Pteridium esculentum*, with grassland in open areas that were probably unsuitable for bracken growth. The arrival of Europeans (*c.* 1840 AD onwards) and the initiation of farming in the Waverley district is indicated by increased grass pollen derived from cultivated pasture, increased Asteraceae from introduced weeds and native scrub, and the first appearance of *Pinus* pollen. *Pteridium* decreased in this period.

WAVERLEY BEACH

The site lies in the cover beds of the Hauriri Terrace, cut by a high sea level stand *c.* 80 000 years ago (Pillans 1981, 1983). On regression, marine sediment was left in places overlying a "bored" marine platform (wave cut surface) cut into Pliocene marine sediments of the Whenuakura Group (Fleming 1953) (Fig. 5, 6). At Waverley Beach (grid ref. 39°50′S, 174°37′E; Q22/488517), a river valley was cut into the Hauriri surface and sediments, and this is now filled with cover bed sediments exposed in outcrop. Peat was deposited during the mid Holocene in coastal interdune swamps which are exposed in the cliff at the back of Waverley Beach. The section includes a series of lignite lenses, separated by unconsolidated dune-sand and sand, silt, and clay alluvium (Fig. 5, 6). A fossil forest is exposed along the intertidal beach, and the outcropping lignite contains *in situ* tree stumps and fallen logs. These logs have charred bark, and six samples of wood were identified as *Podocarpus*

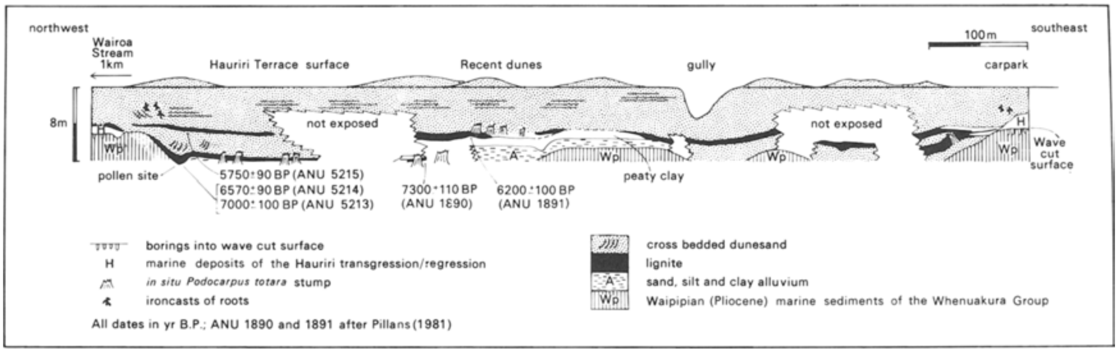


Fig. 5 Coastal stratigraphy of the Hauriri Terrace and cover beds at Waverley Beach.

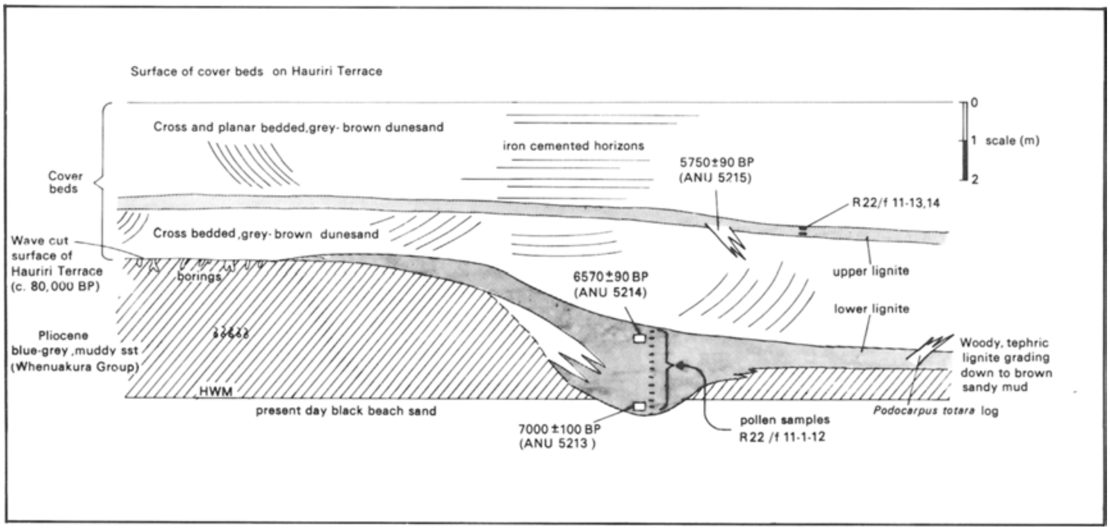


Fig. 6 Stratigraphy of the Waverley Beach pollen site.

totara or *P. hallii* (R. N. Patel, pers. comm.). Fig. 7 shows the distribution of the exposed stumps and logs and the location of identified specimens. The cliff section contains two discontinuous lignite layers and dune-sand displaying steep-angle cross-bedding (Fig. 5, 6). Each of these lignites is not necessarily the same age from one place to another.

The Waverley Beach lignite and fossil forest was included by Fleming (1953) in cover beds overlying the Rapanui wave cut surface. Pillans (1981) considered the deposits to be Holocene cover beds of the Hauriri Terrace (Pillans 1983) cut *c.* 80 000 years ago (fig. 3.10 of Pillans 1981). Pillans obtained two radiocarbon dates from the Waverley Beach lignite at a locality *c.* 300 m east of the pollen site (Fig. 5). In this study, three radiocarbon dates were obtained from the pollen site (Fig. 5, 6). The base of the lower lignite is *c.* 7000±100 BP and the top of the unit is *c.* 6570±90 BP. The upper lignite is dated as *c.* 5750±90BP. Elevation and the dates from 300 m east indicate the time-transgressive nature of the lignites (Fig. 5), as is suggested by their appearance in outcrop. At the pollen site, 2.4 m of massive, soft, green-brown lignite is overlain by 2 m of steeply cross-bedded, grey-brown dune-sand. Above this is 0.3 m of massive, brown lignite, and then *c.* 2 m of grey-brown dune-sand containing iron-cemented horizons, and iron-casts of rootlets. The Waverley Beach stratigraphy is not as simple as drawn by Pillans (1981).

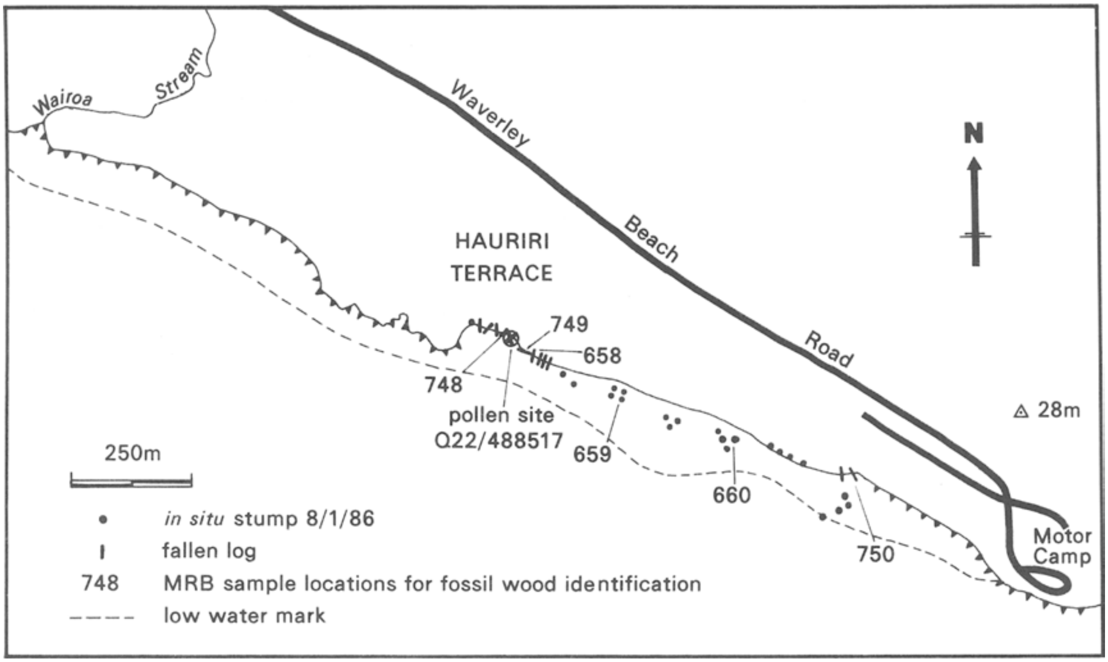


Fig. 7 Distribution of fossil *Podocarpus* logs and *in situ* stumps at Waverley Beach.

Pollen diagram (Fig. 8)

Local pollen zones

Zone 1: Characterised by high levels of *Ascarina lucida* and *Dodonaea viscosa* pollen. *Dacrydium cupressinum*, *Prumnopitys taxifolia*, *Podocarpus*, and *Myrsine* pollen and spores of *Cyathea dealbata*- and *C. smithii*-types are common. Charcoal particles are common throughout and a peak of 14 $cm^2\ cm^{-3}$ is recorded at the base. *Podocarpus* pollen rises to a distinct peak of 33% at 7.8 m below the terrace surface and then it declines in abundance. *Ascarina* and *Myrsine* values generally decline upwards. Cyperaceae values are low.

Zone 2: This zone is characterised by the sudden rise in Cyperaceae pollen and the incoming of the freshwater, colonial alga *Pediastrum*. *Dacrydium cupressinum* and tree fern values increase upwards while *Podocarpus* pollen is reduced to the lower quantities that occurred at the base of zone 1. *Prumnopitys ferruginea*, *Dodonaea viscosa*, and monolete fern values are greater than previously while *Hypolepis* spores are common at the base of the zone. Charcoal abundance peaks at 7.2 m where 18 $cm^2\ cm^{-3}$ is recorded.

Zone 3: Characterised by reduced values for *Ascarina* and *Dodonaea* pollen. The pollen values for most other taxa are similar to zones 1 and 2 except for the following differences. *Metrosideros*, *Leptospermum*/*Kunzea*, *Coprosma*, and *Muehlenbeckia* pollen is more common. There is a substantial increase in values for Cyperaceae, *Typha orientalis*, *Blechnum*, *Phymatosorus diversifolius*, and *Anthocerotaceae*. Charcoal remains common.

Interpretation

Since the Waverley coast is rapidly receding at rates between 0.3–0.7 m yr^{-1} (Gibb 1978), the Waverley Beach Site could have been more than 3.5 km inland from the coast, if the measured coastline recession rates apply throughout the Holocene. With uplift of 0.4 mm yr^{-1} (Pillans 1983), the site elevation may have been 3 m lower than at present *c.* 7000 BP. Absolute sea level at this time was *c.* 5 m lower than at present and achieved present sea level *c.* 6500 BP (Gibb 1983). Thus the site stood only about 2 m a.s.l. when peat began to be deposited.

Surrounding forest was podocarp-hardwood, although the hardwood elements appear sparsely recorded and much of the pollen at this site may be quite locally derived. In particular *Beilschmiedia tawa* is not recorded (Macphail 1980; Bussell 1988) but was probably a common, if not dominant, canopy component. *Elaeocarpus* and *Nestegis* are other canopy hardwoods recorded in small amounts. Podocarps were common: *Dacrydium cupressinum*, *Prumnopitys taxifolia*, and *Podocarpus (P. totara)* were the most abundant whereas *Prumnopitys ferruginea* and *Dacrycarpus dacrydioides* were sparse. Noting that *Podocarpus* pollen is regarded as palynologically under-represented (McGlone 1982), the peak at 7.8 m suggests an apparently dense, local *Podocarpus* forest occupied the site at *c.* 6800 BP. The *in situ* stumps lie at the base of the lignites, whereas many fallen logs lie within lignite. This seems odd since today *P. totara* grows best on well drained soils such as alluvium (e.g., at Otaki to the south-east) whereas the soil at Waverley Beach was probably relatively poorly drained. Moar (1954) identified *Podocarpus totara* wood from some subfossil stumps in the Paraparaumu Peat, some 160 km south-south-east of Waverley Beach, indicating that *P. totara* can occupy relatively poorly drained sites. It can pioneer dry, open sites (Robbins 1962) and shows vigorous regeneration in windthrow gaps, at forest margins or in open country (McSweeney 1982).

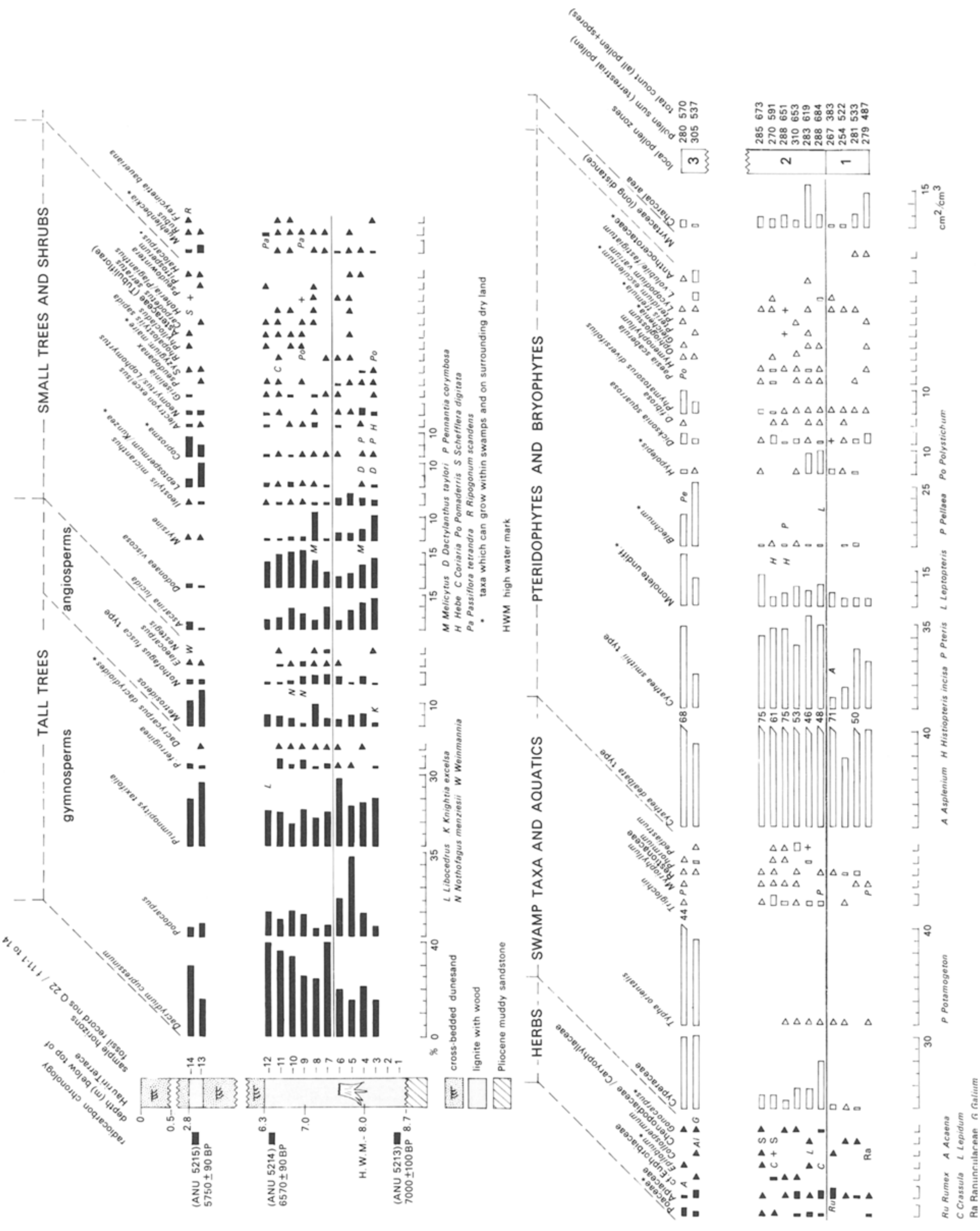
The paucity of local swamp and aquatic pollen in zone 1 indicates that the site did not have abundant surface water, thus the organic sediment was formed under the local fossil forest. The forests surrounding the site included tree ferns and *Ascarina lucida*, while *Dodonaea viscosa* may have been growing in low forest or scrub toward the coast. The occurrence of high levels of *Ascarina* (13%) is typical of mid Holocene pollen diagrams from western New Zealand and has been interpreted by McGlone & Moar (1977) to indicate a mild, drought- and frost-free climate. Both *Ascarina* and *P. totara* grow best in forests without a dense canopy cover (McSweeney 1982). In present day south Taranaki-Wanganui forests, *A. lucida* is only known to occur in the Pouakai Range, north-west of Mt Egmont, where there are a few individual trees (B. D. Clarkson, pers. comm.) but it may have been more widespread in the district (although still sparse) prior to deforestation because trace levels of its pollen are recorded in Lake Waiau swamp. It is also present, but rare, south of the Manawatu Gorge, at the southern end of the Ruahine Ranges, and in the Akatarawa and Tararua Ranges further south (Lees 1986). *Nothofagus fusca*-type pollen (presumably *N. solandri* var. *solandri*) is most likely derived from inland Taranaki-Wanganui where ridge stands may have grown on the poorer soils, as they do at present.

After *c.* 6800 BP, local *Podocarpus* declined markedly but it was still present in significant quantities in surrounding forest, considering its pollen is under-represented. At the same time, *Dacrydium cupressinum* became more abundant in the surrounding forest. It is a tree that prefers moist climate and cannot tolerate drought (Franklin 1968; Atkinson & Greenwood 1972) or permanently waterlogged soils (Hinds & Reid 1957), and it regenerates well after fire (Macphail & McQueen 1983). It is hypothesised that, at the zone 1–2 boundary (*c.* 6750 BP), rising sea level caused water table elevation, resulting in the demise of the dense, local *Podocarpus totara* forest and the establishment of true swamp conditions at the site with at least some surface water, as indicated by the presence of *Pediastrum*. Increased soil moisture with the rising water table may have been responsible for the increases in *D. cupressinum* and tree ferns, and *Dodonaea viscosa*. *Hypolepis* was most likely an early swamp component. Dune-sand deposition caused an end to peat deposition at the site after *c.* 6600 BP. An interdune swamp was again established prior to *c.* 5750 BP. By this time, *Ascarina lucida* and *Dodonaea viscosa* were no longer important in the regional forest. *Metrosideros* became more abundant. The local swamp flora was dominated by sedges and *Typha*, and contained the small tree *Leptospermum*/*Kunzea* (*L. scoparium*?), *Coprosma* shrubs, and the fern *Blechnum* (*B. capense* "blackspot" form?). At this time the swamp was *c.* 2.9 km inland and *c.* 3.5 m above sea level. Further dune-sand deposition ended swampy conditions at the site, and sea level, relative to the site, was falling during this period causing lowering of the near coastal water table.

DISCUSSION

Timing of deforestation

Polynesians first arrived in New Zealand *c.* 1000 BP (Davidson 1984) and lowland deforestation by fire was widespread (McGlone 1983a). In Taranaki-Wanganui, the earliest archaeological sites occur *c.* 45 km north-west of Lake Waiau at the mouths of the Waingongoro (Ohawe and Te Rangatapu Sites) and Kaupokonui Rivers (Buick 1931; Buist 1960, 1962, 1963). These date from *c.* 650 BP (Foley 1980) and contain rich, extinct bird faunas. They suggest the relatively late arrival of Polynesians in the area, although high coastal erosion rates may have destroyed earlier sites. At two other pollen sites in


TALL TREES
gymnosperms
angiosperms
SMALL TREES AND SHRUBS
HERBS
SWAMP TAXA AND AQUATICS
PTERIDOPHYTES AND BRYOPHYTES
radiocarbon chronology
depth (m) below top of Hauriri Terrace
sample horizons
fossil record nos O 22 / f 11-1 to 14
(ANU 5215) 5750 ± 90 BP
(ANU 5214) 6570 ± 90 BP
(ANU 5213) 7000 ± 100 BP
H.W.M.
cross-bedded dunesand
lignite with wood
Pliocene muddy sandstone
L Libocedrus K Knightia excelsa
N Nothofagus menziesii W Weinmannia
M Melicytus D Dactylanthus taylori P Pennantia corymbosa
H Hebe C Coriaria Po Pomaderris S Schefflera digitata
Pa Passiflora tetrandra R Ripogonum scandens
• taxa which can grow within swamps and on surrounding dry land
HWM high water mark
Charcoal area
local pollen zones
pollen sum (terrestrial pollen)
total count (all pollen+spores)
cm²/cm³
Ru Rumex A Acaena
C Crassula L Lepidium
Ra Ranunculaceae G Galium
P Potamogeton
A Asplenium H Histiopteris incisa P Pteris L Leptopteris P Pellaea Po Polystichum

Taranaki, deforestation apparently occurred just before 450 BP, with *Pteridium* replacing forest (M. S. McGlone, pers. comm. in Prickett 1983). The location of Lake Waiau is the approximate inland margin of the deforested coastal strip that early Europeans described as scrub and fern-covered. Most Maori probably lived in this strip of land. Burning was most likely purposeful to maintain youthful patches of *Pteridium esculentum* (Prickett 1983), the rhizomes of which formed a staple food crop. Apparently, Maori settlement of Wanganui Valley occurred *c.* 600 BP (Wanganui River Reserves 1982).

The radiocarbon chronology of the core is not tightly constrained. At 1 m depth, where deforestation is evident from the pollen record, the two dates obtained, taken at face value, suggest that the event occurred between 0–685 CAL BP (ANU 4843 and 6343) (both ages are $\pm 2\sigma$). Therefore, a maximum age of 685 CAL BP seems likely. That these two dates are statistically different and the wide scatter of ages from samples lower in the core (Fig. 3a), indicates a problem in the simple interpretation of the radiocarbon age data. These results provide a warning for other workers to be wary of accepting ages indicated from a small number of radiocarbon dates on similar late Holocene peat deposits.

The pollen sample at 0.6 m depth contains the oldest occurrence of *Pinus* pollen in the core. This is taken as probably indicating a maximum age of *c.* 1840 AD (148 years ago), when Europeans may have introduced *Pinus* to New Zealand. Mechanical downwash of pollen is not considered to be significant in peat deposits (Malmstrom 1923; Rowley & Rowley 1956), neither are changes in the position of the water table (Godwin & Willis 1959; Polach & Singh 1980). Peat is considered to remain stratified and there is insignificant mixing of old and new sediments by bioturbation or cryoturbation (Polach & Singh 1980; Green et al. 1988). Therefore, assuming that the *Pinus* pollen did not originate by sample contamination, its presence at 0.6 m depth is accepted here. The maximum age at this horizon, and the modern age for the surface peat, allow a best-fit age-depth curve to be drawn for the upper 0.6 m of the core and extrapolation of this line back to 1 m depth (Fig. 3a) provides a minimum age of 210 BP (248 years ago) for deforestation at Lake Waiau swamp. On present evidence, the timing of deforestation probably occurred some time between 685 CAL BP and 210 BP.

Dune mobilisation periods

Periods of dune mobilisation recorded in this study are shown by radiocarbon dates to have occurred during the following intervals:

Lake Waiau	–Waiau Stream blocked to form Lake Waiau before *c.* 3500 BP and sand deposition continued for a short time after.
Waverley Beach	–dune-sand deposition soon after *c.* 5700 BP with no soil development towards the top of the section.
	–dune-sand deposition soon after *c.* 6600 BP, finishing before *c.* 5750 BP.

Cowie (1963) reported four dune-building phases in the Manawatu district, and the ages and origins of these were revised by Fleming (1972). The Foxton Phase contains intercalated Paraparaumu Peat dated at *c.* 4730 and 5290 BP (Fleming 1972), and was considered to have formed as the coast prograded following sea level rise to the Holocene maximum. The dunes onlap the Holocene cliff (Fleming 1972). Taupo Dune-sand formed when large amounts of pumice were transported down major rivers from the central North Island, following the Taupo Pumice eruption of 1800 BP, and were washed up on the beaches. The Motuiti Phase post-dates the Taupo Pumice eruption, contains a *Podocarpus totara* stump dated at *c.* 850 BP (Cowie 1963), and was considered to be caused by early human disturbance. The Waitarere Phase postdates introduced plants and European artefacts, and resulted from European disturbance.

The episodes of dune activity at Waverley do not fit Cowie's sequence. It is likely that dune movements along the Wanganui-Manawatu coast occurred episodically at different localities many times in the past (cf. Thom 1978), so that different

⇐ **Fig. 8** ***(opposite)*** Pollen diagram, Waverley Beach.
▷ = less than 1%
+ = taxon recorded after formal count
Pollen sum based on total dry land, native taxa, excluding Pteridophyte spores.
Blacked in histograms shown for taxa included in the pollen sum.

sites are likely to have different records of dune-sand deposition (e.g., Shepherd 1987). A widespread, regional disturbance, such as deforestation, may have caused widespread dune mobilisation but some coastal areas are likely to have remained stable. Although transgressive dunes associated with Holocene sea level rise have formed widespread dune systems (Pye & Bowman 1984), particular causes for dune formation are difficult to pinpoint in stratigraphic sections.

McFadgen (1985) considered that during the last 1800 years there have been three distinct, widespread episodes of coastal deposition with intervening stable periods. These were attributed to climatic causes. Dry, windy periods may have caused widespread instability leading to depositional episodes, whereas stable periods were supposedly moist and less windy. The writer prefers to think that local, episodic dune movement results from either local causes or causes that are more widespread. In the latter case, depositional units may result which may be interpreted as having been deposited during generally unstable periods. Shepherd (1987) found that a number of separate waves of migrating Foxton Phase dunes occur in the Manawatu district. He found that dunes of this phase that occur furthest inland are much younger than those nearer to the coast because of the time required for the dunes to migrate. Thus, within one "phase" the deposits are time-transgressive. The term "phase" in association with dune-sand activity requires clarification with respect to the length of time the deposits of that "phase" may represent.

Fossil forests

Previous workers have reported fossil forest trees with their roots standing below water level at numerous localities along the Taranaki-Wanganui coast. Many of these sites are now destroyed or buried. The most prominent is still present at the mouth of Waitotara River, 8 km south-east of Waverley Beach, where numerous stumps (presumed to be *Podocarpus totara*, but one has been identified as *Dacrydium cupressinum*) stand in the estuarine river mouth (Park 1887; Thomson 1917; Fleming 1953, 1957). Fleming (1957) reported a date from a fossil-stump wood sample as 1020±60 BP and concluded the area had subsided "5–10 feet" in the last 1000 years, because of either exceptional sediment compaction or tectonic depression. Localised tectonic subsidence in this area where the landscape is being regionally uplifted (with maximum doming near to the Waitotara drowned forest) seems unlikely.

Regional vegetation and climatic change

Podocarp-hardwood forest has been present throughout the Holocene in lowland south Taranaki-Wanganui. In the late Pleistocene (14 000–10 000 BP), *Prumnopitys taxifolia*-dominated podocarp-hardwood forest replaced the previous glacial grass-shrubland communities of the central North Island (McGlone & Topping 1977, 1983; McGlone 1980; McGlone et al. 1984). At *c.* 10 000 BP, these forests changed to become *Dacrydium cupressinum*-dominant suggesting a change to a warmer, wetter climate, and cool-climate taxa were reduced in abundance. In the early–mid Holocene (10 000–5000 BP) high levels of *D. cupressinum*, *Ascarina lucida*, and *Dodonaea viscosa* characterise pollen diagrams and suggest a mild, wet climate during this period (McGlone 1983b). At Waverley Beach, *Ascarina* generally declines from *c.* 7000 BP onwards, falling to pollen levels of 1% or less by *c.* 3000 BP at Lake Waiau swamp. *Dodonaea* declines after *c.* 6500 BP. *D. cupressinum* is recorded at the same level of abundance in the late Holocene at Lake Waiau swamp as in the mid Holocene at Waverley Beach. Generally it is seen to be less abundant in late Holocene diagrams (McGlone 1983b). These trends have been taken to indicate slight cooling (onset of a frost- or drought-prone climate) during the mid to late Holocene (McGlone & Moar 1977). *Knightia excelsa* is not recorded in the mid Holocene but is common in the late Holocene—a trend reported at other North Island sites (McGlone 1980, 1983b). Increased forest disturbance during this period may account for this trend.

McGlone (1980) analysed a long pollen record dating from *c.* 14 000–3300 BP from Ngaere Swamp in Taranaki (244 m altitude), about 55 km north-west of the Waverley sites. The general record for the mid Holocene is similar to that at Waverley Beach except that the lower levels of *Dodonaea viscosa* and *Ascarina lucida* suggest that these trees were infrequent in the forests near Ngaere Swamp, or were restricted to coastal or lower altitude Taranaki-Wanganui, and that their pollen was transported into the swamp from these areas. There is also no decline in the abundance of *Dacrydium cupressinum* from the mid to the late Holocene at the Waverley sites. *Lagarostrobos colensoi* was commonly present at Ngaere Swamp in the mid Holocene but was not encountered at the Waverley Beach or Lake Waiau sites. *Tupeia antarctica*, and *Leucopogon fasciculatus* were apparently less common in the Waverley district than near Eltham.

These differences most likely reflect the differences between the sites: Ngaere Swamp is at an inland, higher altitude, wetter environment (using present day analogies) than the semi-coastal, Waverley sites. Nevertheless, both *Ascarina* and *Dodonaea* decline in abundance after *c.* 5500 BP at Ngaere Swamp (zone 6), thus there is close correspondence with Waverley Beach.

Nothofagus fusca-type (*N. solandri* var. *solandri*?) has probably not been important in the coastal to semicoastal forests of Wanganui district in the mid and late Holocene periods, and the low pollen percentages recorded in the Waverley sites are most likely derived mainly from inland ranges. Likewise at Ngaere Swamp, *N. fusca*-type pollen occurs only in trace amounts in the last 10 000 years.

Marine transgression culminating at 6500 BP (Gibb 1983) caused water table elevation near the coast, resulting in changes in vegetation composition in lowlying areas.

Other changes recorded between the pollen spectra from Lake Waiau swamp and Waverley Beach, such as an increase in *Nestegis* abundance, most likely relate to local site factors rather than regional trends. Fire may have had a more significant role in causing vegetation change than we are able to appreciate from pollen records. The most significant and devastating Holocene change that occurred in south-western North Island forests was Polynesian deforestation through burning, a trend which has been continued by Europeans to the present day.

ACKNOWLEDGMENTS

Thanks are extended to Drs G. Singh, J. Chappell, B. Pillans, J. Owen, and an anonymous referee for reviewing the manuscript. Assistance from Dr B. Sneddon, Mrs D. Moss, Ms D. Thiriet, Ms C. Ranieri, and the Royal Forest and Bird Protection Society for field accommodation is gratefully appreciated. Dr R. Patel identified fossil wood samples from Waverley Beach. The ANU Radiocarbon Dating Laborating provided radiocarbon measurements and assisted with their interpretation. Mr L. Pancino and Mr N. Duffey assisted with drafting the figures.

REFERENCES

Allan, H. H. 1961: Flora of New Zealand. Vol. I. Wellington, Government Printer.

Anderton, P. W. 1981: Structure and evolution of the South Wanganui Basin, New Zealand. *New Zealand journal of geology and geophysics 24*: 39–63.

Atkinson, I. A. E.; Greenwood, R. M. 1972: Effects of the 1969–70 drought on two remnants of indigenous lowland forest in the Manawatu district. *Proceedings of the New Zealand Ecological Society 19*: 34–42.

Brownsey, P. J.; Given, D. R.; Lovis, J. D. 1985: A revised classification of New Zealand pteridophytes with synonymic checklist of species. *New Zealand journal of botany 23*: 431–489.

Buick, T. L. 1931: The mystery of the moa. New Plymouth, Thomas Avery. 52 p.

Buist, A. G. 1960: Reports of archaeological fieldwork from the lower half of the North Island. South Taranaki. *New Zealand Archaeological Association newsletter 3 (4)*: 17–23.

———1962: Archaeological evidence of the archaic phase of occupation in south Taranaki. *New Zealand Archaeological Association newsletter 5 (4)*: 233–237.

———1963: Kaupokonui midden, south Taranaki. *New Zealand Archaeological Association newsletter 6 (4)*: 175–183.

Bussell, M. R. 1988: Modern pollen rain, central-western North Island, New Zealand. *New Zealand journal of botany 26*: 297–315.

Clark, R. L. 1982: Point count estimation of charcoal in pollen preparations and thin sections of sediments. *Pollen et spores 24*: 523–535.

Clarkson, B. D. 1981: Vegetation studies in the Taranaki Land District, New Zealand. Unpublished D. Phil. Thesis, University of Waikato, Hamilton.

———1985: The vegetation of the Kaitake Range, Egmont National Park, New Zealand. *New Zealand journal of botany 23*: 15–31.

Cockayne, L. 1967: New Zealand plants and their story. Ed. 4. Godley E. J. *ed.* Wellington, Government Printer. 268 p.

Connor, H. E.; Edgar, E. 1987: Name changes in the indigenous New Zealand flora, 1960–1986 and nomina nova IV, 1983–1986. *New Zealand journal of botany 25*: 115–170.

Cowie, J. D. 1963: Dune-building phases in the Manawatu district, New Zealand. (With an appendix on pollen analysis by D. J. McIntyre). *New Zealand journal of geology and geophysics 6*: 268–280.

Davidson, J. 1984: The prehistory of New Zealand. Auckland, Longman Paul Ltd. 270 p.

Dickson, M.; Fleming, C. A.; Grant-Taylor, T. L. 1974: Ngarino Terrace: an addition to the late Pleistocene standard sequence in the Wanganui-Taranaki District. *New Zealand journal of geology and geophysics 17*: 789–798.

Dieffenbach, E. 1843: Travels in New Zealand. London. Murray, 2 Vols. 431+396 p.

Dodson, J. R. 1976: Modern pollen spectra from Chatham Island, New Zealand. *New Zealand journal of botany 14*: 341–347.

Downes, T. W. 1915: Old Whanganui. Wanganui, W. A. Parkinson. 334 p.

Esler, A. E. 1978: Botany of the Manawatu. *New Zealand Department of Scientific and Industrial Research information series 127*. 206 p.

Faegri, K.; Iversen, J. 1975: Textbook of pollen analysis. Ed. 3. London, Blackwell. 237 p.

Fleming, C. A. 1953: The geology of Wanganui subdivision. *New Zealand Geological Survey bulletin 52*: 361 p.

———1957: The ages of some Quaternary sediments from Wanganui district (N137, N138). *New Zealand journal of science and technology B 38*: 726–731.

———1972: The contribution of ^{14}C dates to the Quaternary geology of the "Golden Coast", western Wellington. *Tuatara 19*: 61–69.

Foley, D. 1980: Analysis of faunal remains from the Kaupokanui Site (N128/3B). Unpublished MA thesis, University of Auckland.

Franklin, D. A. 1968: Biological flora of New Zealand. 3. *Dacrydium cupressinum* Lamb. (Podocarpaceae) rimu. *New Zealand journal of botany 6*: 493–513.

Gibb, J. G. 1978: Rates of coastal erosion and accretion in New Zealand. *New Zealand journal of marine and freshwater research 12*: 429–456.

———1983: Sea levels during the past 10 000 years B.P. from the New Zealand region–South Pacific Ocean. *Abstracts from the International Symposium on Coastal Evolution in the Holocene, Tokyo*: 28–31.

Godwin, H.; Willis, E. H. 1959: Radiocarbon dating of prehistoric wooden trackways. *Nature 189*: 490.

Green, D. G.; Singh, G.; Polach, H.; Moss, D.; Banks, J.; Geissler, E. A. 1988: A fine resolution palaeoecology and palaeoclimatology from southeastern Australia. *Journal of ecology 76*:

Gupta, S. K.; Polach, H. A. 1985: Radiocarbon dating practices at ANU. Handbook, Radiocarbon Laboratory, Research School of Pacific Studies, The Australian National University. 173 p.

Healy, J. 1964: Volcanic mechanisms in the Taupo Volcanic Zone, New Zealand. *New Zealand journal of geology and geophysics 7*: 6–23.

Hinds, H. V.; Reid, J. S. 1957: Forest trees and timbers in New Zealand. *New Zealand Forest Service bulletin 12*: 1–211.

Jowsey, P. C. 1966: An improved peat sampler. *New phytologist 65*: 245–248.

Lees, C. M. 1986: Late Quaternary palynology of the southern Ruahine Range, North Island, New Zealand. *New Zealand journal of botany 24*: 315–329.

McFadgen, B. G. 1985: Late Holocene stratigraphy of coastal deposits between Auckland and Dunedin, New Zealand. *Journal of the Royal Society of New Zealand 15*: 27–65.

McGlone, M. S. 1980: Late Quaternary vegetation history of central North Island, New Zealand. Unpublished D. Phil. Thesis, University of Canterbury, Christchurch.

———1982: Modern pollen rain, Egmont National Park, New Zealand. *New Zealand journal of botany 20*: 253–262.

———1983a: Polynesian deforestation of New Zealand: a preliminary synthesis. *Archaeology in Oceania 18*: 11–25.

———1983b: The history of New Zealand lowland forest since the Last Glaciation. *In:* Lowland forests in New Zealand. Proceedings of a Symposium held at the University of Waikato, Hamilton. Pp. 1–17.

McGlone, M. S.; Moar, N. T. 1977: The *Ascarina* decline and post-glacial climatic change in New Zealand. *New Zealand journal of botany 15*: 485–489.

McGlone, M. S.; Neall, V. E.; Pillans, B. J. 1984: Inaha Terrace deposits: a late Quaternary terrestrial record in south Taranaki, New Zealand. *New Zealand journal of geology and geophysics 27*: 35–49.

McGlone, M. S.; Topping, W. W. 1977: Aranuian (post-glacial) pollen diagrams from the Tongariro region, North Island, New Zealand. *New Zealand journal of botany 15*: 749–760.

———1983: Late Quaternary vegetation, Tongariro region, central North Island, New Zealand. *New Zealand journal of botany 21*: 53–76.

McKelvey, P. J. 1963: The synecology of the west Taupo indigenous forest. *New Zealand Forest Service bulletin 14*. 127 p.

Macphail, M. K. 1980: Fossil and modern *Beilschmiedia* (Lauraceae) pollen in New Zealand. *New Zealand journal of botany 18*: 453–457.

Macphail, M. K.; McQueen, D. R. 1983: The value of New Zealand pollen and spores as indicators of Cenozoic vegetation and climates. *Tuatara 26*: 37–59.

McSweeney, G. D. 1982: Matai/totara flood plain forests in south Westland. *New Zealand journal of ecology 5*: 121–128.

Malmstrom, C. 1923: Degero stormyr. *Meddelanden statens skogsforsoksanstalt 20*.

Maunder, W. J.; Browne, M. L. 1972: The climate and weather of the Wanganui region, New Zealand. *New Zealand Meteorological Service miscellaneous publication 115*: 13 p.

Moar, N. T. 1954: Peat profiles Whareroa Block, Paekakariki, New Zealand. *New Zealand journal of science and technology 36A*: 221–231.

———1970: Recent pollen spectra from three localities in the South Island, New Zealand. *New Zealand journal of botany 8*: 210–221.

Moore, L. B.; Edgar, E. 1976: Flora of New Zealand. Vol. II. Wellington, Government Printer.

Neall, V. E.; Stewart, R. B.; Smith, I. E. M. 1986: History and petrology of the Taranaki volcanoes. *In:* Late Cenozoic volcanism in New Zealand. *Royal Society of New Zealand bulletin 23*: 251–263.

Ogden, J.; Caithness, T. A. 1982: The history and present vegetation of the macrophyte swamp at Pukepuke Lagoon. *New Zealand journal of ecology 5*: 108–120.

Park, J. 1887: On the geology of the western part of Wellington provincial district and part of Taranaki. *New Zealand Geological Survey report on geological exploration 1886–87 18*: 24–73.

Pearson, G. W.; Stuiver, M. 1986: High precision calibration of the radiocarbon time scale, 500–2500 BC. *Radiocarbon 28*: 839–862.

Pillans, B. J. 1981: Upper Quaternary landscape evolution in south Taranaki New Zealand. Unpublished D. Phil. Thesis, The Australian National University, Canberra.

——— 1983: Upper Quaternary marine terrace chronology and deformation, south Taranaki, New Zealand. *Geology 11*: 292–297.

Pocknall, D. T. 1978: Relative pollen representation in relation to vegetation composition, Westland, New Zealand. *New Zealand journal of botany 18*: 67–95.

Polach, H.; Singh, G. 1980: Contempory ^{14}C levels and their significance to sedimentary history of Bega Swamp, New South Wales. *Radiocarbon 22*: 398–409.

Prickett, N. 1983: Waitotara Ki Parininihi: aspects of the archaeology of the Taranaki region. *In:* Bulmer, S.; Law, G.; Sutton, D. *ed.* A lot of spadework to be done. Essays in honour of Aileen Fox. *New Zealand Archaeological Association monograph 14*: 281–329.

Pullar, W. A.; Birrell, K. S.; Heine, J. C. 1973: Named tephras and tephra formations occurring in the central North Island, with notes on derived soils and buried paleosols. *New Zealand journal of geology and geophysics 16*: 497–518.

Pye, K.; Bowman, G. M. 1984: The Holocene marine transgression as a forcing function in episodic dune activity on the eastern Australian coast. *In:* Thom, B. G. *ed.* Coastal geomorphology in Australia. Academic Press. Pp. 179–196.

Robbins, R. G. 1962: The podocarp-broadleaf forests of New Zealand. *Transactions of the Royal Society of New Zealand (botany) 1 (5)*: 33–75.

Robertson, N. G. 1957: The climate districts of New Zealand. *Proceedings of the New Zealand Ecological Society 4*: 6, 22–23.

Rowley, J. R.; Rowley, J. 1956: Vertical migration of spherical and aspherical pollen in a *Sphagnum* bog. *Proceedings of the Minnesota Academy of Science 24*: 2–30.

Shepherd, M. J. 1987: Holocene alluviation and transgressive dune activity in the lower Manawatu Valley, New Zealand. *New Zealand journal of geology and geophysics 30*: 175–187.

Stuiver, M.; Polach, H. A. 1977: Discussion: reporting of ^{14}C data. *Radiocarbon 19*: 355–363.

Thom, B. G. 1978: Coastal sand deposition in southeast Australia during the Holocene. *In:* Davies, J. L.; Williams, M. A. J. *ed.* Landform evolution in Australasia. ANU Press. Pp. 197–214.

Thomson, J. A. 1917: The Hawera Series or the so-called "Drift Formation" of Hawera. *Transactions of the New Zealand Institute 48*: 414–417.

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

Topping, W. W.; Kohn, B. P. 1973: Rhyolitic tephra marker beds in the Tongariro area, North Island, New Zealand. *New Zealand journal of geology and geophysics 16*: 375–395.

Wanganui River Reserves 1982: A scenic, historic and wilderness experience – the Wanganui River. Department of Lands and Survey, Wellington. 112 p.

Wardle, P.; Bulfin, M. J. A.; Dugdale, J. 1983: Temperate broad-leaved evergreen forests of New Zealand. *In:* Ovington, J. D. *ed.* Temperate broad-leaved evergreen forests. Amsterdam, Elsevier Science Publishers, Pp. 33–71.

Wendelken, W. J. 1976: Forests. *In:* Ward, I. *ed.* New Zealand Atlas. Wellington, Government Printer.